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SECRETARY OF THE AIR FORCE

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Test and Evaluation

COMMAND, CONTROL, COMMUNICATIONS, COMPUTERS AND INTELLIGENCE (C4I) TEST AND EVALUATION PROCESS

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This manual describes the Air Force Test and Evaluation Process for the C4I mission area. It provides a test and evaluation methodology for use by program managers, test managers, test engineers, test organization personnel, contractors developing C4I systems, major command headquarters staffs, and others involved in test and evaluation of C4I systems. It takes the Air Force Test Process described in AFI 99-103 and implements its use for C4I Test and Evaluation. Specific guidance regarding DT&E and OT&E is contained in AFI 99-101, *Developmental Test and Evaluation* and AFI 99-102, *Operational Test and Evaluation*, respectively. Non-use of the process described herein shall be by exception only and requires written approval by the Director, Test and Evaluation, Headquarters United States Air Force (HQ USAF/TE).

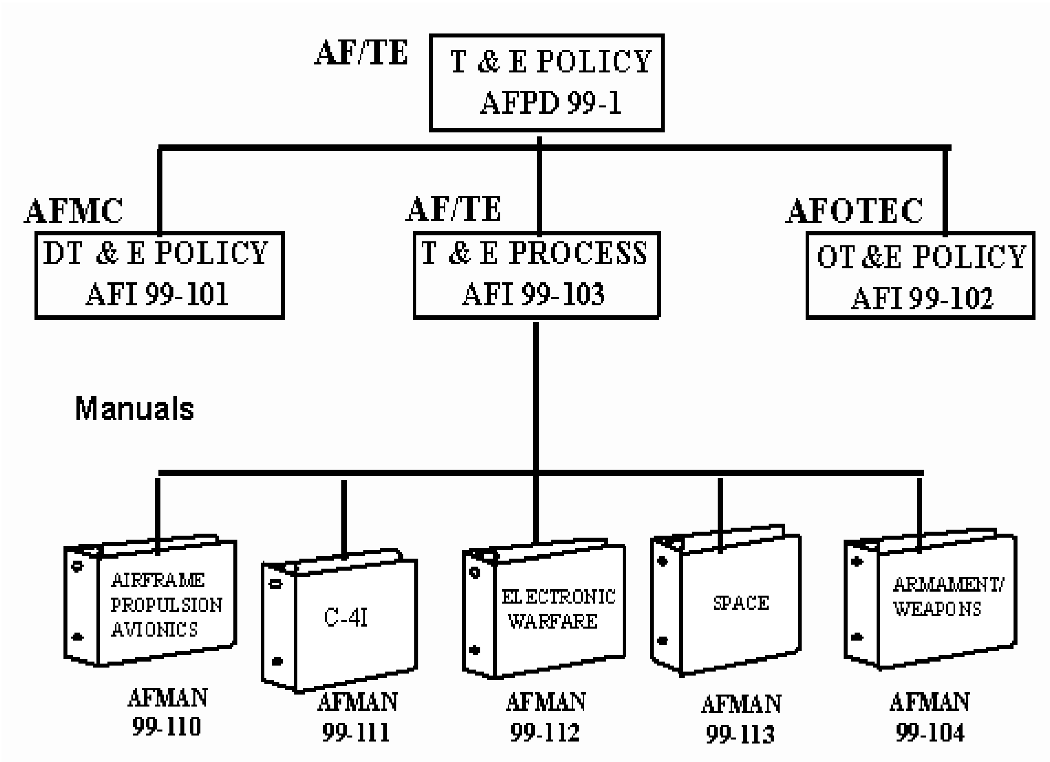
Section A—Introduction to the C4I T&E Process

1. Overview. The Command, Control, Communications, Computers, and Intelligence (C4I) Test and Evaluation (T&E) Process is intended to be used by both Government and contractors in any phase of the acquisition cycle, whether the test and evaluation phase is contractor, development, operational, or combined. The use of the C4I T&E Process implements a plan-predict-test-compare philosophy and stresses early involvement of the tester in the acquisition process.

1.1. Philosophy. The Air Force test and evaluation process is a scientific approach that supports a plan-predict-test-compare philosophy for testing acquisition systems. Discipline in the test process contributes to cost effective systems acquisition and lifecycle sustainment that satisfy the needs of the decision maker. A disciplined and structured test program reduces the risk of acquiring an ineffective or unsuitable system and provides a program manager with information required to make prudent decisions during system development and modification. Testing encompasses many forms, from component tests in laboratories to full mission demonstrations in a real world environment. Regardless of the type of test, however, there are several fundamental principles to help ensure the system under test fulfills its intended purpose. These will be addressed in **Section B**.

1.2. Direction. *Air Force Instruction (AFI) 99-103, the Air Force Test and Evaluation Process*, describes the Air Force approach to test and evaluation and its relationship to the overall acquisition process as described in the DOD 5000 directives. AFI 99-103 provides guidance that supports a plan-predict-test-compare philosophy for testing systems. By following these guidelines, a test program will be conducted in a disciplined, scientific, and cost-effective manner. **Figure 1.** depicts other Air Force Instructions and Test and Evaluation (T&E) Process Manuals that provide policy and guidance relating to T&E.

Figure 1. AF Test and Evaluation Planning Support Documentation.



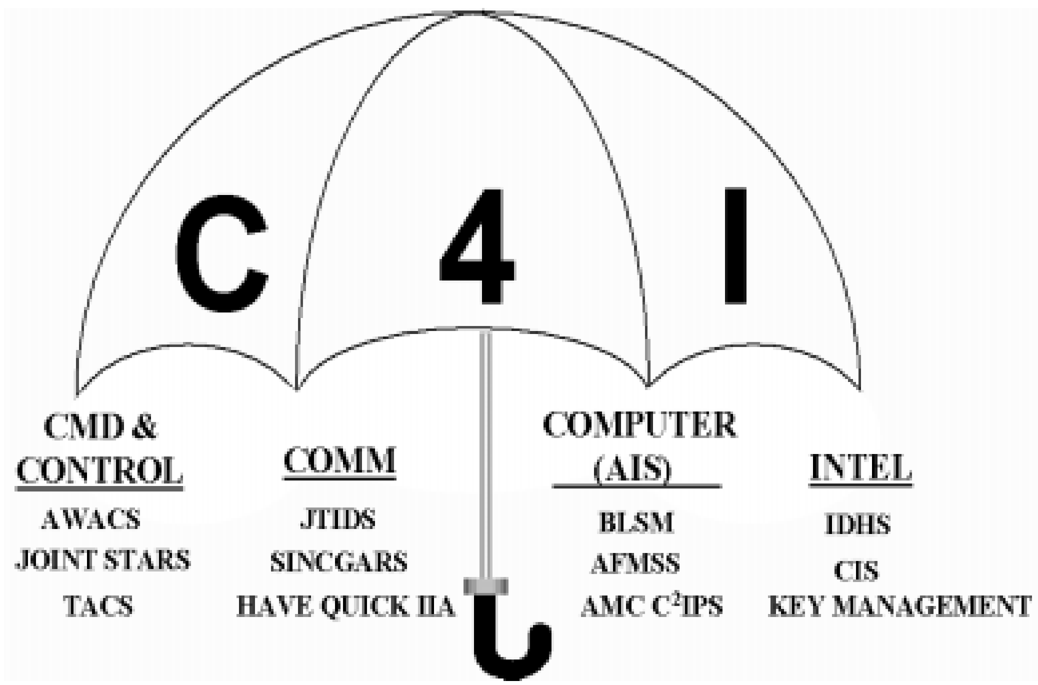
1.3. Purpose. The purpose of this manual is to supplement AFI 99-103, by providing specific information that relates to T&E of C4I systems. This manual describes how the Air Force Test and Evaluation Process applies to test and evaluation of command and control, communication, computer (automated information), and intelligence systems. Also presented are topics related to test and evaluation of C4I systems such as combined development and operational testing, test and evaluation of software intensive systems, test and evaluation of non-developmental items, and interoperability certification.

1.4. Objectives. A comprehensive C4I T&E process allows early evaluation of a program's technical and operational feasibility and facilitates earlier, more cost-effective correction of system deficiencies. Thus the process provides potentially shorter acquisition schedules with delivery of high quality products to the user. Throughout the lifecycle of a system, test and evaluation fulfills four primary objectives:

- Identify, assess, and reduce the risk that costly hidden flaws remain in the system,
- Demonstrate the system is functioning as expected and will meet the needs of the user,
- Ensure operational effectiveness and suitability of the system,
- Contribute timely, accurate, and affordable information to support lifecycle acquisition and logistic decisions.

1.5. Scope. C4I systems include command, control, communication, computer (automated information), or intelligence systems or equipment that assist a commander in planning, directing, and controlling forces in both war and peace. C4I systems typically consist of some combination of hardware, software, personnel, facilities, and procedures. Their function is to collect, process, transfer, integrate, store, produce, disseminate, and/or display information. Many automated information systems (AISs) serve a similar function for information less directly associated with a commander controlling forces, such as personnel, finance, or supply information systems. This manual includes AIS that are used by the battlefield commander as well as those used by the commander of a support unit. See **Figure 2.** for a list of typical C4I programs and the particular element of C4I to which they relate. This figure contains only a sample list of C4I programs and is not intended to be comprehensive.

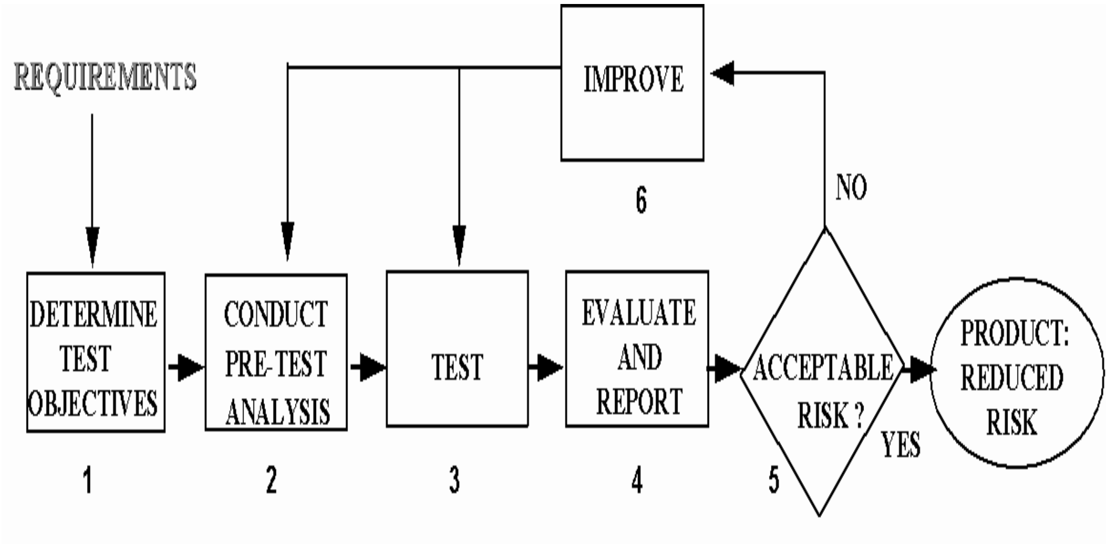
Figure 2. The C4I Umbrella.



Section B—Description of the C4I T&E Process

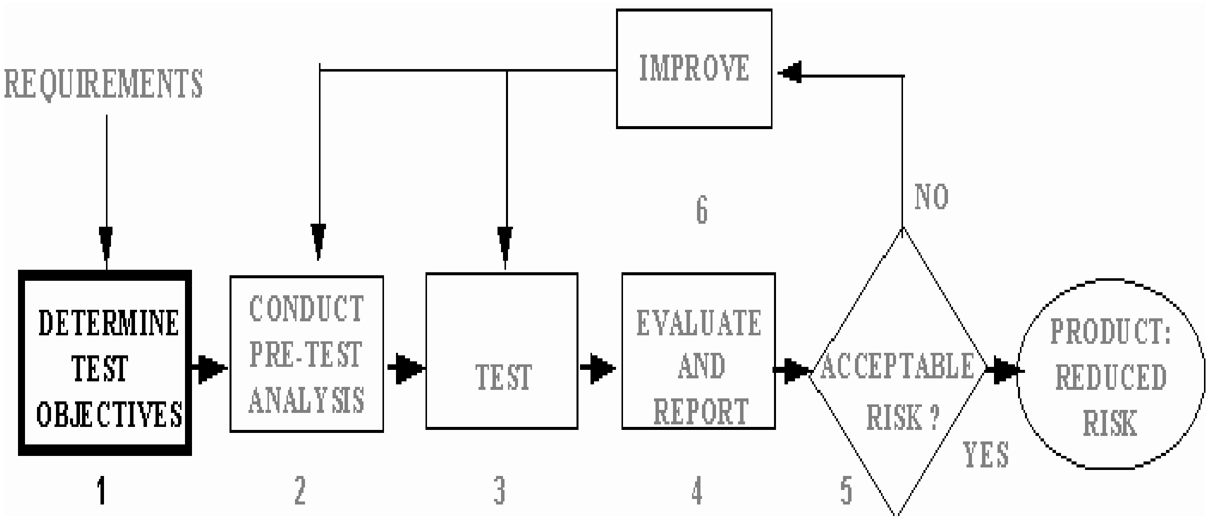
2. The C4I Test and Evaluation Process. The key objective of the C4I T&E Process is to reduce the risks associated with the C4I acquisition program by providing effectiveness and operational suitability information to key decision makers. This is accomplished by using a scientific, disciplined, and structured application of the C4I T&E Process throughout the entire life-cycle of a C4I system. The C4I T&E Process, depicted in **Figure 3.**, utilizes the plan-predict-test-compare philosophy documented in AFI 99-103.

Figure 3. The C4I T&E Process.



2.1. Step 1--Determining Test Objectives. Determining test objectives (**Figure 4.**) is step one of the C4I T&E Process. Test objectives are statements that identify the evaluation goals and information requirements of a particular test. Test objectives are used to assess how well a system meets requirements. They subdivide critical technical or operational issues into discrete testable elements and relate planned testing to stated system performance and mission capability requirements. If system requirements are not clearly defined by the user, the tester's job is extremely difficult, or even impossible. Ambiguous requirements will, if not corrected early in the acquisition process via ORD changes, lead to major problems in both development and test of the system.

Figure 4. Determine Test Objectives.



Sample questions to consider:

⇒ ***What are the issues that must be addressed?***

⇒ ***What information is required by the decision makers?***

⇒ ***Are the test objectives based upon mission and performance requirements?***

2.1.1. To determine test objectives, source documents are reviewed and analyzed. Among these are:

- Mission Need Statement (MNS)
- Operational Requirements Document (ORD)
- Requirements Correlation Matrix (RCM)
- System Threat Assessment Report (STAR)
- Cost and Operational Effectiveness Analysis (COEA)
- Concept of Operations (CONOPS)
- Design and Performance Specifications
- These documents provide details regarding user requirements and the threats that may be encountered by the C4I system once deployed. Information gleaned from these source documents is used to develop Critical Operational Issues (COIs), Measures of Effectiveness (MOEs), Measures of Performance (MOPs), the Integrated Logistics Support Plan (ILSP), the System Maturity Matrix (SMM) and the Test and Evaluation Master Plan (TEMP). See AFI 99-103, *The Air Force T&E Process*, for a detailed description of each of these documents. (Refer to AFI 10-601, *Mission Needs and Operational Requirements Guidance and Procedures*, for additional information on requirement source documents.)

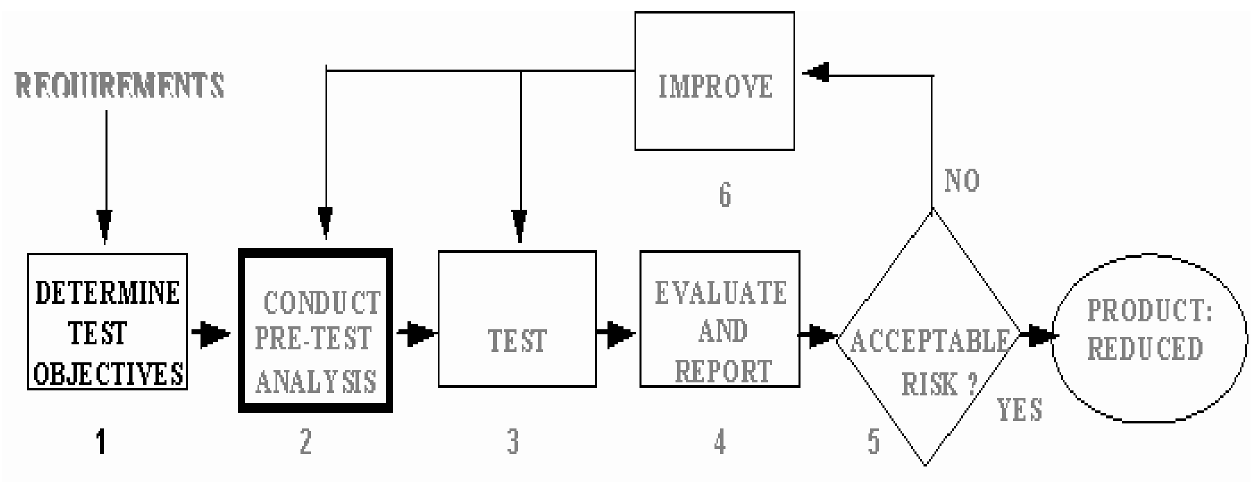
2.1.2. Determining test objectives marks the beginning of early test planning. During this step of the process, test managers should contact the ARMAMENT/WEAPONS-C4I-EW SFTC office and request their assistance in determining cost effective options for the T&E effort. The T&E community should be involved in the generation of operational requirements to help ensure quantifiable, testable requirements are developed and documented.

NOTE:

The following tools are helpful during step one of the process: The Air Force Acquisition Model (AFAM), POC: ASC/CYM, DSN 785-0423; The Automated Test Planning System (ATPS), POC: OUSD(A&T)/DT&E, DSN 225-4608; DoDI 5000.2M, Part 7, TEMP Preparation, and Joint Logistics Commanders' Guidance.

2.2. Step 2--Pre-Test Analysis. After test objectives are identified, pre-test analysis (**Figure 5.**) is used to predict expected values for technical and system performance parameters and to begin developing test plans. An acceptable range of variation in test results from expected values should be determined during this step. The System Maturity Matrix (SMM) is a primary reference used for determining the expected values and predicted level of performance at the time of test. Test data gathered previously from earlier representations such as brassboards or prototypes as well as similar systems can be used to predict system performance. Modeling and Simulation (M&S) resources, such as a Digital System Model (DSM), is also a valuable tool that should be used during this step to predict system performance. The DSM is described in paragraph **2.8.1.** of this manual.

Figure 5. Pre-Test Analysis.



Sample questions to consider:
⇒ ***What resources are needed to collect the data?***
⇒ ***What types and quantities of data are required?***
⇒ ***What are the predicted results?***

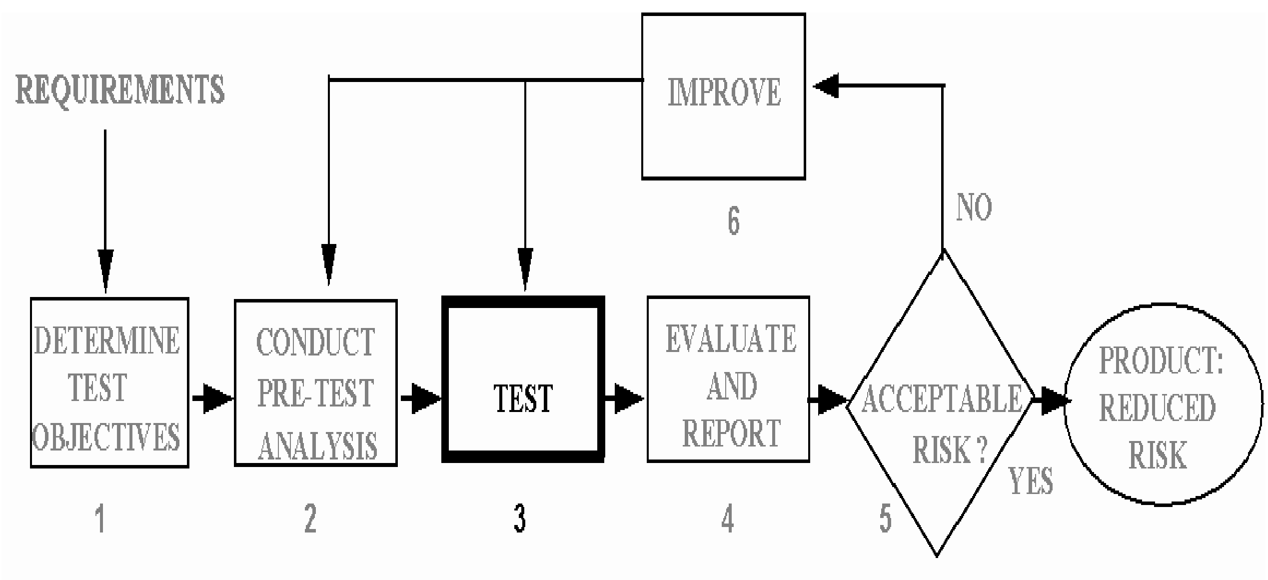
2.2.1. During pre-test analysis, test planners determine how to: design the test scenario; set up the test environment; properly instrument the test articles; man and control the test resources; and sequence the test trials. If pre-test analysis indicates the system or the test method is not ready for test, problems must be corrected before expending costly test resources. This step should not be exited until the test method is judged to be adequate and the system is predicted to have an acceptable probability of passing the test.

2.2.2. An outcome of the pre-test analysis step may be the discovery that current test resources are insufficient to accomplish the desired testing. In that case, contact the SFTC office to assist in defining alternatives or developing needs and solutions for required C4I test resource investments.

2.3. Step 3--Test. Conducting the test (**Figure 6.**) is the next step of the process. After determining what to test and how to test it, the test is conducted using appropriate facilities and/or capabilities. Activities occurring during the test step include test planning, test conduct, and data management.

2.3.1. Test Planning. Test planning is done to define risk areas where early testing is required to identify problems areas so modifications can be incorporated while it is economically feasible. Test planning activities are also accomplished so that T&E is conducted in an orderly and efficient manner. During test planning, detailed test objectives, test conditions, test article configurations, and data requirements are blended to form a matrix of test points or discrete test events. Pre-test briefings should occur prior to the test to focus test personnel on the task at hand. Test planning documents include development test (DT) and operational test (OT) test plans, program introduction documents (PID), and statement of capability (SOC) documents. Detailed test plans evolve from work accomplished during Step 2--Pre-test Analysis. These detailed test plans are finalized during the test step and are used by test personnel to plan and execute the test.

Figure 6. Test.

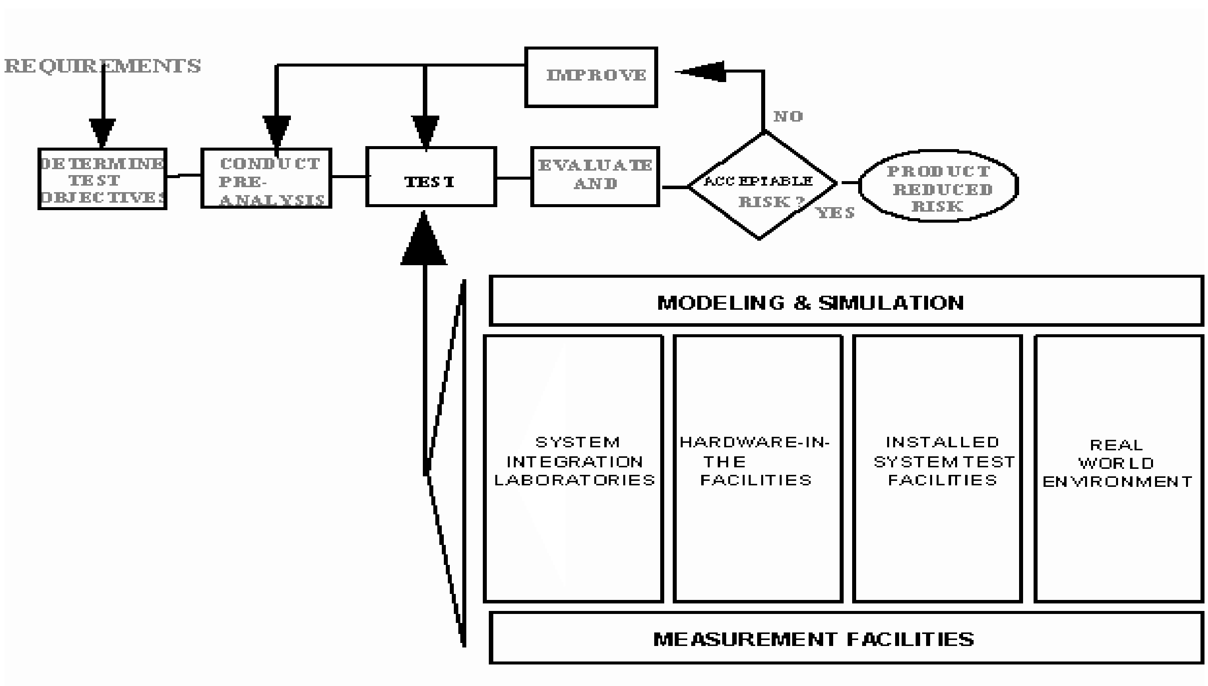


Sample questions to consider:
⇒ ***Are test procedures and conditions being followed?***
⇒ ***Is required information being collected and analyzed?***
⇒ ***Is the test adequately stressing the system?***

2.3.2. Test Execution. Test execution is accomplished by using the test capabilities and facilities from six general T&E resource categories. These resource categories are presented in detail in paragraph **4.** of this manual and also described in AFI 99-103. **Figure 7.** shows that T&E capabilities in all six resource categories support the **test** step of the C4I T&E Process. During the test step, required data are collected to support the needs of the decision maker. Real-time data quality assessment should be done, if possible. A "quick-look," real-time comparison of test data and predicted results will help determine if test points need repeating. Repeating test points, while test assets are in place, is more efficient and more cost-effective than having to set-up test equipment and retest at a later date. Since the test process is repeated many times during the system development process, post-test reviews should be held after each test to help focus the "evaluate" step and begin planning for the next test.

2.3.3. Test Data Management. Test data management includes data processing, handling, and archiving. This begins with collecting the raw test data, converting data to a desirable format, analyzing, validating, and delivering the data to the people and organizations that need it for information and storage. Test results should be documented in a test log describing anomalies, test points completed, and events of interest. In situations where the system under test might be destroyed or is a one of a kind item, a Data Acquisition, Handling and Analysis Plan (DAHAP) should be developed to fully document data requirements and responsibilities.

Figure 7. All Resource Categories Support the *TEST* Step.

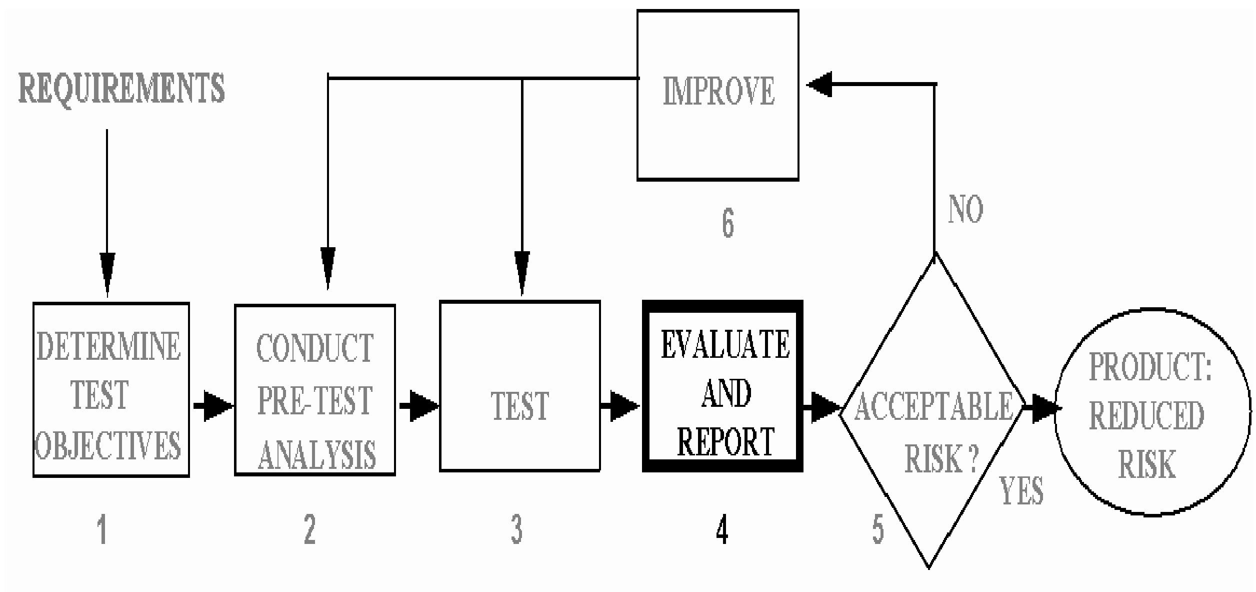


2.4. Step 4--Evaluate and Report. During the evaluate and report step (**Figure 8.**), test results are analyzed to determine if predicted values were achieved and if technical and operational requirements were met. In DT&E, if differences between measured and predicted results indicate deficiencies, the test manager, with inputs from the System Program Office (SPO) and the developing contractor, determines if: 1) the test method was flawed; 2) the analysis/simulation conducted during pre-test analysis was in error; or 3) the system under test failed to achieve the required performance.

2.4.1. To help make this determination, the test log from the "test" step should be reviewed to ensure that the test method was valid. The data quality, based upon accuracy, data processing algorithms, and instrumentation calibrations, must be analyzed. If the test method or the prediction tool was determined to be in error, the test method or the tool is corrected (via "Improve" step) and the test is redone, prior to information being presented to the decision maker. If the test is determined to be valid and the data are determined to be accurate, but different from the predicted values, then the prediction tool is in error and must be updated, or the system under test failed to perform as intended due to a design or manufacturing deficiency.

2.4.2. Evaluation is not complete until all test objectives have been analyzed and any differences between predicted and measured values resolved. Even when test results match the predicted outcome, analysis must be done to ensure that results were obtained due to the proper behavior of the system under test. At times, systems appear to function properly, but detailed analysis still uncovers deficiencies.

Figure 8. Evaluate and Report.



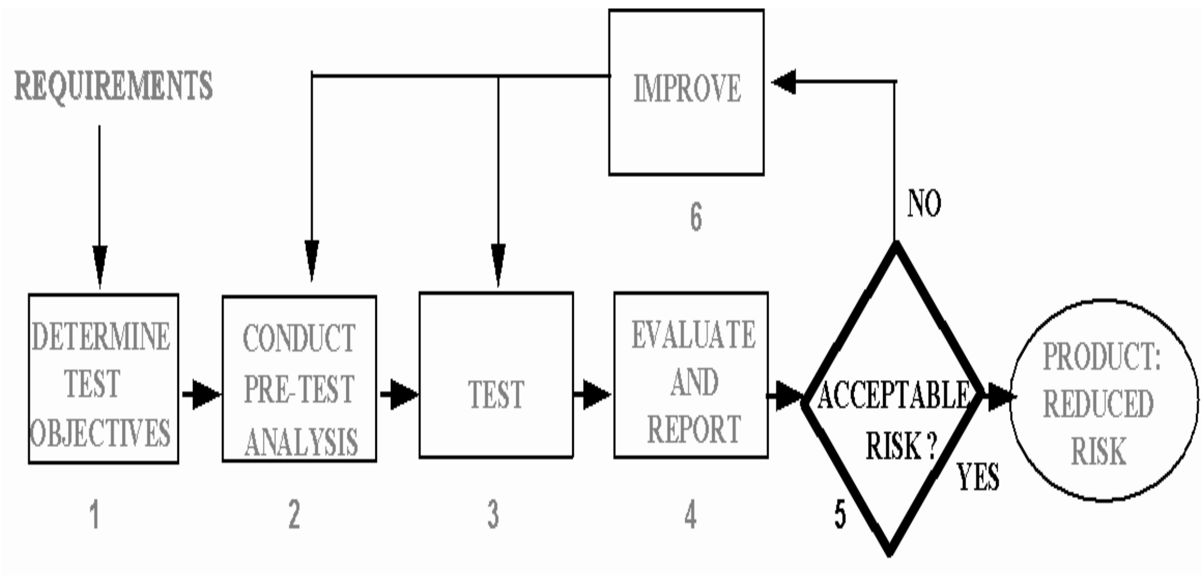
Sample questions to consider:
⇒ ***Did post-test analysis compare predicted outcomes to test results?***
⇒ ***Were expected results achieved?***
⇒ ***Was information reported to proper decision makers?***

2.4.3. Test reporting is an important activity during the evaluate and report step of the process. Test reports include "quick look" reports for immediate feedback, briefings to decision makers, formally published documents, and deficiency reports. System deficiencies are identified during the test step, and during the evaluate and report step are to be documented in accordance with TO 00-35D-54. Deficiency report status updates are provided to the operational user. The Deficiency Reporting (DR) system provides a systematic way to report, investigate, track, and resolve problems. It is important that an interface exists between Government and contractor deficiency reporting systems. A link between the Government's Deficiency Reporting system and the contractor's Failure Reporting and Correction Action System (FRACAS) ensures timely flow of data information from one test phase to the next.

2.5. Step 5--Acceptable Risk Decision. This step (**Figure 9.**) is a yes/no decision point by the decision maker. The test manager determines if the test satisfied the objectives, ensures the adequacy of the test, and makes recommendations to the decision maker. Based upon T&E information and recommendations from the test manager, the decision maker (typically the single manager (SM) or higher authority) assesses if the product met the requirements stated in the system specification or the ORD and determines if it is ready to move ahead to the next step of the acquisition process.

- Sample questions to consider:
- Were technical and operational risks reduced to acceptable levels?
- Did the system meet the mission requirements stated in the ORD?
- Is the product ready to move ahead to the next step?

Figure 9. Acceptable Risk Decision.



Sample questions to consider:
⇒ Were technical and operational risks reduced to acceptable levels?
⇒ Did the system meet the mission requirements stated in the ORD?
⇒ Is the product ready to move ahead to the next step?

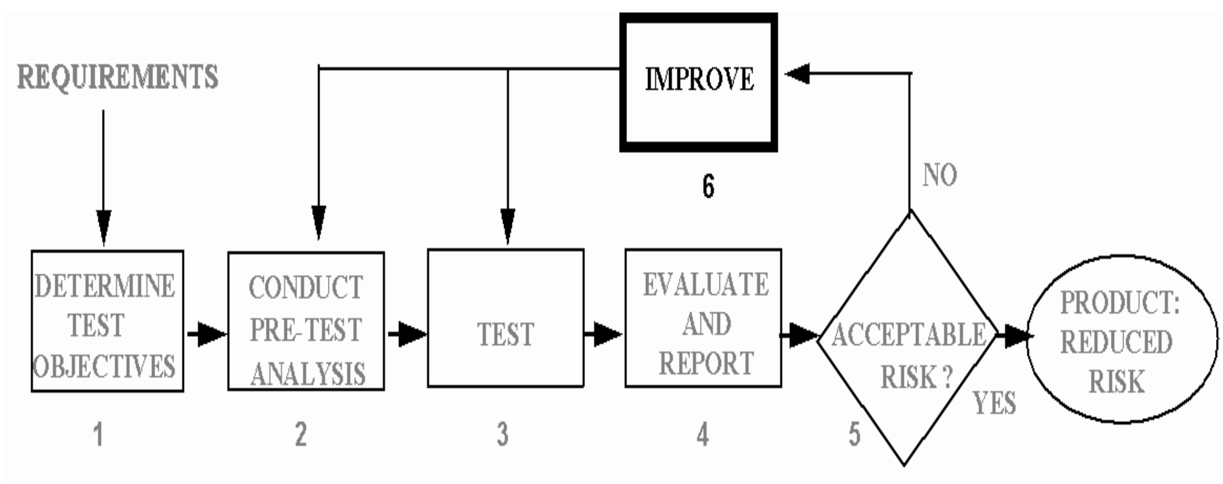
2.5.1. If the outcome of the test was not satisfactory, a design, manufacturing, or workmanship deficiency may exist in the product. The degree of risk associated with a given deficiency depends on its effect on the user's operational task or mission. Acceptable risk varies with the circumstances and is keyed to the ultimate penalty due to a system or component failure. If a system failure means a mission failure or loss of life, then acceptable risk implies a very high confidence level in the component or system. On the other hand, if system failure results in only a temporary inconvenience, then less confidence in a component or system may be sufficient. A sound risk management approach, however, will assume a deficiency exists until proven otherwise.

2.5.2. Properly employed testing at the right time reduces risk by early identification of areas that need improvement. The plan-predict-test-compare ... then fix philosophy is the way to develop a quality system for the user.

2.6. Step 6--Improve. This is the feedback loop of the process where corrective actions occur. If problems were discovered during T&E, they could be due to problems with the system design, implementation of the design, problems with the test method, or flawed pre-test predictions. If problems with the system are discovered, the developer fixes the deficiencies, pre-test analysis is re-accomplished and the item is retested. If problems with the test method are discovered, these problems are corrected by the tester and the system is retested.

2.6.1. Analyzing and correcting design and workmanship problems is the key to reducing product risk. The "IMPROVE" step (**Figure 10.**) provides timely feedback, from the evaluation step, to the system developer. During Contractor T&E and Development T&E, the "improve" step provides early feedback to the system developer. Early in the system development cycle, design changes can be economically incorporated into the system. Problems not discovered until late in an acquisition program (i.e., Operational T&E or later) are almost always more difficult and costly to correct.

Figure 10. Improve.



Sample questions to consider:
⇒ ***Were pre-test predictions accurate?***
⇒ ***Was the test flawed or are there problems with the system design?***
⇒ ***What must be changed or refined?***

2.6.2. As development and testing of the C4I system progresses, predictions of measures of performance and effectiveness are verified and improved. If significant problems are discovered during DT&E, other testing can proceed, if not influenced by the deficiency. If significant problems are noted during OT&E, the testing is stopped. At this point, a decision is made whether to fix the system, accept it “as-it-is," or cancel the program.

2.7. Output Product: Reduced Acquisition Risk. Each level of an overall test program requires individual planning, predicting, and comparing test data with anticipated results. If the tests are unsuccessful, feedback loops re-address the planning or prediction until a successful outcome or acceptable level of technical and operational risk is achieved. The C4I T&E process can be utilized at each level of system development, is applicable throughout each phase of T&E, and is also applicable to individual test events. Properly conducted T&E of C4I systems identifies system deficiencies so that early design modifications can be made and a better product can be delivered to the user. Benefits derived from use of the C4I T&E Process include:

- Early and thorough evaluation of system concepts;
- Early and continuous feedback to the design process;
- Establishment of clear links between operational requirements stated in the ORD and test criteria;
- Timely and credible test results to support milestone decisions;
- Increased Feasibility of combining DT&E and OT&E;
- Early review of interoperability certification challenges;
- Identify needed improvements or shortfalls in test capabilities and facilities
- Help the user refine requirements for follow-on increments.

2.8. Test Process Tools. In addition to test facilities, Modeling and Simulation tools and a historical file of T&E information are required to properly execute the C4I T&E Process. The Modeling and Simulation resource category supports all six steps of the C4I T&E Process and is especially useful during the pre-test analysis step. The Test Process Archive (TPA) is used to maintain a complete history of the T&E and provide traceability to user requirements.

2.8.1. Digital System Model (DSM). The DSM, a modeling and simulation tool, should be developed early in an acquisition program (pre-MS I). The DSM is useful in system design, in performing pre-test analysis, and in evaluating the results obtained from T&E. A DSM is typically a digital representation (model) of the system under development. It can however, be a prototype used to refine the system design with the help of the user. The DSM is updated as the requirements and the system design matures and is maintained throughout the system’s lifecycle to provide a baseline for assessing candidate modifications.

2.8.1.1. C4I DSMs are usually developed as part of the system engineering process to support the system design process as well as to support the T&E process. DSMs will typically be built by the developing contractor as a contract deliverable. The C4I DSM should be maintained by the System Program Office (SPO) or the Single Manager (SM) responsible for AF management of the system.

2.8.1.2. Not all C4I systems, such as some of the ones presently fielded have a DSM to support the C4I T&E process. If no DSM exists, an alternate technique of predicting pre-test performance must be used. For example, data from similar systems or an analog model can be used if available.

2.8.2. Test Process Archive (TPA). An important aspect of executing the test and evaluation process, is maintaining a record of all T&E associated with the C4I system. The TPA is a file of information, maintained by the Responsible Test Organization (RTO) and SPO, that documents the history of all T&E efforts for a C4I system for the life of that system. This historical archive contains budgets, decisions, and the rationale for the way T&E was planned and executed. Each C4I T&E program should record this historical information in a Test Process Archive (TPA) to be used by future acquisition and T&E personnel. The TPA should contain as a minimum the T&E Structure, Test Data Collected, Plans, Evaluations and Results, and Annual Test Process Summaries.

2.8.2.1. T&E Structure. The T&E structure of the TPA refers to the hierarchy of documentation that supports development and execution of the C4I T&E program. This part of the TPA, typically maintained by the SPO, includes all top level program management, systems engineering and test program documents such as the MNS, ORD, CONOPS, STAR, PMD, ADM, TEMP, SMM, Threat Validation and Baseline reports, and Prime Item Development Specifications (PIDS). In addition, it includes the System Requirements Document (SRD), Technical Requirements Document (TRD) and any documents from which test objectives are derived and which support development of the C4I T&E program. This hierarchy of documentation is used to develop an audit trail linking all test objectives including supporting Critical Operational Issues (COIs), Measures of Performance (MOPs), and Measures of Effectiveness (MOEs), with documented user requirements.

2.8.2.2. Test Data. Test data includes 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. Development T&E activities, which are managed by the Responsible Test Organization (RTO), and Operational T&E activities, managed by an Operational Test Agency (OTA) yield different processed data products. The RTO and OTA maintain sufficient data to support reporting requirements and future analysis requirements. Major acquisition programs typically review and analyze test results for the life of a program and archive sufficient data to support future operational anomaly evaluations or aging comparisons. Long term data retention requirements should be addressed as part of the T&E planning process. At a minimum, all test data should be retained for at least one month after results are reported. After this period, the test manager can designate the data to be retained and dispose of data no longer needed.

2.8.2.3. Plans, Evaluation, and Results. This record includes the supporting technical detail of the T&E program. Information contained in this T&E record include: predicted test results; resource identification and selection process documentation; detailed test plans and data acquisition, handling and analysis plans (DAHAPs); and relevant documentation describing T&E accomplished. Documentation describing how the test reports answer the test objectives' questions is also included here.

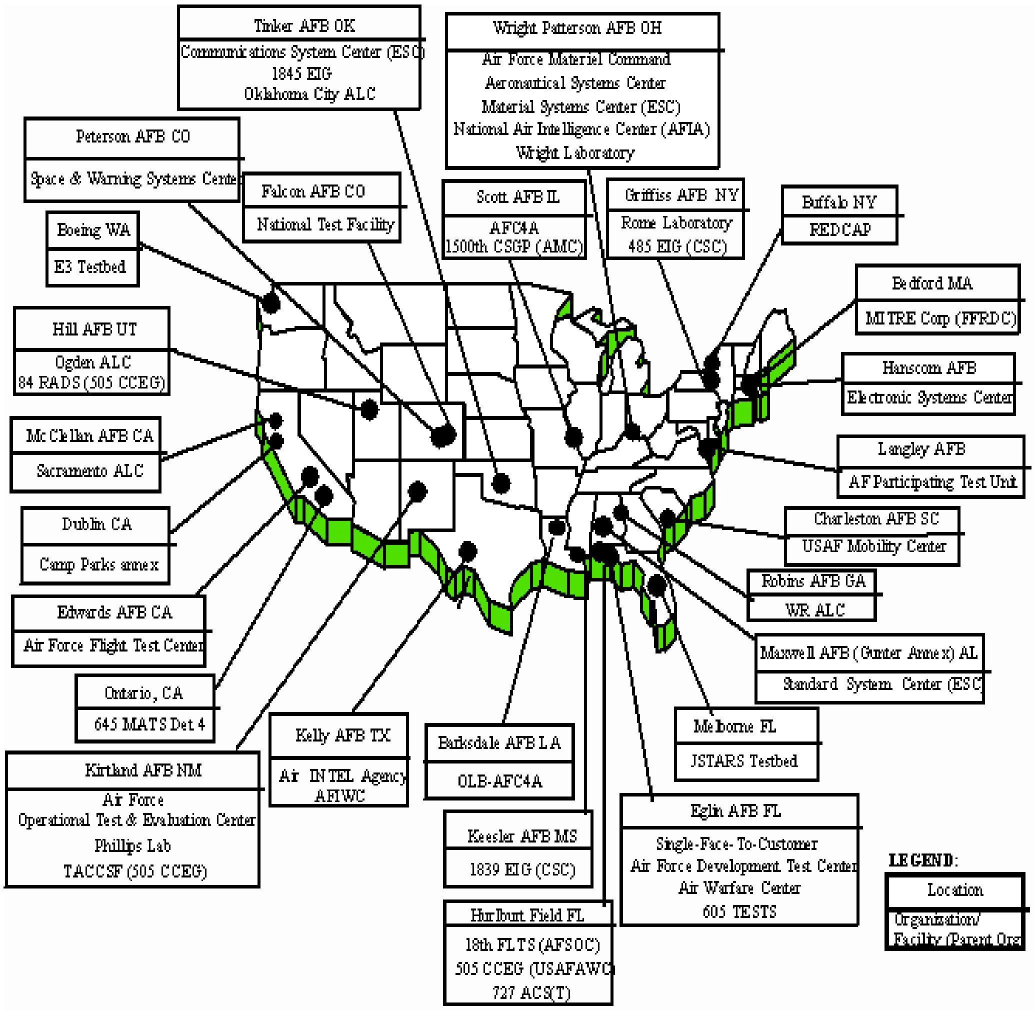
2.8.2.4. Annual Test Process Summary. An annual Test Process Summary (TPS), compiled by the SPO, will record all DT&E and OT&E accomplished, key T&E process decisions, T&E deficiencies and identified risk areas. This summary will also list all documents added to the TPA during the year. The TPS provides a record of testing, decisions, deficiencies, and risk areas typically below the level of detail contained in the TEMP. The format for the TPS is determined by the SPO and can be included in the annual interim “End of Phase Report” documented in paragraph 7.6 of AFI 99-101, *Developmental Test and Evaluation*.

2.9. Integrated Processes. The C4I T&E process supports and must be integrated with the overall acquisition process addressed in AFI 99-103, *The Air Force Test and Evaluation Process*. The user defines system requirements and deploys the system after development. The Single Manager (SM) responsible for the system controls program specifications, design, development, and production. The Responsible Test Organization (RTO) and the Operational Test Agency (OTA) are responsible for detailed test planning, conduct, evaluation, and reporting. Information, relating to the system to be acquired, must be gathered and shared between the user, developing contractor, tester, and acquisition community. Ultimate system responsibility resides with the SM who makes decisions based upon T&E information provided by the RTO and OTA. The C4I T&E Process requires an integrated effort to obtain a quality product that meets the needs of the user. See AFI 99-103, *The Air Force Test and Evaluation* Process and DoD 5000 directives for a detailed description of how T&E relates to the five acquisition phases and milestones.

Section C— Application of the C4I T&E Process

3. The Air Force C4I T&E Community. Effective employment of Air Force resources in a dynamic and demanding world environment requires compact, robust, user friendly, and sometimes highly mobile C4I systems. These qualities can be achieved only through maximum standardization and adherence to well-conceived development, acquisition, sustainment and test and evaluation processes. The following paragraphs will help you understand roles of the different C4I organizations involved in development and operational C4I test and evaluation and how they support the C4I T&E process. Geographic locations of the Air Force C4I Community are shown in **Figure 11.** and a description of each appears in **Attachment 2**. **Attachment 3** describes C4I T&E capabilities of the other Services.

Figure 11. The Air Force C4I T&E Community.



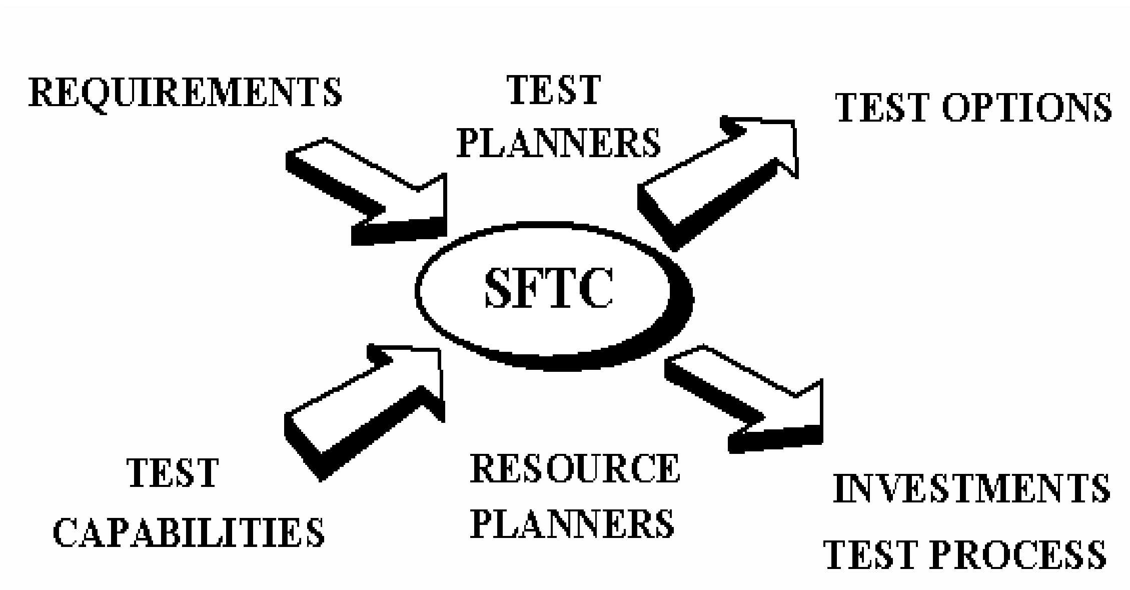
3.1. ARMAMENT/WEAPONS-C4I-EW Single-Face-To-Customer, Eglin AFB, FL. The SFTC is the first organization to contact for C4I T&E planning support. The SFTC's purpose is to improve efficiency and cost effectiveness by assisting customers with disciplined application of the C4I T&E Process. The SFTC identifies risks in various test options available to customers, and helps customers understand the capabilities and test applications of the resources available to them. **Figure 12.** illustrates the concept of operations for the SFTC.

3.1.1. The ARMAMENT/WEAPONS-C4I-EW SFTC is the Office of Primary Responsibility (OPR) for AFMAN 99-111, *The Air Force C4I T&E Process* documentation and provides assistance with its implementation. The SFTC offers experienced test planners to help customers define cost-effective test and evaluation options for their programs and provides interfaces with the other functional area SFTCs. The SFTC also has investment planners familiar with current and future test facilities and capabilities of the Air Force, Navy, Army and FAA that assist with test planning and any needed test resource investments. The SFTC also maintains a data base of C4I test facilities.

3.1.2. The services of the SFTC can be used throughout the acquisition cycle. Early in the acquisition program, the SFTC can save the program office considerable time and effort by providing early test planning assistance. Later, when a Responsible Test Organization (RTO) is designated (such as a test wing, squadron or facility), the RTO prepares detailed test plans and interfaces with the SFTC for specific test support needs.

3.1.3. The SFTC typically provides test planning services during the early phases of C4I acquisition programs or the early phases of modifications/P3I programs. Once initial T&E planning is completed, the role of the SFTC diminishes to the role of test cognizance and support of the RTO, as requested. AFI 99-101, *Developmental Test and Evaluation*, requires a program office or RTO to coordinate with the SFTC Office in the following situations: 1) if the C4I program is a new start and has a Program Management Directive (PMD) or 2) if a Test and Evaluation Master Plan (TEMP) is being developed or revised.

Figure 12. SFTC Concept of Operations.



3.2. Responsible Test Organization (RTO). The RTO is the lead organization responsible to the single manager (system manager, product group manager, material group manager or laboratory) for specified DT&E. The PMD usually documents the RTO selection. However, if the PMD does not list an RTO for a new C4I program, the SM should contact the SFTC for RTO recommendations. The SFTC will recommend an RTO after considering the following factors (not in priority order):

- Center of expertise -- experience and past performance with similar programs
- Capacity -- ability of a test center or facility to accommodate the new test workload
- Geographical -- proximity of ranges to product center, logistics center or contractor and life-cycle test considerations
- Relationships -- existing cadre of contractor personnel
- Facilities -- availability of existing test facilities or links to C4I participating test systems (DoD and other government facilities should be used, when available)

- Customer satisfaction -- past performance (metric data) for previous or similar programs
- Reliance -- other Service's capability to conduct the test

3.2.1. After considering the SFTC's recommendation, the SM forwards its RTO nomination to HQ AFMC/DO for official RTO designation. The RTO for C4I programs will typically be an Air Force test center. If there is a compelling reason for not selecting a test center, the SM will obtain an RTO concurrence decision through either the Integrated Acquisition Strategy Panel (IASP) or through the Designated Acquisition Commander (DAC) as appropriate; the SM then forwards the RTO selection to HQ AFMC/DO for official RTO designation. Upon designation of an RTO, test planning assistance transitions from the SFTC to the RTO.

3.2.2. The RTO is the lead organization for designing and conducting all or assigned portions of the test program. The RTO will help prepare and update the TEMP or test section of the Program Management Plan, and the RTO will plan, program, estimate test cost, and manage test support resources. Thus, it is imperative that the RTO understand and implement the C4I T&E Process into the test program. During the lifetime of a system, different RTOs may be needed for specific tests; however, there should be only one RTO for each major test at a given time.

3.3. Participating Test Organization (PTO). A PTO is sometimes designated to perform a portion of a program's T&E, as determined by the RTO, and the program office. PTOs are selected for their specific knowledge or capability to plan, support, or conduct a portion of the overall test program. PTOs collect, reduce, analyze, and evaluate data associated with their part of a test program and send a report or data package to the RTO and program manager.

3.4. Operational Test Agency (OTA). During Initial Operational Test and Evaluation (IOT&E) and Qualification Operational Test and Evaluation (QOT&E), the Air Force Operational Test and Evaluation Center (AFOTEC) at Kirtland AFB is the Operational Test Agency (OTA) and is supported by the using command's test centers and operational units. Later, Follow-On Operational Test and Evaluation (FOT&E) may be conducted by a using command test organization, such as the Air Warfare Center (AWC) at Eglin AFB, FL.

3.5. Air Force C4I Test Support Infrastructure. The six general categories of C4I T&E resources are: Digital Modeling and Computer Simulation (M&S), Measurement Facilities (MF), System Integration Laboratories (SIL), Hardware-In-The-Loop (HITL) facilities, Installed System Test Facilities (ISTF), and Real World Environments (RWE). These resource categories are discussed in detail in chapter four. **Figure 13.** shows locations of various Air Force C4I test support capabilities and the resource category this infrastructure most accurately represents. The Air Logistics Centers (ALCs) have depot maintenance support capabilities that can be used to support T&E activities based upon current workloading. Many C4I test facilities provide support to other T&E mission areas. Some resources support only one aspect of C4I testing, e.g., C2, while others are engineering development tools or operational units that provide real world links for realistic T&E. **Attachment 2** provides a description of each Air Force organization supporting C4I.

Figure 13. The Air Force C4I Test Support Infrastructure.

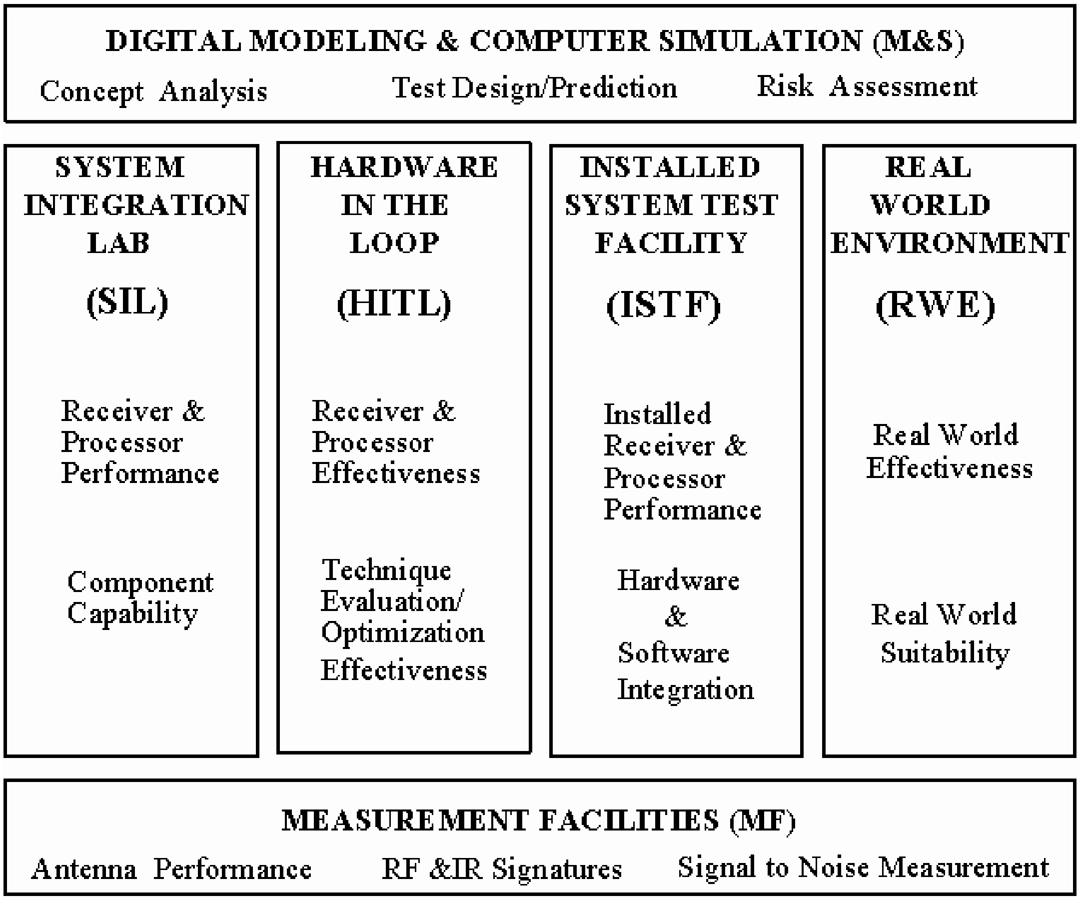
LOCATION	CAPABILITY	M	MF	SI	HI	IS	R
ANNAPOLIS, MD	JOINT SPECTRUM CENTER						
BARKSDALE, LA	C4 TECHNOLOGY VALIDATION OF-						

BOEING, WA	E-3 TESTBED						
BUFFALO, NY	REDCAP						
CHARLESTON	USAF MOBILITY CENTER						
DUBLIN, CA	CAMP PARKS COMMUNICATIONS ANNEX						
EDWARDS AFB,	BENEFIELD ANECHOIC CHAMBER						
EDWARDS AFB,	IFAST						
EDWARDS AFB,	T&E MISSION SIMULATOR (TEMS)						
EGLIN AFB, FL	BASE INSTALLATION SECURITY SYSTEM (BISS)						
EGLIN AFB, FL	ENHANCED JTIDS SYSTEM EXER-CISER						
EGLIN AFB, FL	FREEMAN COMPUTER SCIENCE CENTER						
EGLIN AFB, FL	MISSION VERIFICATION SYSTEM						
EGLIN AFB, FL	PRIMES						
FALCON AFB, CO	NATIONAL TEST FACILITY						
GRIFFIS AFB, NY	VARIOUS C4I TESTBEDS at ROME						
GRIFFIS AFB, NY	ANTENNA MEAS FACILITY at ROME LAB						
HANSCOM AFB,	VARIOUS C4I TESTBEDS at ESC						
HILL AFB, UT	SOFTWARE TECH SUPP CTR.at						
HOLLOMAN AFB,	RATSCAT/RAMS						
HURLBURT FLD,	727 ACS(T)						
KEESLER AFB, MS	1839 EIG TEST ENG						
KELLY AFB, TX	AFIWC						
HURLBURT FLD,	18FLTS (AFSOC)						
KIRTLAND AFB, NM	THEATER AIR C2 SIMULATION FA-CILITY						
LANGLEY AFB, VA	AF PARTICIPATING TEST UNIT (AF PTU)						
MAXWELL AFB, GUNTER ANNEX, AL	STANDARD SYSTEMS CENTER (SSC)						
MC CLELLAN	SACRAMENTO ALC						
MELBOURNE, FL	JSTARS TESTBED						
MITRE CORP BED-	VARIOUS C4I TESTBEDS						
ONIZUKA AFB, CA	SPACECOM TEST AND EXP. DIREC-TORATE						
PETERSON AFB ,	SPACE & WARNING SYSTEMS CEN-						
ROBINS AFB, GA	VARIOUS TESTBEDS at WR-ALC						
SCOTT AFB, IL	AFC4A - INTEROP TEST CENTER						

TINKER AFB, OK	COMMUNICATIONS SYSTEMS CEN-						
TINKER AFB, OK	OC-ALC (E3,E 4)						
WRIGHT PATTERSON AFB, OH	WRIGHT LAB - LASER COMM LAB						
WRIGHT PATTERSON AFB, OH	MATERIAL SYSTEMS CENTER (MSC)						

4. C4I T&E Resource Categories. A wide variety of test facilities and their associated resources are needed to fully execute the C4I T&E process. As discussed previously paragraphs 2.3 and 3.5, test resources fall into the categories of M&S, MF, SIL, HITL, ISTF, and RWE. Examples of how these resource categories support various types of C4I T&E are displayed in **Figure 14.** Definitions and examples for each of these categories are provided in the following paragraphs. Also, to illustrate the logical progression from one step in the process to the next, a real-world example is presented in the case of T&E conducted for the Joint Tactical Information Distribution (JTIDS) program. JTIDS is an advanced radio system which provides secure, jam resistant and high capacity data and voice information distribution that dramatically increases information available for tactical military operations. Essentially, JTIDS allows computers of various tactical elements to exchange data automatically.

Figure 14. C4I T&E Resource Categories for JTIDS (Example).



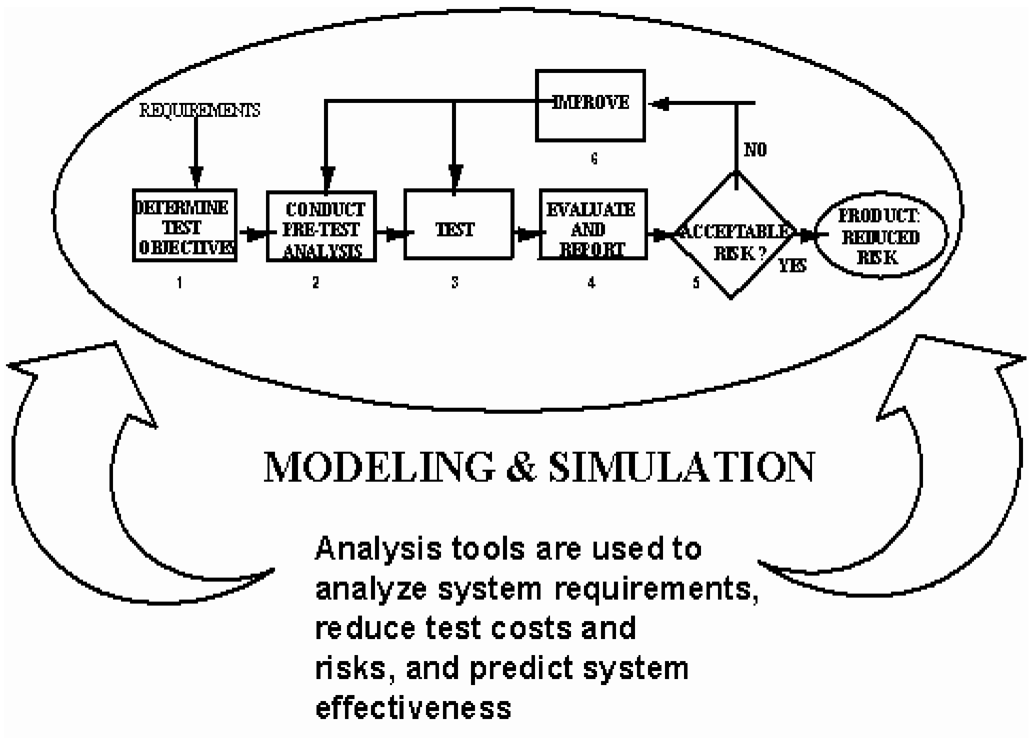
4.1. Digital Modeling and Computer Simulation (M&S). Modeling and Simulation tools are used in conducting feasibility studies, system design, performance bench marking, threat modeling, risk reduction, and test resource planning. M&S can and should support all steps of the C4I test process as shown in **Figure 15.**

4.1.1. Digital models and computer simulation tools are used to represent C4I systems, host platforms, other friendly players, and the combat environment. They can be used to help design C4I systems (as in modeling throughput or rapid prototyping of user-system interface) and define test requirements. Due to their relatively low cost and ability to produce consistently repeatable results, models and simulations can be run many times to explore various alternatives. M&S can also be used to explore the widest possible range of system parameters without tying up high-cost, limited assets or concern for flight safety. The four most common M&S levels are:

- **Level I--Engineering Models.** These are component level models used to examine the technical performances of an individual component or sub-system.
- **Level II--Platform Models.** Weapon system level models used to evaluate effectiveness, including associated tactics and doctrine, in the context of an integrated weapon system engaged with varying-density scenario.

- Level III--Mission Models. Multiple weapon system level models combined into a simulated mission to analyze mission effectiveness and force survivability of friendly, multi-platform composite forces opposing many enemy threats.
- Level IV--Theater or Campaign Models. This level incorporates the C4I contributions of joint-Service operations against a combined threat force (force-on-force). Level IV integrates various missions into regional, day and night, and joint operations.

Figure 15. M&S Supports Each Step of the C4I T&E Process.



4.1.2. C4I T&E efforts should use M&S to assist in defining critical performance parameters; designing and focusing testing; supporting model validation; and expediting system development and modification. M&S use should start early in the acquisition program, ideally during concept exploration, and continue through real-world environment testing. M&S is not limited to development testing, it can be used to assist in operational assessments to replace certain portions of operational testing requiring multiple high-cost, high priority assets.

4.1.3. M&S tools have been used in the C4I T&E area in the Modular Control Equipment (MCE) P3I program. The prime contractor designed and built an In-Plant Simulator (IPS), to support in-plant T&E work. This simulator has been used in conjunction with the JTIDS System Exerciser to provide data link and radar input to the mission computer. This allowed a reduction of planned flight test and data collection, thus saving time and money.

4.2. Measurement Facilities (MF). Measurement facilities establish the character of C4I related system/subsystem or technology. They provide capabilities to explore and evaluate advanced technologies such as those involved with digital techniques for information exchange, radio modulation schemes for systems requiring specific data exchanges, and various sensor and antennas technologies.

Measurement facilities have capabilities to measure antenna patterns, electromagnetic interference, and environmental and platform signatures.

4.2.1. The JTIDS program conducted antenna pattern measurement test and evaluation at Rome Laboratory at Griffiss AFB, NY. Rome Laboratory provides the ability to mount an aircraft upside-down and right-side up in order to optimize antenna placement and fully characterize antenna patterns. While possible to accomplish in flight, it would be significantly more expensive, more time-consuming, and probably less accurate and less comprehensive. For the North Warning System (NWS) test program, one contractor built a test range and support tower to conduct measurement of antenna patterns. This allowed for antenna pattern characterization long before system deployment, at a point when problems could be addressed without significant impact. **Note:** Even though this T&E was accomplished over 10 years ago, the results are still used in new studies today.

4.3. System Integration Laboratories (SIL). SILs are facilities designed to test the performance and compatibility of components or subsystems 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 weapon system. A variety of computer simulations, test equipment, and actual hardware and software are used to generate scenarios and environments to test the component for functional performance, reliability, and safety. SILs are generally weapon-system specific and are found primarily at contractor facilities.

4.3.1. The Enhanced JTIDS System Exerciser (EJSE) is an integration tool developed for the JTIDS program. The EJSE is basically a lab set-up that includes a JTIDS Class 2 Terminal, Terminal Interface Processor, Display Processor, Simulation Processor, and a variety of other equipment. It is used to support integration of the JTIDS with its host platform, and to provide a capability for software testing, including stressing the JTIDS network.

4.4. Hardware-in-the-Loop (HITL) Facilities. HITL facilities provide secure indoor ground environments to test systems against manned, closed and open-loop threat simulators and high-fidelity targets. HITL facilities are used to evaluate the effectiveness of actual system hardware and software under controlled, repeatable, non-destructive test conditions at different stages of development (e.g. breadboard, brassboard, and production). HITL facilities can also be useful in tactics development, allowing rapid, flexible testing under changing conditions.

4.4.1. The Real-time Digitally Controlled Analyzer Processor (REDCAP) is an example of a C4I HITL facility. REDCAP provides the ability to determine how a system under test will respond to or impact the command and control links of an Integrated Air Defense System (IADS). The REDCAP is managed by the Air Force Development Test Center (AFDTC) at Eglin AFB and located at and operated by CALSPAN Corporation in Buffalo NY.

4.5. Installed Systems Test Facilities (ISTF). ISTFs provide secure capabilities to evaluate systems and functions installed on and integrated with host platforms. These test facilities often include anechoic chambers in which free-space radiation measurements are made during simultaneous operation of the system and other host platform systems.

4.5.1. In order to determine if there was any electromagnetic interference or incompatibility between the installed JTIDS and the F-15 IFF, TACAN, or radar warning receiver, an F-15 was suspended in the Preflight and Integration of Munitions and Electronics Systems (PRIMES) chamber at Eglin AFB, FL. Because the PRIMES chamber is a completely shielded anechoic chamber, it was possible to operate all of the systems in all of their modes to determine any EMI/EMC problems, without interference from unknown sources.

4.6. Real World Environment (RWE). Real world test capabilities are used to evaluate systems in an operationally realistic, dynamic environment. These resources include test ranges, airborne test beds, and fixed system operational locations (e.g. NORAD). Real world testing is usually the most costly and requires numerous missions or operating hours to collect significant amounts of data, but the RWE test resource category also provides an opportunity to evaluate the system in an environment closely approximating the actual operational environment. Testing may be ground or airborne with an emphasis on providing real-world phenomena and environment. Airborne test beds consist of various airframes modified to support spread-bench installation and testing of C4I systems in early stages of development and/or modification. Test ranges that are highly-instrumented with threat simulators and systems, measurement equipment, and radar tracking capabilities such as those at Eglin AFB, FL and Edwards AFB, CA are typically used for RWE T&E.

4.6.1. The JTIDS program has used the real-world environment for regression testing. When software and hardware changes have been made to the system, and the contractor's lab, SIL, HITL, and ISTF testing have been conducted, real-world testing is the next step. JTIDS has used the Electromagnetic Test Environment (EMTE) at Eglin AFB, FL to conduct real-world missions using multiple JTIDS-equipped aircraft. These missions have been conducted to evaluate the navigation capability, which can only be done in the open-air environment, and to confirm results of testing conducted in the labs. Another RWE example is the Tower Restoral Vehicle (TRV), which used the tank range at Aberdeen Proving Ground to conduct a Type IV Mobility Road Test. Also, the Base Installation Security System (BISS) program has its own dedicated test range at Eglin AFB. This range provides an instrumented test arena to evaluate various personnel detection sensors in a typical threat environment. All of these facilities provide a test capability that would be virtually impossible to duplicate in a laboratory environment.

5. Test and Evaluation Phases. The need for a well-defined C4I Test and Evaluation Process is evident by the problems that have plagued acquisition of C4I systems in the past. Many times problems did not surface until late in the acquisition program, necessitating expensive fixes and significant schedule delays. As a system advances through its development cycle, there are typically three phases of test and evaluation. These are Contractor Conducted **Development Test and Evaluation (**DT&E**), Government** Conducted **Development Test and Evaluation ,** and **Operational Test and Evaluation (OT&E).** Government conducted DT&E and OT&E are always conducted by the government. Three aspects of the test and evaluation phases are significant: the objectives of each type of testing differ, the different testing phases overlap, and the development test team involves a combined effort with the program office technical staff, the responsible test organization (RTO), and representatives from the development contracting team. **Figure 16.** highlights key differences among the three T&E phases.

Figure 16. T&E Phases for C4I Systems.

(DT&E) CONTRACTOR	(DT&E) GOVERNMENT	(OT&E) OPERATIONAL TEST AND EVALUATION
• Conducted by Contractor with some Government involvement • Verifies Technical Performance Specifications • Aids Engineering Design and Development • Determines Readiness for DT&E	• Conducted by Government Responsible Test Organization (RTO) with some Contractor involvement • Identifies cost-performance trade-offs and design risks • Verifies Contractor Design, Development and Test Effort • Certifies Readiness for OT&E	• Conducted by Goverment Operational Test Agency • Complete Independent Evaluation • Determines operational effectiveness and suitability under realistic combat conditions • Verifies operational requirements are achieved as specified in the ORD

5.1. Contractor Conducted **Development Test and Evaluation.** During DT&E, the contractor uses his test program to support engineering design and development activities and to verify that the technical performance specifications are being met. Although complete reliance on the contractor to conduct necessary and sufficient test and evaluation is inappropriate, specific data collected during DT&E should be utilized to satisfy similar objectives of development T&E conducted by the government. Contractor conducted DT&E verifies readiness for government conducted DT&E.

5.2. Government Conducted **Development Test and Evaluation.** Government DT&E is conducted by the Responsible Test Organization (RTO), typically an Air Force Test Center. Government DT&E measures a contractor's progress, verifies the contractor's design, development, and test effort, and validates that contract specifications are being met. The System Program Office (SPO) will not serve as their own RTO except under unusual circumstances. Whenever possible, DT&E test objectives should be tailored to complement OT&E objectives. Government DT&E should be conducted in as an operationally realistic environment as possible and address issues of effectiveness, suitability, supportability, reliability and maintainability. Discovering problems during DT&E allows necessary system modifications to be done more cost-effectively than during the OT&E phase. DT&E is followed by Operational Test and Evaluation (OT&E), conducted by the Air Force Operational Test and Evaluation Center (AFOTEC) or a MAJCOM operational test unit.

5.3. Operational Test and Evaluation (OT&E). OT&E is conducted to prove that the system meets user requirements and focuses on questions of operational effectiveness, suitability, and supportability. OT&E uses a realistic operational environment to test to user requirements, not the specifications as in DT&E. Contractor involvement diminishes as the system moves into OT&E. DT&E data can be used to support conclusions in OT&E as long as it was collected under operationally realistic conditions without undue contractor influence on operationally representative test articles. Key players involved in OT&E are the Air Force Operational Test and Evaluation Center (AFOTEC), the Government Program Office Test Staff and RTO in coordination roles, and the Government User of the System Under Test.

5.4. Combining Development (DT&E) & Operational Test and Evalua tion(OT&E). Conducting DT&E and OT&E sequentially often extends acquisition time or increases the acquisition costs.

Although DT&E and OT&E are usually conducted as separate and distinct activities, the resources needed to conduct and support the two efforts are often very similar. A combined DT&E and OT&E approach should be used whenever there can be significant savings of time and funds.

5.4.1. Much of the test data generated by each are beneficial to both phases of tests; therefore, testers may conduct a combined DT&E/OT&E to expedite system acquisition and reduce costs. DODI 5000.2 encourages combined testing and states that “a combined DT&E and OT&E approach should be considered when there are time and cost savings." The Single manager (SM) will document the plan to conduct combined testing in the Test and Evaluation Master Plan (TEMP). When planning for combined testing, development and operational testers must integrate the necessary test conditions and data requirements. Planning efforts must be carefully coordinated early in the acquisition program to ensure data is obtained to satisfy the needs of both the developing agency and the independent operational tester. Care must also be exercised to ensure a combined test program contains dedicated operational test events to satisfy the requirement for an independent operational evaluation.

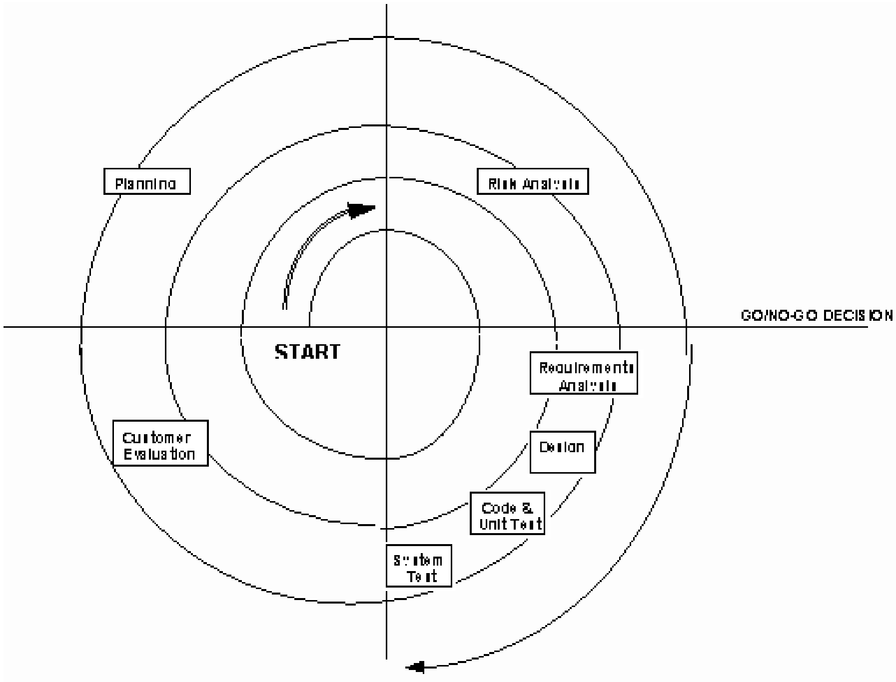
5.4.2. Combined testing typically can be divided into three segments. In segment one, DT&E events usually assume priority because critical technical and engineering tests must be accomplished to satisfy the engineering and development process. During this early segment, OT&E personnel participate to gain familiarity with the system under test and to gain access to any test data that can support OT&E. The next step, which is the combined portion of the testing, includes shared objectives or joint data requirements between DT&E and OT&E testers . The last data segment normally contains the dedicated OT&E or separate OT&E events to be conducted by the OT&E agency. The OT&E agency and the implementing command must ensure that combined testing is planned and executed to provide the necessary operational test information. The OT&E agency provides an independent evaluation of the OT&E portion directly to the Milestone Decision Authority and User and is ultimately responsible for achieving OT&E objectives.

6. Software Intensive Systems. C4I systems require significant amounts of software to collect, process, disseminate, control, utilize, and store critical information. The software development process consists of several well-defined steps that, if properly followed, lead to well designed, maintainable software. The basic phases of the software development process are shown in **Figure 17.**

6.1. Defining Software Requirements. A robust definition of requirements is one of the most important actions influencing the success of a C4I acquisition program. Software requirements, like hardware requirements, must be realistic, unambiguous, consistent, traceable, and testable. A software solution to a user’s need must be viable and address critical issues such as, system performance, reliability, maintainability, and operational suitability. Software requirements provide the basis for design activities and guide planning for software testing that will determine if the software operates according to the requirements. Requirements must state what the software is to do in terms of inputs, outputs, processing speed, and accuracy. Evolutionary acquisition programs will often be able to document mature operational requirements only for near-term increments; however, it is imperative that immature requirements in later increments be defined before initiation of the next increment’s software development.

6.1.1. A recent study, conducted by TRW, showed that 64 percent of all software errors are introduced during the requirements analysis and design specification phases, and that only 30 percent of these errors are detected before the software is delivered for system testing. In contrast, only 36 percent of the errors are introduced during coding, and of these errors, a full 75 percent are found before system testing begins (**Figure 18.**).

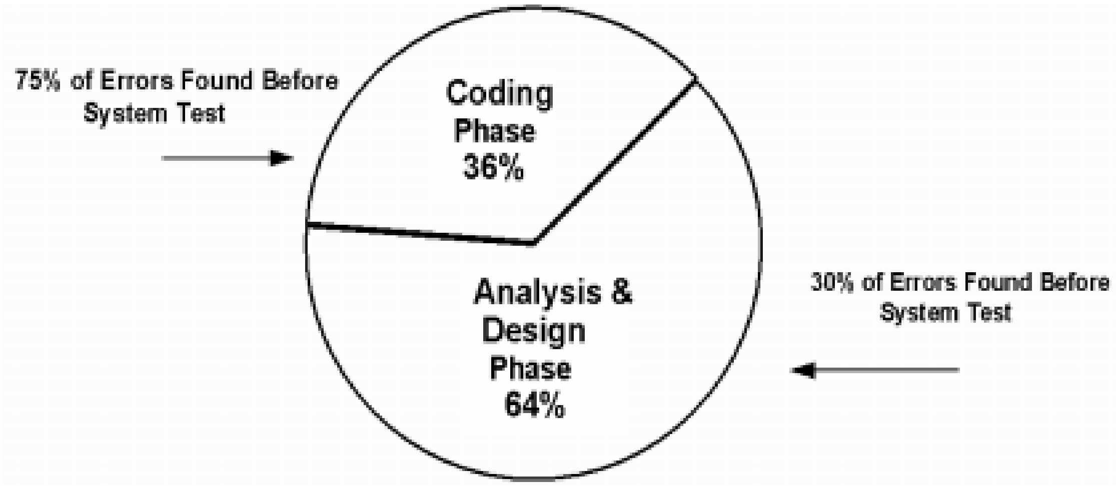
Figure 17. The Spiral Model of Software Development.



6.1.2. As each phase of the software development effort is completed, the cost of correcting errors increases by an order of magnitude. An error found during the design stage costs a negligible amount to correct. An error found during unit testing of a single module is not usually difficult to fix but costs more than fixing an error during design. Correcting an error discovered during integration testing often involves several people and requires communication among multiple groups. This situation easily costs an order of magnitude more than for errors found during earlier phases of development. An error found in a production system involves costs that increase by another order of magnitude or more.

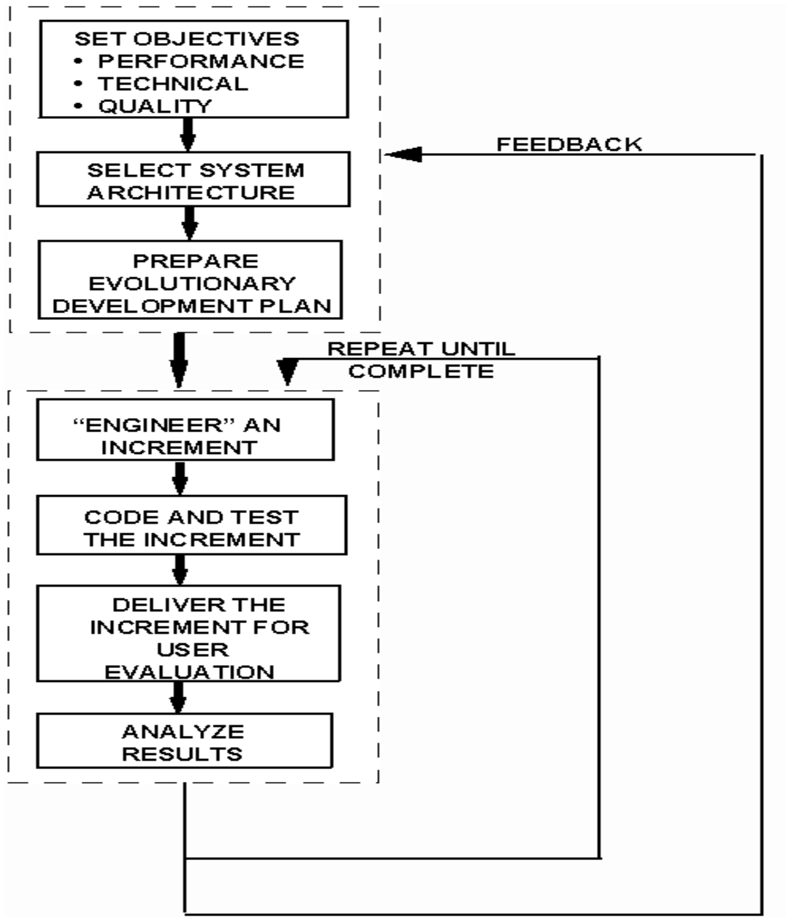
6.1.3. A resolution to this problem is to identify software problems before they are coded, or to do whatever is possible to prevent them from occurring in the first place. Users, developers, and testers should participate jointly in requirements analysis and definition phases of the development. They should be mutually responsible for ensuring that requirements are clearly documented, implemented, and testable. Testers also need to be involved early so they can begin test planning activities to ensure the test infrastructure and proper test tools are in place when the system is ready for testing. If an RTO has not been identified during the early phases of a software intensive, C4I acquisition effort, the SFTC represents the DT&E community during early planning activities.

Figure 18. Most Software Errors Are Introduced Early in the Software Development Process.



6.1.4. Without an effective software test and evaluation effort, the software, and therefore the system has unmanaged risk. Software testing must be conducted in accordance with written test plans and procedures. Since software tests can only address a small number of potential inputs and input combinations, the tests that are performed must be carefully selected with the intent of revealing possible errors or deficiencies. Often the developing contractor's tests are defective in this regard. The developing contractor performs software test and evaluation using contractor developed data bases and scenarios to demonstrate that its products have no errors. Software test experts point out that if you are not looking for errors in testing, chances are you will not find many. An effective software T&E effort has as its objective the discovery of errors, not the demonstration that there are no errors in the software. A software test organization, managed by the government and independent of the software design and coding organization should be responsible for development testing of the software. This independent group will not suffer from the preconceptions and assumptions that introduced the software errors in the first place.

Figure 19. The Evolutionary Software Development Process.



6.2. Evolutionary and Incremental Software Development. Evolutionary software development is used when the user is unable to clearly define all the requirements up front. A core set of requirements are defined initially as a starting point. C4I systems, Automated Information Systems (AIS) in particular, are likely candidates for evolutionary development because they are characterized by system requirements that are difficult to quantify or even articulate and are expected to change as a function of scenario, mission, theater, threat and emerging technologies.

6.2.1. The traditional practice of testing only once with a large quantity of code after analysis, design and coding procedures is no longer recommended due to the galloping speed of advances in technology. However, if a large software development does not field incrementally, the spiral model (**Figure 17.**) represents the development process. The system is "built a little, test a little" extending the product incrementally until the system development is complete.

6.2.2. In an evolutionary or incremental software development acquisition strategy, however, the development and fielding processes can be characterized as being both developed and fielded a piece at a time.

6.2.2.1. In the incremental software development process (see figure 6.3), the general system and software objectives are defined, the system architecture is selected, and an incremental development plan is prepared. The initial core increment defines a core set of functional requirements and usually provides the core hardware architecture. After a core increment is designed, coded and tested, it is delivered to the user for evaluation and, in some cases, actual operation. The results of this evaluation and operation are then used to select, design, code, and test the next increment which will provide additional system capabilities. This process is repeated until the entire system has been developed. If significant problems are encountered with a portion of the development, it may be necessary to re-examine and revise the overall system objectives, modify the system architecture, and update the incremental development plan.

6.2.2.2. The evolutionary development strategy contributes to reduction of risks involved in software system acquisition. Evolutionary development accomplishes this risk reduction by reducing the system's development and testing to more manageable increments. By dividing the system's requirements into phases of development, each evolution's experience and results are applied to the next evolutionary phase. An important part of an evolutionary strategy includes using the results of first evolution to refine and modify the requirements. An advantage of the evolutionary method is that the developing contractor and the SM can demonstrate to the user, a piece at a time, that the system under development will work as advertised. This approach provides an early, useful capability to the user, even though detailed overall system requirements cannot be fully defined at the time of the program's inception. Notably, this method also provides information to the user which should help to further refine the operational requirements needed in the next increment. To avoid fielding increments with latent software problems, it is important to conduct comprehensive T&E at the end of each phase of development prior to fielding. Forcing operational users to debug software for the system developers is not an effective manner in which to conduct T&E.

6.2.3. Testers contribute to the requirements process of the evolutionary software development process through feedback of test results to the user and must judge the ability of the system to evolve. Testers must become involved early in the acquisition process and contribute throughout the development and fielding of the core and the subsequent increments of the system.

6.3. Software Test Phases. The phases of software testing are unit, integration, and system test. **Figure 20.** shows the typical relationship between software development, integration and test and evaluation activities.

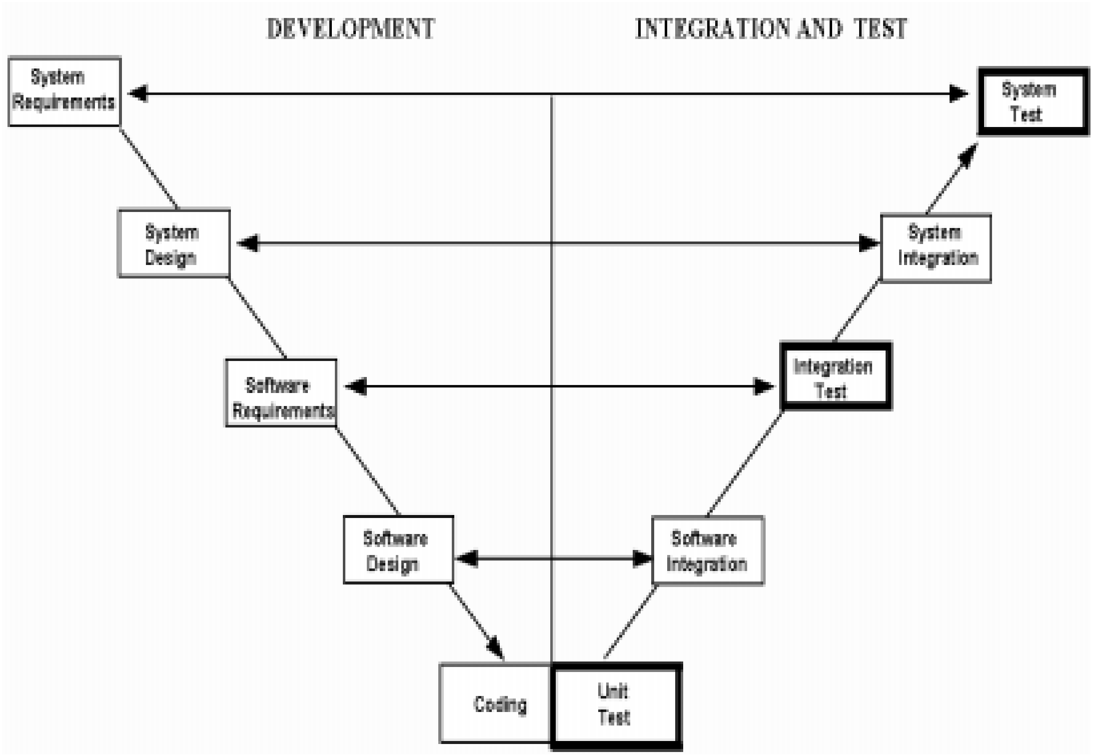
6.3.1. Unit Test Phase. Unit testing involves testing each individual module developed during coding. Typically, unit testing is conducted by the software engineer who coded it. A structured walkthrough, typically consisting of a few members of the software development team, should also be used to check for design and coding errors. A software development effort that is efficient and comprehensive, will detect most of the coding errors during unit testing so that the units delivered for integration testing are nearly error-free. Errors not discovered until integration testing involving several units are much more difficult to isolate than errors occurring within a particular unit.

6.3.2. Integration Test Phase. The purpose of the integration test phase is to combine the software units that have been individually tested into the total software product. In this phase, software components are combined into a complete software system, the software is installed on its intended hardware platform and the system is exercised in a realistic environment. The software development team, in close conjunction with a selected group of functional users, usually conducts integration testing. A top-down integration and test approach, which is analogous to the top-down design approach, is often the best strategy. In a top-down approach, the highest level modules in the design hierarchy are integrated with the next lower levels, and then the combination is tested. If a particular combination of modules performs a specific system function, then that combination should be integrated and tested in this top-down fashion. The sequence in which modules or groups of modules are integrated and tested should be described in the Software Development Plan (SDP), the Program Development Specification (PDS), and the Software Test Plan.

6.3.3. System Test Phase. The purpose of this test phase is to demonstrate that the software and hardware, working as a system, accomplish all system functions and that the system is ready for production and deployment. Acceptance, as a result of this test phase, includes all documentation needed to use and maintain the software. Thus system test also includes review and comparison of software documentation with the delivered source code. Particular attention should be paid to verifying that changes made to the code as a result of integration testing are reflected in the user and design documents. If errors are discovered during the System Test activity, the impact of these errors must be assessed. If the error has a significant impact on system performance, the System Test activity should be interrupted until the software is fixed and regression testing accomplished. Minor problems should be recorded and fixed at the end of the System Test activity.

6.3.3.1. The system test phases can be divided into three phases: Alpha, Beta Phase I, and Beta Phase II testing. Alpha testing is directed and conducted by the developing contractor, at the contractor's site. Alpha testing is the first level of formal software tests that requires Government approved test plans, descriptions, and procedures. Test documentation should be received by the Government for review at least 30 days prior to the start of testing. Once formal testing begins, approved plans and procedures must be followed. Alpha Testing is very similar to Contractor conducted Test and Evaluation (DT&E) presented in paragraph 5.

Figure 20. Typical Relationship Between Software Development and Test Activities.



6.3.3.2. Beta Testing is a development test and evaluation (DT&E) activity that can be divided into two phases, I and II. Beta Phase I testing is directed and conducted by an independent Government test organization, typically an RTO, at a Government Test Facility. The same test plans and procedures used during Alpha Test are also used during Beta I test. Beta Phase I testing typically uses functionally representative interfaces whereas Beta Phase II uses real world data bases, hardware interfaces, and data links. Beta Phase II, like Beta Phase I is directed and conducted by the Government but testing is done at one or more user sites instead of a Government test facility.

6.3.3.3. The plan-predict-test-compare test philosophy applies to all levels and phases of software testing. Utilizing the C4I T&E Process will reduce risk in software intensive, C4I acquisition programs.

NOTE:

For information regarding software reviews and audits, reference MIL-STD-1521B, *TECHNICAL REVIEWS AND AUDITS FOR SYSTEMS, EQUIPMENT, AND COMPUTER PROGRAMS*.

7. Non Developmental Items (NDI). NDI refers to materiel coming from a variety of sources but involving little or no development effort. A Non Developmental item is:

- Any item available in the commercial marketplace;
- Any previously developed item in use by a federal, state or local agency of the United States or a foreign government with which the United States has a mutual defense cooperation agreement;

- Any item described above that requires only minor modification to meet the requirements of the procuring agency;
- Any item currently being produced that does not meet the three requirements above solely because it is not yet in use or available in the commercial marketplace (DODI 5000.2, 6-L).

7.1. NDI Types. NDIs can be separated into three general categories. Each category requires a modified testing approach. These categories are:

- Commercial off-the-shelf (COTS) items for use in the same environment for which the items were designed. These items require test and evaluation to ensure that the products meet user requirements stated in the ORD and to verify integration and interoperability with other systems.
- COTS items for use in an environment other than the one for which the items were designed. Such items may require modifications in hardware and/or software. COTS in this category may have different performance requirements and logistics support factors. These items require testing in an operational environment, pre-production qualification testing and production qualification testing.
- Government Furnished Equipment (GFE), also referred to Government Off-The-Shelf (GOTS), which includes previously developed items in use by a US Government agency or a foreign government with which the US has a mutual defense cooperation agreement.

7.2. NDI Considerations. The use of NDIs in a system acquisition can provide considerable time and cost savings. Advantages of using NDI include: the time to field a system is greatly reduced; a quick response to the user's needs is provided; research and development costs are reduced; and state-of-the-art technology is available immediately. Disadvantages of using NDIs include: NDIs may be difficult to standardize with the current C4I equipment; NDIs can create logistics support difficulties; and engineering and test data may not be available.

7.3. NDI Test and Evaluation. The test approach used for an NDI acquisition must be carefully tailored to the type of system, the environment in which it will be used, and the amount of test data already available. The C4I T&E community must engage early in the acquisition process to ensure that all test issues are adequately addressed and timely comprehensive evaluations are provided to decision authorities. The C4I T&E Process should be used throughout the acquisition of a system that involves NDI just as in the classic acquisition approach. The SM must ensure that the test community is fully involved in the acquisition from the start.

7.3.1. The amount and level of testing required depends upon the nature of the NDI, and its anticipated use. T&E should be planned to support the design and decision process. At a minimum, T&E of the NDI should be conducted to verify integration and interoperability with other system elements. All modifications necessary to adapt an NDI to the weapon system environment will also be subjected to T&E. Available test results from commercial and Government sources will determine the actual extent of testing necessary.

7.3.2. There are some inherent advantages in an NDI acquisition from a T&E perspective. For example, an NDI usually encompasses a mature design. In addition, there are more production items available for use in the test program. Although regression testing is required for an NDI not used as it was originally designed, using an NDI acquisition strategy reduces acquisition time. Consequently, it is important that testing not be redundant to that already accomplished by the developing contractor. NDI T&E can be minimized by:

- Obtaining and assessing contractor test results (if available);
- Obtaining usage/failure data from other customers;
- Observing contractor testing;
- Obtaining test results from independent test organizations such as Underwriter's Laboratory;
- Verifying selected contractor test data.
- If it is determined that more information is needed after the initial data collection from the above sources, NDI candidates may be purchased or leased, and technical and operational tests conducted.

8. Joint Interoperability Certification. It is DoD policy that all C4I systems developed for use by or in support of US forces must be certified as interoperable with systems with which they have a requirement to exchange information. Interoperability requires that systems are interoperable to the degree specified by the warfighter and necessary to ensure timely, efficient, and survivable C4I functions at all force levels. Interoperability certification is critical to approval for production (Acquisition Milestone III). For ACAT I programs, the timeline for certification is set by the JROC schedule. For ACAT II-IV programs, the request for certification must occur at least 30 days prior to milestone decisions. Major hardware and software modifications that affect interoperability of fielded C4I systems require recertification before those modifications are fielded for initial operational capability (IOC). A waiver from interoperability certification or re-certification, based on justifiable circumstances and impacts, may be granted but will not be permanent. This waiver, known as Interim Authority To Operate (IATO), covers circumstances such as the first system to use a particular standard or one having an urgent operational need to be fielded.

8.1. Interoperability Certification. Interoperability is achieved through an early joint review of C4I requirements, the application of standards to the solution of those requirements, certification testing to verify interoperability and correct implementation of standards, and configuration management to maintain the interoperability achieved. Standards are the foundation for interoperability. Their availability, use, and enforcement are the basis for achieving the ultimate goal of a seamless environment. Requirements for new or modified systems must be based on an identified need that addresses their use in operations. Requirements for interfaces, software integration with other C4I-related weapon systems, supporting functional information systems, or for interconnection with the Defense Information System Network will be clearly identified in requirements documents.

8.2. The Joint Interoperability Test Command (JITC). The Joint Interoperability Test Command (JITC) located at Ft Huachuca, AZ is the DoD Executive Agent for interoperability testing and certification of C4I systems and equipment. JITC responsibilities include:

- Providing acquisition managers with recommended interoperability T&E criteria and standards for inclusion in acquisition documents and test plans;
- Reviewing documents such as the Mission Need Statements (MNS), Operational Requirements Documents (ORD), and Test and Evaluation Master Plans (TEMP) for interoperability test requirements.
- Observing service DT&E and OT&E interoperability test events or conducting interoperability testing when services are unable to address interoperability in DT&E and OT&E;
- Reviewing or developing test assessments of data collected on interoperability from all sources;

- Certifying or re-certifying C4I systems and equipment that meet interoperability certification requirements based upon service DT&E and OT&E results or JITC test results, if required.

8.2.1. JITC can use test data collected during DT&E and OT&E for interoperability certification if that data is adequate and appropriate for joint certification decisions. Accordingly, the SM should plan for interoperability testing as an integral part of DT&E and OT&E. The SM is responsible for ensuring that documents, such as the ORD and the TEMP, are provided to JITC for information review. These documents will be reviewed to ensure that interoperability requirements have been identified and that test planning is structured to address them.

8.2.2. Test and Evaluation will be conducted throughout the C4I system's lifecycle to ensure interoperability. JITC can participate with the Service tester to ensure that test duplication is minimized and data collected is valid and sufficient for interoperability certification purposes. If Service conducted DT&E and OT&E cannot meet joint interoperability certification requirements, additional testing will be required. JITC personnel can monitor or conduct tests to verify that test plans and procedures are followed, and that test data collected are complete and accurate.

NOTE:

Procedural testing is conducted with other service/agency Operational Facilities (OPFACS) to ensure the interoperability and compatibility of a system's joint message standard. Procedural testing relates to interoperability T&E conducted on Tactical Digital Information Links (TADILS) and Message Text Formats (MTF). The Air Force Participating Test Unit (AF PTU) at Langley, AFB VA conducts procedural test and evaluation for the Air Force prior to JITC testing. See **Attachment 2** for a description of the AF PTU.

8.3. The Joint Certification Process. Joint Interoperability certification of C4I systems and equipment is the culmination of successful completion of tests where results show compliance with the required standards profile, and compliance with interoperability in the joint arena. Interoperability certification will be based on an independent assessment by the JITC. Certification of C4I systems and equipment is based upon JITC's:

- Review of requirements and test reports;
- Witnessing or conducting interoperability related portions of the DT&E and OT&E testing;
- Analysis of independently gathered test data;
- Reporting of interoperability certification testing, as necessary.
- Upon successful completion of certification testing, the JITC will certify the C4I system or equipment for joint interoperability by letter to the appropriate development and operational testing organizations, the Director, OT&E, and to the Chairman of the Joint Chiefs of Staff.

9. Conclusion. This C4I T&E Process Manual describes a top-level methodology for how to perform T&E for C4I systems. It describes the approach you should use when planning and conducting tests for C4I systems at all levels and all acquisition phases. Other documents such as handbooks, test concepts, test directives, and test procedures contain detailed *how to test* information. These documents are developed by the various RTO and OTA test organizations. *How to test* is dependent upon the kind of testing (DT&E, OT&E or Combined), the test concept chosen, and the specific C4I system being tested. For assistance relating to C4I T&E, call or write the ARMAMENT/WEAPONS-C4I-EW SFTC Office as listed below:

ARMAMENT/WEAPONS-C4I-EW SFTC Office
AFDTC/DRC
101 West D Ave Ste 125
Eglin AFB FL 32542-5495
Phone (904) 882-3890 or DSN: 872-3890
FAX (904) 882-9361 or DSN: 872-9361

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

Attachment 1

GLOSSARY OF REFERENCES, ABBREVIATIONS, ACRONYMS, AND TERMS

References

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AFMAN 99-112, *The Electronic Warfare Test and Evaluation Process* (Draft)

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Abbreviations and Acronyms

AIS—Automated Information System

C4I—Command, Control, Communications, Computers, and Intelligence

COEA—Cost and Operational Effectiveness Analysis

COI—Critical Operational Issues

CONOPS—Concept of Operations

CTP—Critical Technical Parameter

DAHAP—Data Acquisition, Handling, and Analysis Plan

DEMVAL—Demonstration and Validation

DOD—Department of Defense

DR—Deficiency Report

DSM—Digital System Model

DT&E—Development Test and Evaluation (Includes both Contractor-conducted and Government-conducted Development Test and Evaluation)

FOT&E—Follow-On Operational Test and Evaluation

FRACUS—Failure, Reporting, And Corrective Action System

HITL—Hardware-In-The-Loop

IADS—Integrated Air Defense System

ILSP—Integrated Logistics Support Plan

ISTF—Installed System Test Facilities

JTIDS—Joint Tactical Information Distribution System

M&S—Modeling and Simulation

MCE—Modular Control Equipment

MF—Measurement Facility

MNS—Mission Need Statement

MOE—Measures of Effectiveness

MOP—Measures of Performance

MS—Milestone

MTF—Message Text Format

NDI—NonDevelopmental Item

OA—Operational Assessment

OAR—Open Air Range

ORD—Operational Requirements Document

OSD—Office of the Secretary of Defense

OT&E—Operational Test and Evaluation

OTA—Operational Test Agency

P3I—Pre-planned Product Improvement

PID—Program Introduction Document

PM—Program Manager

PMD—Program Management Directive

PO—Program Office

POC—Point of Contact

PTO—Participating Test Organization

RCM—Requirements Correlation Matrix

RCS—Radar Cross Section

RTO—Responsible Test Organization

SFTC—Single-Face-To-Customer

SIL—System Integration Laboratories

SINCGARS—Single Channel Ground and Airborne Radio System(s)

SM—Single Manager

SMM—System Maturity Matrix

SOC—Statement of Capability

SPO—System Program Office

STAR—System Threat Assessment Report

SUT—System Under Test

T&E—Test and Evaluation

TACS—Theater Air Control System

TADIL—Tactical Digital Information Link

TD&E—Tactics Development and Evaluation

TEMP—Test and Evaluation Master Plan

TPA—Test Process Archive

TPWG—Test Planning Working Group

TR—Technical Report

TRP—Test Resource Plan

TSPI—Time-Space-Position-Information

Test Process and Resource Terms

Acquisition Process—Process through which new systems are developed and acquired by the USAF. Normally, the structured procurement consists of five phases (Concept Exploration and Definition, Demonstration and Validation, Engineering and Manufacturing Development, Production and Deployment, and Operations Support) with key decision points at the end of each phase. (DOD Instruction 5000.2, *Defense Acquisition Management Policies and Procedures)*

Analysis—The detailed examination and application of disciplined techniques (for example, mathematics or statistics) to anything complex in order to understand its nature or determine its essential features.

Collect—Receiving and recording data with no analysis or evaluation.

Combined Testing—Joint testing conducted by the development and operational testers when, because of cost, schedule, or test item availability, they share test facilities and resources.

Compare—Analysis for the purpose of perceiving likeness and difference in test items.

Component—A subsystem, assembly, subassembly or other major element of a military system.

Contractor Test and Evaluation (CT&E)—Development Test and Evaluation (DT&E) performed by the developing contractor prior to development testing conducted by the Responsible Test Organization (RTO). The single manager, with the support of the RTO, will approve all contractor test plans and reports.

Critical Technical Parameter—Test and Evaluation Master Plan performance measures of the system that have been or will be evaluated during testing. Critical technical parameters are derived from the Operational Requirements Document critical system characteristics and should include the parameters in the Acquisition Program Baseline.

Data Acquisition Handling and Analysis Plan (DAHAP)—This plan contains detailed and explicit data collection, handling, and analysis methodology, procedures, and algorithms that are important but too detailed for the body of the test plan. The DAHAP should reflect the test plan objectives and provide a perspective for the tasks required to reduce test data to meaningful results.

Demonstrate—Testing to clearly show or make evident by action or display. Demonstration serves as conclusive evidence of feasibility or possibility without inference to expected behavior or performance.

Determine—Testing to reveal, recognize or establish a particular characteristic, trait, or attribute.

Development Test and Evaluation (DT&E)—Process used to measure progress, verify accomplishment of development objectives, and to determine if theories, techniques, and material are practical and if systems or items under development are technically sound, reliable, safe, and satisfy specifications (AFM 11-1, DT&E in this manual refers only to Government conducted testing. See also Contractor Test and Evaluation.

Digital Models—Computer models that consist entirely of software and require no unique hardware other than the particular main-frame, mini, or micro-computer on which it’s hosted.

Digital System Model (DSM)—A model representing a system under development, or a description of the system in sufficient detail to represent pertinent system characteristics in an accepted Air Force model. The DSM is a software equivalent of the system, and aids engineering development.

Evaluate—Review and analysis to establish worth (effectiveness, suitability, adequacy, usefulness, capability, or the like) of a test item.

Hardware-In-The-Loop (HITL) Facilities—HITL facilities are indoor test facilities that provide a secure environment to test C4I components, sub-systems and systems..

Installed System Test Facility (ISTF)—Facilities designed to test the performance and compatibility of components, sub-systems, or systems when they are integrated with other functions or systems.

Interoperability Testing—Assesses the degree to which the developmental interface standards support a user’s ability to successfully prepare, exchange, interpret, and use common data items and messages.

Measure—Testing to make a quantitative determination.

Measure of Effectiveness (MOE)—A measure of a system's task accomplishment.

Measure of Performance (MOP)—A qualitative or quantitative measure of a system's capabilities or characteristics. It indicates the degree to which that capability or characteristic performs or meets the requirement under specific conditions.

Measurement Facilities (MF)—Test resources used for exploring and evaluating C4I technologies. Data collected from these resources include antenna patterns, radar cross sections and infrared and laser signatures.

Model—A physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process.

Modeling and Simulation (M&S)—Tools used for feasibility studies, system design, performance benchmarking, threat modeling, risk reduction, and test resource planning. Digital models can be used to represent systems, host platforms, other friendly players, and the combat environment.

Real World Environment (RWE)—A test capability used to provide a realistic operating environment, i.e., on an open air test range or on an airborne platform.

Operational Test and Evaluation (OT&E)—Test and evaluation conducted in as realistic an operational environment as possible to estimate the prospective system's military utility, operational effectiveness, and operational suitability. In addition, operational test and evaluation provides information on organization, personnel requirements, doctrine, and tactics.

Participating Test Organization (PTO)—An organization designed to perform a portion of a program's T&E because of its specific knowledge or capability to plan, support, or conduct a portion of the overall test program.

Procedural Testing—Test and evaluation conducted on Tactical Digital Information Links (TADILS) and Message Text Format (MTF) to ensure interoperability exits between C4I systems and equipment.

Preliminary Report of Results—A briefing or report intended to present initial test results in a timely and concise manner.

"Quick-Look" Report—Unevaluated information available at the completion of a test event.

Responsible Test Organization (RTO)—The organization responsible for government development testing of a system. The RTO is usually located at one of the Air Force test centers.

Simulation—A method for implementing a model over time. Also, a technique for testing, analysis, or training in which real-world systems are used, or where real-world and conceptual systems are represented by a model.

System—An organization of hardware, software, materials, facilities, personnel, data and services required to perform a designated function with specified results.

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

System Program Office (SPO)—The organization comprised of technical, administrative, and business management personnel assigned full-time to a system program director. The office may be augmented with additional personnel from participating organizations.

System Threat Assessment Report (STAR)—The STAR is the basic authoritative threat assessment, tailored for and focused on, a particular major defense acquisition program. It describes the threat to be countered and the projected threat environment. The threat information is based on Defense Intelligence Agency (DIA) validated documents (AFI 10-601).

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.

Test and Evaluation (T&E)—Process by which a system or components are compared against requirements and specification through testing. The results are evaluated to assess progress of design, performance, reliability and maintainability and supportability. The term "evaluation" denotes the review and analysis of data produced during current or previous testing, and data obtained from tests conducted by other government agencies and contractors.

Test and Evaluation Master Plan (TEMP)—The basic planning document for all test and evaluation which is used in planning, reviewing, and approving proposed testing for a particular system acquisition. The TEMP integrates critical issues, test objectives, evaluation criteria, system characteristics, responsibilities, resources, and schedules for test and evaluation. (DOD Manual 5000.3-M-1)

Test Process Archive (TPA)—A file of 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 an annual Test Process Summary.

Validation—The process of determining the degree to which a model or simulation is an accurate representation of the real-world from the perspective of the intended uses of the model or simulation.

Verification—The process of determining that a model or simulation implementation accurately represents the developer's conceptual description and specifications.

Verify—Testing to confirm a suspected, hypothesized, or partly established contention.

Attachment 2

THE AIR FORCE C4I TEST SUPPORT INFRASTRUCTURE

A2.1. Air Force Development Test Center (AFDTC), Eglin AFB FL. AFDTC oversees the activities of the 46 Test Wing and the 46 Test Group. The 46 Test Wing, located at Eglin, is responsible for T&E of many command, control and communications and intelligence systems, including intrusion and detection systems. Test resources include the Enhanced JTIDS System Exerciser (EJSE), Freeman Computer Science Center, Air Force Electronic Warfare Evaluation Simulator (AFEWES) and Real-Time Electromagnetic Digitally Controlled Analyzer Processor (REDCAP) hardware-in-the-loop facilities, the Advanced Seeker Evaluation Test System (ASETS) airborne testbed, the Preflight Integration of Munitions and Electronic Systems (PRIMES), and the Electromagnetic Test Environment (EMTE) open-air test range. AFEWES, located in Fort Worth, Texas, provides a closed-loop, man-in-the-loop test capability for effectiveness evaluation of C4I system defensive capabilities against terminal threats. REDCAP, located in Buffalo, New York, provides a closed-loop, man-in-the-loop test capability for effectiveness evaluation of C4I defensive systems against early warning, acquisition, tracking, ground control intercept, battle management, and C3 threats. The ASETS is used to perform captive multi-spectral seeker evaluations and both spectral and spatial measurements of ground/airborne targets and countermeasures. The AFEWES and REDCAP are useful in T&E of C4I platform defensive systems while the ASETS provides an airborne platform for support of T&E of various sensors. The McKinley Climatic Laboratory produces global environmental climatic testing conditions so that systems may be evaluated as required by DOD directives.

A2.1.1. 46 Test Group, Holloman AFB NM. The 46 Test Group, located at Holloman AFB, New Mexico, operates and manages the radar target scatter (RATSCAT) facility and the RATSCAT Advanced Measurement System (RAMS). RATSCAT is the DOD center of expertise for monostatic and bi-static radar cross-section (RCS) measurements of aircraft, spacecraft, unmanned vehicles, and decoys. The RAMS is used for performing RCS measurements on low observable vehicles.

A2.2. Air Force Flight Test Center (AFFTC), Edwards AFB CA. The AFFTC oversees the activities of the 412 Test Wing, and 545 Test Group. The 412 Test Wing, located at Edwards AFB, California, is primarily responsible for the Air Force DT&E of aircraft systems; supports IOT&E and FOT&E flight tests; and develops, operates, and maintains test facilities used to support flight testing. Test facilities include the Avionics Test and Integration Complex (ATIC) located at Edwards, which is comprised of the Benefield Anechoic Facility (BAF), the Integration Facility for Avionics Systems Testing (IFAST), and the Test and Evaluation Mission Simulator (TEMS). Some of its C4I-related flight test resources are the ECCM-Advanced Radar Testbed, ECM testbed aircraft (C-135s), ECM target aircraft (T-39s), and the Big Crow and Little Crow aircraft operated for the US Army.

A2.2.1. 545 Test Group, Hill AFB UT. The 545 Test Group includes the 6501 Range Squadron at Hill AFB, Utah, which manages the Utah Test and Training Range (UTTR) and operates and maintains the UTTR facilities and equipment. UTTR has a radio frequency (RF) emitter complex, NATO tactical targets, and calibrated bar targets for T&E of reconnaissance systems.

A2.3. Electronic Systems Center (ESC), Hanscom AFB MA. The Electronic Systems Center is responsible for planning and managing the acquisition and installation of C4I systems used in all physical environment and ground based electronic systems. ESC possesses several system specific test beds used in the development of C4I systems.

A2.3.1. Standard Systems Center (SSC), Maxwell AFB (Gunter Annex) AL. The Standard Systems Center is a software development activity of AFMC's Electronic Systems Center. It is responsible for cradle-to-grave development, test and evaluation, and maintenance of Air Force standard communication-computer systems in support of base-level, MAJCOM, and standard systems. The SSC predominately supports Management Information Systems (MIS)/Automated Information Systems (AIS) for logistics, comptroller, medical, engineering, services, etc. used by the Air Force wing and warfighting commander to support the accomplishment of their mission. The SSC currently conducts life-cycle T&E (except OT&E) for all assigned systems utilizing both lab and operational environments.

A2.3.2. Communications Systems Center (CSC), Tinker AFB OK. The CSC provides engineering installation services for the Department of Defense and other government agencies. The CSC organization, which reports to ESC, is comprised of ten active duty units stationed throughout the world fortified by 19 Air National guard units in the continental United States. It provides necessary materials for a project through a centralized warehouse containing over 10,000 components at Tinker AFB. Its Directorate of Communications Software provides customized software programming support for air traffic control, telecommunications and meteorological systems.

A2.3.2.1. 1839 Engineering Installations Group (EIG), Keesler AFB MS. The Test Engineering Division of the 1839 EIG (a CSC organization) provides measurement and specialized engineering services to include communications circuit analysis, electromagnetic compatibility (EMC), radio frequency (RF) radiation hazard measurements, interference resolution and direction finding, shielding effectiveness measurements and electromagnetic pulse (EMP) hardness verification testing on fielded C4I facilities.

A2.3.2.2. 485 EIG, GRIFFISS AFB, NY AND 1845 EIG, Tinker AFB OK. The 485 EIG and 1845 EIG analyze new technologies, establish engineering and installations requirements and integrate new systems with existing systems. The system prototype integration facilities (SIFs) are used to certify new system compatibility with existing base level subsystems.

A2.3.3. Material Systems Center (MSC), Wright Patterson AFB OH. The Material Systems Center (MSC) is a software development activity of AFMC's Electronic Systems Center. It is responsible for cradle-to-grave development and maintenance of Management Information Systems including the areas of depot maintenance, asset management, and contracting and logistics management. A software testing organization exists under a software quality assurance (SQA) group. This function develops and implements test plans and procedures which closely follows the guidelines set down by the Software Engineering Institute (SEI) Capability Maturity Model (CMM).

A2.4. Rome Laboratory (RL), GRIFFISS AFB NY. Rome Laboratory plans and executes Air Force exploratory and advanced development programs for electromagnetic intelligence techniques, for reliability and compatibility of electronic systems, communications, and for information displays and processing. It provides technical and management assistance to support studies, analyses, development planning activities, acquisition, test and evaluation, modification, and operation of aerospace systems and related equipment. Rome Lab is also responsible for development and integration of Intelligence Data Handling System (IDHS) capabilities for DoD and USAF directed programs. It is also responsible for P3I for Common User Baseline for the Intelligence Community (CUBIC). C4I-related test resources available at

Rome Laboratory are the antenna pattern measurement, and command, control and communications countermeasures evaluation facilities. Test beds/facilities include: Intelligence Information Processing Facility (IIPF), ELINT Development Facility, Imagery Exploitation 2000, SIGINT Support Facility, Speech Facility, Intelligence Crypto facility, and the Command & Control Technology Center.

A2.5. Wright Laboratory/Avionics Directorate, Wright Patterson AFB OH. The Laser Communications Laboratory (LCL) of the Wright Laboratory is a free space laser communications testbed. Laser communications testing includes links between the 12th floor tower laboratory and the USAF Museum taxiway/runway, the WPAFB Area C runway and the LCL Transmit Facility (LCLTF) located at the off base Trabein test site. Wright Lab also operates an airborne satellite communications testbed installed in a C-135 aircraft, available worldwide to simulate, test and evaluate experimental satellite communications equipment and systems.

A2.5.1. The Communications System Evaluation Laboratory (CSEL). CSEL primarily supports in-house research, development , and evaluation of low probability of intercept and low probability of exploitation communication systems. Computer controlled generation of threat and interference signals provide realistic background and jamming signal environments for dynamic evaluation.

A2.5.2. The Integrated Electromagnetic System Simulator (IESS). IESS provides primarily in-house simulation and validation support of global strike technologies via advanced integrated communications, navigation, and identification avionics systems.

A2.6. Developmental Manufacturing and Modification Facility (DMMF), Wright Patterson AFB, OH. The DMMF is a T&E Associate Activity providing T-2 aircraft modification support for flight test of C4I equipment and systems. The DMMF is a R&D industrial facility which can also modify and prototype test equipment. Resources include aircraft modification hangars (114,000 sq ft), an R&D fabrication facility (220,000 sq ft) with the ability to prototype printed circuit boards, and an engineering design and analysis division supported by a 64 workstation Computer Aided Engineering (CAE) system. Avionics integration is provided through a partnership with the Naval Air Warfare Center, Aircraft Division, Indianapolis, IN.

A2.7. Air Force Information Warfare Center (AFIWC), Kelly AFB TX. The AFIWC's services include analysis, modeling and simulation of C2 Warfare (C2W) capabilities and vulnerabilities of friendly and hostile information, sensors and weapon systems, communications-computer security vulnerability surveys, countermeasures , a C2W library and C2W databases containing equipment parametrics, orders of battle, and signatures.

A2.8. 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 conducted under realistic conditions of user requirements prior to a production decision. The Air Force Operational Test and Evaluation Center (AFOTEC) has responsibility for Initial Operational Test and Evaluation (IOT&E) and Qualification Operational Test and Evaluation (QOT&E). MAJCOMs maintain individual test organizations to conduct Follow-on Operational Test and Evaluations (FOT&Es). The MAJCOM test activities also support AFOTEC conducted IOT&E/QOT&E.

A2.8.1. Air Force Operational Test and Evaluation Center (AFOTEC), Kirtland AFB NM. The Air Force Operational Test and Evaluation Center (AFOTEC) is a direct AF reporting unit, independent of acquisition and operational commands. AFOTEC 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 C4I T&E Process implementation during IOT&E and QOT&E. AFOTEC also conducts FOT&E of systems on the DOT&E Review List. Specific AFOTEC responsibilities include the following:

- 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 suitability.
- Plan and conduct OT&E in accordance with the C4I T&E Process.
- Serve as a member of the TPWG.
- Prepare the OT&E section of the TEMP.
- 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:

OT&E can be either an IOT&E, QOT&E or FOT&E.

A2.9. Air Combat Command (ACC), Langley AFB VA. ACC, as the CONUS representative of the Combat Air Force (CAF), is responsible for developing, consolidating, documenting, and submitting MNSs, ORDs, and COEAs described *in AFI 10-601, Mission Needs and Operational Requirements, Guidance and Procedures*. When developing the Requirements Correlation Matrix (RCM) which is a mandatory attachment to every ORD, ACC works with AFMC and AFOTEC to document requirements in testable operational terms.

- ACC monitors and supports T&E conducted by other agencies through milestone IIIB and conducts FOT&E of systems not on the DOT&E review list after milestone IIIB. In addition, ACC conducts T&E and special projects in support of mission needs and the requirements definition process.
- ACC supports mission software for fielded CAF C4I systems through in-command System Support Facilities (SSFs) as described in MCR 800-2, Management of Weapon System Software Resources. The SSFs function as Operational Facilities (OPFACs) during service and joint certification compatibility and interoperability testing. ACC with support of the AF Participating Test Units (PTU) is responsible for ensuring the CAF weapon systems are operationally certified and nominated for joint certification. The SSFs also can be scheduled to support other types of T&E conducted by ACC and other agencies.

A2.9.1. USAF Air Warfare Center (USAFAWC), Eglin AFB FL.

A2.9.1.1. 505 Command and Control Evaluation Group (CCEG), Hurlburt AFB FL. The 505 CCEG is responsible for 605 Test Squadron, 727th Air Control Squadron (Test), 84 Radar Evaluation Squadron (RADES), USAF Battlestaff Training School (USAFBTS), USAF Air Ground Operations School (USAFAGOS), and the Theater Air Command and Control Simulation Facility (TACCSF).

A2.9.1.1.1. 605 TESTS, Eglin AFB. The 605 TESTS manages FOT&E and TD&E of C4I systems and reconnaissance data collection, processing and exploitation systems. It provides or arranges for ACC resources to support DT&E and OT&E conducted by other agencies. The 605 TESTS is the single C4I point of contact within USAFAWC for conducting and arranging support for C4I testing.

A2.9.1.1.2. Det 1, 605 TESTS, Seattle, WA. Det 1, 605 TESTS provides operational mission crew and maintenance personnel to the E-3 Airborne Warning and Control System (AWACS) joint test force (JTF). It operates test system-3 (TS-3) which is currently the only Block 30/35 E-3 AWACS.

A2.9.1.1.3. Det 2, 605 TESTS, Melbourne, Fl. Det 2, 605 TESTS provides operational aircrews, system operators, and maintenance personnel in support of the AFOTEC conducted E-8 Joint Surveillance Target Attack Radar System (Joint STARS) multiservice OT&E. It provides aircrews and mission crews for the only three existing E-8 Joint STARS aircraft. Use of the three aircraft is currently limited due to Joint STARS development and testing.

A2.9.1.1.4. 727th ACST, Hurlburt Field, FL. The 727th ACST supports T&E of C3I systems, USAFAGOS, USAFBTS, Joint Warfare Center, and development and testing of tactics, techniques, concepts and procedures for Theater Air Control System (TACS) elements. The squadron is equipped and manned to be representative of a Control and Reporting Center (CRC) or a Control and Reporting Element (CRE) when supporting T&E.

A2.9.1.1.5. 84 RADES, Hill AFB, UT. The 84 RADES provides evaluation services for ground-based long-range surveillance radar systems. It also provides technical assistance during T&E, acceptance, certification, and system integration of radar sensor systems. The 84th manages the world wide Air Force radar evaluation technical library.

A2.9.1.1.6. USAFBTS, Hurlburt Field, FL. The USAFBTS in addition to its training responsibilities, hosts tests and demonstrations for future systems and procedures.

A2.9.1.1.7. Det 4, 505 CCEG, Kirtland AFB, NM. Det 4, 505 CCEG operates the man-in-the-loop Theater Air Command and Control Simulation Facility (TACCSF). The TACCSF simulates air defense functions such as tracking, identification, weapons allocation and control, and kill assessment for all execution levels of integrated Army/Air Force air defense. It is used to investigate a variety of aircraft identification, air defense missions, and command and control tasks for both the Army and Air Force air defense systems.

A2.9.1.2. 68 Electronic Combat Group (ECG), Eglin AFB FL. The 68 ECG is responsible for production, generation, and T&E of mission data for fielded C4I systems. Mission data are the threat parametric information that is stored in the re-programmable data bases of C4I systems. Testing consists of verifying that mission data changes perform as required and that no unintentional changes were introduced. The 68 ECG also conducts special C4I tests to determine the effectiveness of US C4I systems against foreign assets.

A2.9.2. Air Force Participating Test Unit (PTU), Langley AFB VA. The Air Combat Command Computer Support Squadron (ACC CSS), the AFPTU, operates the tactical C3I testbed to ensure compatibility and interoperability (C&I). It assists in development testing of tactical digital information links (TADILs), conducts CAF C4I testing, and participates in joint C4I testing. Facilities consist of test support systems, radar sensor input systems and OPFACs. The PTU interfaces with the Facility for Interoperability Testing (FIT) at Tinker AFB, the Joint Interoperability Evaluation System (JIES) at Ft Huachuca, the F-15 OPFAC at Eglin AFB, and the RADIL/SOCC at Tyndall AFB.

A2.10. 18 Flight Test Squadon (FLTS), Hurlburt Field FL. The 18 FLTS (formerly SMOTEC) conducts operational test and evaluation including logistics service tests, and participates in joint service test projects. They also support AFOTEC in the IOT&E and QOT&E of AFSOC C4I systems. The C4I Division participates in DT&E to make early operational assessments of systems and equipment under development. The C4I Division directs, conducts, and monitors OT&E and foreign military exploitation programs of new and modified systems and equipment. They prepare and conduct briefings on test accomplishments and developments. The C4I Division proposes recommendations to improve doctrine, operational concepts, requirements, tactics, techniques, and procedures for the employment of C4I systems on all special mission aircraft.

A2.11. Air Mobility Command (AMC), Scott AFB IL.

A2.11.1. AF Mobility Center (USAFMC), Charleston AFB SC. USAFMC plans and executes C4I T&E for Air Mobility Command (AMC). It conducts follow-on operational test and evaluation (FOT&E) of C4I systems on airlift and tanker aircraft. USAFMC uses DoD test ranges and facilities for their C4I tests. Their test aircraft come from the AMC operational fleet.

A2.11.2. 1500TH Computer Systems Group (CSGP), Scott AFB IL. AFMC is developing a new integration testbed to test and evaluate joint release software among its C4 systems, interfaces to internal and external systems, and provide a training facility for AMC users. The new facility is being linked to the AFC4A testbed and the USTRANSCOM testbed.

A2.12. Air Force C4 Agency (AFC4A), Scott AFB IL. The AFC4A operates an Interoperability Test Center (ITC) to provide a controlled communications-computer laboratory environment to test systems in the following functional areas: local/wide area networks (LAN/WAN), radio communications, and telephone switching.

A2.12.1. C4 Technology Validation Office (C4VTO), Barksdale AFB LA . The C4VTO,an operating location base for the AFC4A, performs C4I operational validation. The C4TVO evaluates proposed technical solutions, suggests alternatives where applicable; solves integration problems and defines requirements for standard systems.

A2.13. Air Force Space and Missile Systems Center (SMC), Los Angeles CA. SMC's Space Test and Experimentation Directorate, Onizuka AFB, Sunnyvale, Ca conducts tests of various space systems including ground support (C4I) systems. The Space and Warning Systems Center (an AFSPC organization), Peterson AFB, CO, a non-operating test facility supports T&E of ground station portion of space systems.

A2.14. The National Air Intelligence Center (NAIC), Wright-Patterson AFB OH. NAIC provides information on the threat to be faced by a USAF C4I system from the beginning of the systems' existence and throughout its entire life cycle. During initial concept and early system development, NAIC provides threat definition to government and contractor organizations by identifying specific threat systems and their capabilities. Throughout development and test, NAIC continues to provide threat support through continued participation in threat working groups, providing briefings and specialized reports, and by inputting to, producing, or commenting on System Threat Assessment Reports (STARs). In the operational phases of a C4I systems' life, NAIC provides Electronic Warfare Integrated Reprogramming (EWIR) database products for C4I defensive systems, and provides briefings and documents relating to specific worldwide threats.

A2.15. Air Logistics Centers. USAF C4I programs are primarily managed at the Ogden Air Logistics Center (OO-ALC), Sacramento Air Logistics Center (SM-ALC), Oklahoma City Air Logistics Center (OC-ALC), Warner Robins Air Logistics Center (WR-ALC), the Electronic Systems Center (ESC) and the Aeronautical Systems Center (ASC). The C4I SMs at these Centers are responsible for all planning, development, and sustainment activities for assigned C4I systems. The C4I program single manger reports to the Commander of the Center, who is the Designated Acquisition Commander (DAC) or the Program Executive Officer, whichever is appropriate. The C4I Development Systems Manager (C4I DSM) is responsible for assigned development requirements. The DSM reports to the applicable SM. The program offices must have T&E information to prove they have met the performance and operational requirements of the user. They will generate TEMPs, DT&E and detailed test plans that should use the C4I T&E Process. The Logistics Centers involved in sustainment and maintenance of C4I systems are:

A2.15.1. Warner Robins ALC (WR-ALC), Robins GA. WR-ALC is the Product Group Manager for Common Avionics, Electronic Warfare, Special Operations Forces, and Space and Special Systems. WR-ALC's C4I test support infrastructure includes the JSTARS Software Support Facility, the Electronic Warfare Avionics Integration Support Facility (EWAISF), the Extendable Communications Integration Support Environment (ECOMISE) Facility, and the Joint Tactical Information Distribution System (JTIDS) Integration Support Facility.

A2.15.2. Ogden ALC (OO-ALC), Hill AFB UT. OO-ALC is the System Support Manager for weapon systems such as training devices/simulators, the Mission Planning System and Air Force Mission Support Systems (AFMSS). The Avionics Integrated Support Facility (AISF) serves as the software development/test facility for engineering support of assigned weapon systems and equipment including real world test of supported radar systems. It includes assigned Operational flight Programs and the system Integration Laboratory for AFMSS.

A2.15.2.1. Ogden Software Development Activity (MSC/SO), Hill AFB UT. The Ogden Software Development Activity (SDA) is an Operational Location (OL) which reports to the Material Systems Center (MSC) at Wright-Patterson AFB, OH. MSC/SO's primary mission is legacy system software maintenance, asset management, and logistics management business areas, as defined by the Joint Logistics Systems Center (JLSC). MSC uses a variety of tools in its software development process. The Resource Management System (RMS) is a locally developed software tool which rigorously controls and tracks major projects from requirement identification to completion. Structured Iterative Development (SID) is a structured, repeatable software development process which incorporates the best features of software engineering and rapid prototyping. SID allows for the development of systems in close cooperation with functional users and decreases long term software maintenance costs.

A2.15.3. Oklahoma City ALC (OC-ALC), Tinker AFB OK. OC-ALC is the System Support Manager for the domestic and foreign E-3 AWACS and the System Program Manager for the E-4B National Emergency Airborne Command Post and the EC-135 Worldwide Airborne Command Post. Its Avionics Integrated Support Facility (AISF) serves as the single Mission Critical Computer Resource software organization for engineering support for the sustainment and maintenance of all assigned prime systems and equipment including C-135, E-3 and E-4 aircraft. It contains the only Air Force E-3 AN/APY-1 Surveillance Radar Laboratory facilities in existence. (Boeing and Westinghouse have E-3 AN/AP-1 and AN/APY-2 surveillance radar laboratory facilities).

A2.15.4. Sacramento ALC (SM-ALC), Sacramento CA. The SM-ALC supports ground based C2 systems through the employment of the Scope Command III System Hot Mockup. This capability replicates field system operations including (a) prototype hardware and software modifications, (b) a Phased Array Antenna, (c) a near Field Test Range, (IOC 1996), to test all Phased Array Antenna. (d) Software Assessments and Analysis for modified radar and communications systems.

A2.15.5. SM-ALC - Near Field Test Ranges. The Near Field Test Ranges can accommodating virtually any type of radar but are currently directed to the diagnostic test for repair of specific large phased array antennas. These ranges offer an interference free environment suitable for confirmation of antenna or system performance to design specifications. Capabilities include main beam, side lobe, and full 360 degree T&E. With the ability to detect the performance of individual components, the range has the capability to create a fault-free analysis for established radar systems and to utilize that data in the development of new radar systems or improvements through modification rather than new acquisitions.

A2.16. Air Force Space Command, Peterson AFB, CO.

A2.16.1. Space and Warning Systems Center (SWSC) Facility, Peterson AFB, CO. The SWSC is an offsite test facility for the Cheyenne Mountain Complex (CMC). The facility supports software development, modification and DT&E prior to its incorporation into the CMC.

A2.16.2. Camp Parks Communications Annex (CPCA), Dublin CA. Camp Parks Communications Annex reports to the 21 Space Squadron, Onizuka AFB CA, and provides on-orbit calibration, configuration and check-out of a variety of operational satellites. The station provides a means of satellite radiometric calibration, engineering testing, checkout of hardware and software developments in such areas as: precision measurements of RF signals at X/L/S-bands and UHF frequencies, evaluating the orbital performance characteristics of communications, and communications satellite acceptance testing.

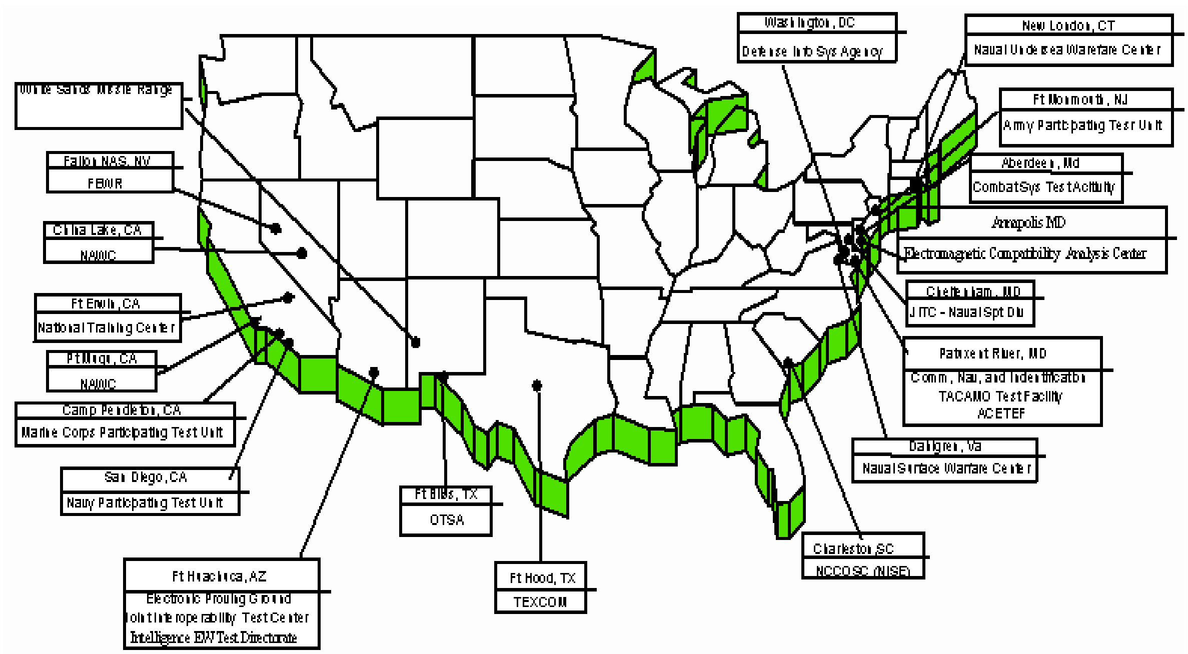
A2.16.3. National Test Facility, Falcon AFB, CO. The National Test Facility (NTF) is the hub of a national network of test centers which specialize in research, modeling, and simulation of C4I & space defense systems. It provides a unique Department of Defense capability supporting local and distributed forms of modeling and simulation. Special features include world-class computational resources, high speed networks, and specially designed facilities. High speed data networks make the resources of the NTF available to military installations, laboratories, and research facilities throughout the country and around the globe. Users connected to the network have wide-area access to computer resources, simulations, standard tools and data bases, standard threat products, distributed exercise and test activities, and analytic problem solving expertise. The NTF provides: (a) An adaptable system test complex which includes the infrastructure, organization and experience to support live fire testing. Its capabilities include pre-test planning and analysis, test monitoring, data recording, and post-test data reduction and analysis. The system test complex supports communication links to most major US test ranges; (b) A mission control center to support operations for orbital flight testing. It includes connectivity to the Air Force Satellite Control Network and employs the latest in telemetry, tracking and control systems; (c) A real-time test environment employing simulation and live data to support integration and element testing of ballistic missile defense command and control components; and a real-time control framework and environment drivers to support hardware-in-the-loop testing.

Attachment 3

THE ARMY, NAVY, AND JOINT C4I TEST SUPPORT INFRASTRUCTURE

A3.1. Introduction. Information regarding other Service and DoD major test resources can be found in DoD Directive 3200.11-D, Major Range and Test Facility Base Summary of Capabilities. This directory has a collation of functional testing capabilities as well as overviews of the mission, location, features, ranges and facilities of each activity. In addition, AFOTEC/XRR maintains the Automated Test Resources Information System (ATRIS); a PC database containing detailed DoD test resource capabilities information (the data base is accessible through TECNET).

Figure A3.1. The Army, Navy, and Joint C4I Test Support Infrastructure.



NOTE:

The ARMAMENT/WEAPONS-C4I-EW SFTC is developing a database that will include all DoD C4I test capabilities. **Figure A3.1.** depicts Army, Navy, Marine Corps and Joint T&E test facilities. The SFTC will update A3.2 as information becomes available.

A3.2. The Joint Spectrum Center (JSC), Annapolis MD. The JSC, formally the Electromagnetic Compatability Analysis Center (ECAC), is a joint DoD center that provides advice and assistance concerning electromagnetic compatibility (EMC) and Electromagnetic Vulnerability (EMV) matters to the Secretary of Defense, the Joint Chiefs of Staff, the Services, and other DoD components and departments of the US Government.

A3.2.1. JSC capabilities include test planning and analyses with an emphasis on Modeling and Simulation (M&S) for pre-test prediction of test outcomes and for efficiency in test planning. Using a myriad of EMC-related databases and automated modeling capabilities, JSC provides data analysis on

EMC at the intra-system, inter-system, and system-to-environment levels. JSC serves as the DoD repository for EMC and EMC-related databases. These encompass electromagnetic environmental data, optical and equipment technical characteristics data, frequency assignment data, space system orbital data, tactical deployment data, and topographic data.

A3.2.2. JSC possesses automated EMC M&S capabilities that range from antenna and propagation models to terminal-device-performance models. JSC's M&S of electromagnetic interactions begins at the basic component level, extends to the intra- and inter-system levels, and to the system-to-environment level, i.e. system operational effectiveness in the intended operational electromagnetic environment.

A3.3. Defense Information System Agency (DISA), Washington DC. Serves as the DoD single point of contact for development of information technology standards (information , information processing, and information transfer). It also develops and conducts C4I systems interoperability testing and certification, in conjunction with the other DoD components. It reviews all C4I TEMPS to assess whether test objectives adequately support compatibility and interoperability testing. The DISA accomplishes its responsibilities through the Joint Interoperability Test Center (JITC), Joint Interoperability and Engineering Organization (JIEO) and its Center for Standards (CFS), Center for Interoperability and Integration (CFI), its Center for Architecture (CFA), Center for Engineering (CFE), Center for Information Management (CIM) and its Center for Information System Security (CISS) .

A3.3.1. Joint Interoperability Test Center (JITC), FT Huachuca AZ. The JITC conducts a wide range of independent C4I hardware and software interoperability and standards conformance testing. The center can interface with all of its on-site hardware and software capabilities and network with any other testing or operational facility worldwide. JITC also reviews C4I MNSs/ORDs , TEMPs and prepares and coordinates concurrence/certification recommendation letters to the CINCs/Services/Agencies/Joint Staff(J6).

A3.4. Theather Air Command and Control Simulation Facility, Kirtland AFB (TACCSF), NM. See paragraph A2.9.1.1, Det 4 505 CCEG.

NOTE:

Contact the ARMAMENT/WEAPONS-C4I-EW SFTC for more information regarding C4I T&E capabilities of the other Services'.

Attachment 4

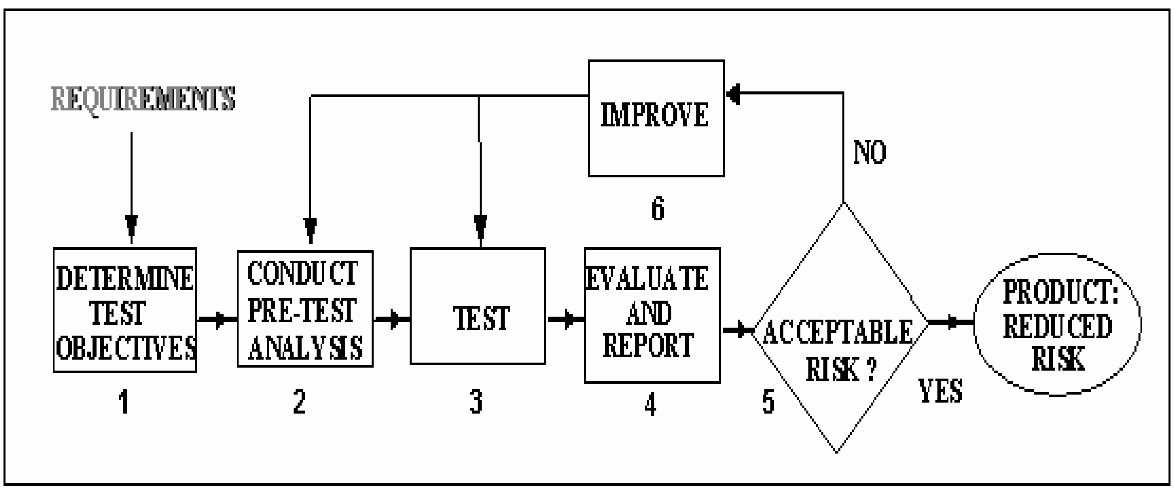
LESSONS LEARNED

A4.1. OVERVIEW. During the acquisition process, several phases of testing are conducted, beginning with conceptual testing during Phase 1 and continuing through operational T&E even after a system receives a favorable production decision. In fact, testing is conducted throughout the life of the fielded system to ensure the system continues to perform adequately as the threat changes and software updates are installed. Numerous articles have been published pertaining to lessons learned while testing a particular system and how testing could have been conducted more effectively. Unfortunately, these articles have not been read by all system program directors, program managers, and test team members. Even if they had read these articles, the same mistakes are repeated test after test for several reasons. In many instances, the fault lies in the fact that the regulations were not followed while planning for, or conducting the test. On other occasions, lack of patience caused testers to deviate from the plan, or use work-arounds to stay on schedule, which ultimately caused significant problems. Regulations clearly state that testing should be event driven; however, too many times it is schedule driven. When the developer insists on staying on schedule and the user insists on acquiring the system as soon as possible, the potential for T&E failure becomes great.

A4.1.1. The Air Force supplement to DODI 5000.2, Defense Acquisition Management Policies and Procedures, requires all persons involved with acquisition and operational programs to submit lessons learned to ASC/CYM, Wright-Patterson AFB, OH, DSN 785-3454. One can obtain a detailed list of lessons learned from there or use the Air Force Acquisition Model computer program. Additionally, for a list of lessons learned pertaining to operational testing, contact AFOTEC/RS, Kirtland AFB, NM, DSN 246-5341.

A4.2. C4I T&E PROCESS. As discussed in paragraph 2, there are six steps which should be followed while executing the T&E process (**Figure A4.1.**).

Figure A4.1. The C4I T&E Process.



The following are general lessons learned applicable to each T&E process step.

A4.2.1. STEP 1--DETERMINE TEST OBJECTIVES. Early in a program, the using command must be encouraged to establish realistic operations and maintenance concepts. These elements are essential to the development of requirements and evaluation criteria. Send a letter or message to the using command's headquarters to inform them if any elements of the operations or maintenance concepts are incomplete and request clarifications. Also, obtain and review all applicable source documents in order to thoroughly understand the user's mission. Develop a list of planned and potential users. If this list includes allies, U.S. friendly nations, or international organizations, early definition of T&E (including interoperability concepts) should be made. This international T&E planning should include what the planned or potential interfaces are compatible with and what types of operational tests can be used to satisfy their needs.

A4.2.2. STEP 2--CONDUCT PRE-TEST ANALYSIS. Prior to starting a test, a complete rehearsal of the test should occur. This should include all phases of the test, from equipment operations through data collection and validation. Adjust plans to avoid problems discovered during the rehearsal. If the predicted results are only at the specification level, the tester needs to watch for any degradation from what was planned. When considering the test setup, ensure you have captured the true capability of the system. One should predict the results to be greater than the values listed in the specifications. For example, if a radio being tested is supposed to have a range of 200 miles, plan for it to communicate for at least 250 miles. Then design the test scenario to attempt to achieve these results.

A4.2.3. STEP 3--TEST.

A4.2.3.1. EARLY TEST PLANNING.

- A "watch list" should be developed by the SPO which tracks potential or known problems identified during CT&E and DT&E. This will alert OT&E personnel to past problem areas that should be watched closely.
- C4I systems should be considered for combined DT&E/IOT&E test programs. DT&E and OT&E of these often one-of-a-kind systems closely resemble each other for both development specification and operator requirements. Combined testing greatly reduces test resource requirements, while reducing the time to bring a system through the test periods.
- When using the combined T&E approach, integrate the DT&E and OT&E test team early. This will reduce overall training requirements and the influence of experienced personnel will add stability to the test team.
- If one is considering a combined test approach, early participation in programs or projects is of paramount importance. This includes participating in working groups, system acquisition reviews, and ground preparation and tests, many being held at the contractor's facilities. Additionally, test concepts should be developed earlier than usual by both the developmental and operational testers to ensure a more effective test and eliminate duplication of effort.
- Approximately 45 days should be scheduled between the completion of DT&E and the reliability/maintainability/availability demonstrations or the start of IOT&E, whichever date is earlier. During this period, hands-on training for maintenance and operations personnel must have first priority over development or testing by the acquisition contractor. This will allow the test team to evaluate the system under truly operational conditions with fully trained and qualified personnel operating and maintaining the system.

- Allow someone not involved with the writing of documents to review them for technical correctness and quality control. Designate a person who is not directly involved with writing the documents but has the expertise to identify technical problems.
- The most effective way to train test managers or test team members is to have them participate in other tests first. Experience gained from one test is often-times applicable to other programs.
- In order to test communications systems that have not entered the DOD inventory, a frequency allocation is necessary. The SPO should contact their base frequency manager at least 1 year prior to requested test start date regarding permission to test the new system. For testing communications systems already in the DOD inventory, a frequency assignment is also necessary. That request should be submitted to the base frequency manager at least 120 days prior to the need date. Late program office requests regarding frequency allocations or assignments for radiating devices might cause program delays and cost overruns, erode existing relationships with the FCC and FAA, or result in disapproval to test at a particular DOD range.

A4.2.3.2. DT&E.

- Field system testing should not begin until the in-plant DT&E is completed and the fixes have been incorporated in the equipment to be used in the field OT&E. This should be observed even if it means schedule slippage.
- If possible, instrument all test articles so that they are fully interchangeable regardless of test activity. For example, a primary test article may become unusable and a backup one would be required to continue testing. Instrumentation would then need to be moved to the backup test article. Decisions not to instrument based on the projected test schedule will probably lead to restricted use of the non-instrumented articles.
- Ensure that only one contractor is involved with complete integration and testing during DT&E. This should reduce the indecision of assessing responsibility for problems during the OT&E. If a program has multiple contractors, the test manager should consider including system integration as a requirement for test readiness certification.
- Do not include software developers, who had a role in developing the software being tested, on the software test team. Developing programmers' familiarity with the software and the documentation can bias the evaluation. Such evaluators cannot exclude system knowledge they have gained through association with the program from their scoring decisions.
- Ensure the contractor understands that government DT&E not only includes specification requirements but also injects operational considerations into DT&E.

A4.2.3.3. OT&E.

- Allow at least a 1-2 week familiarization period just prior to IOT&E for test team augmentees to become familiar with the system to be tested and the detailed test procedures.
- Quick fixes and work-arounds in the middle of a test can often mask significant problems. The purpose of a test is to gather meaningful and reasonably complete data to evaluate operational suitability and effectiveness. The temptation to use short cuts during the test, in order to meet test schedules, should be avoided.

- A major source of data used for OT&E is development testing. Obtaining DT&E documents requires formally written requests along with constant monitoring and assertiveness. Whenever a document request is sent, a tracking system must be initiated to determine what documents are not received in a timely manner. The documents that are not received or accounted for should be formally requested again at a higher level.
- IOT&E testing should not be allowed to be conducted in "portions," e.g., effectiveness testing or suitability testing. DODI 5000.2 requires the developing agency to formally certify that the system is totally certified ready for a dedicated phase of OT&E. This will ensure complete attention by the prime contractor on all phases of testing.
- When the developing command is also the operating command, IOT&E should be conducted by an independent outside agency. Minimize reliance on contractors for IOT&E support.
- The acquisition agency should have a representative on site when a prime or subcontractor is responsible for system operation during an I/maintenance OT&E.

A4.2.4. STEP 4--EVALUATE AND REPORT. In order to compare predicted outcomes to test results, one needs to start data reduction early in the test program to establish trends and determine adjustments to future test scheduling. For example, if a system consistently fails to meet expectations, the tester needs to determine whether the test was improperly designed, expectations are too great, or the fact that the system is basically unsatisfactory. Additionally, using a system maturity matrix could assist in assessing the tested system's performance and capabilities as the test progresses.

A4.2.5. STEP 5--ACCEPTABLE RISK DECISION. During this decision step, extreme care should be taken by the decision maker. Perhaps the safest decision is that the test outcome was unsatisfactory. Provided the previous test process steps were followed properly, the unacceptable system would go through the next test process step, improvement, before moving ahead in the acquisition cycle. However, if a system is deemed to be an acceptable risk, there is still an inherent problem. Numerous engineering change proposals could be required to make the system "operationally ready." This decision is ultimately costly and ends up taking more time to fix than if the system had been judged to be initially unacceptable, improved upon, retested, and then deemed to be acceptable.

A4.2.6. STEP 6--IMPROVE. If a system is found to be unacceptable during testing, one must determine whether it was due to improper test design or system design. During both DT&E and OT&E, if problems with the test method are discovered, these must be corrected by the test team. For this reason, it is paramount that Air Force presence (DPRO, the developer, the test team, etc.) should be required during all applicable testing. Test design problems will be identified more quickly, corrected, and the test item can be retested. If it is determined that the problem is system design, changes can be incorporated into the system during DT&E. If a system design problem is discovered during OT&E, the test is stopped. OT&E is restarted only after changes are made. If design changes are made to a system, especially software-intensive systems encountered during C4I testing, one needs to use extreme care that "fixes" to correct one problem do not cause adverse effects to another area of the system. Some regression testing may be necessary in this situation. In software-intensive systems, a software evaluation is needed early on in planning to review contractor software development. Reviewing the documentation while it is being developed enables the tester to get a better understanding of the software's capabilities and deficiencies.

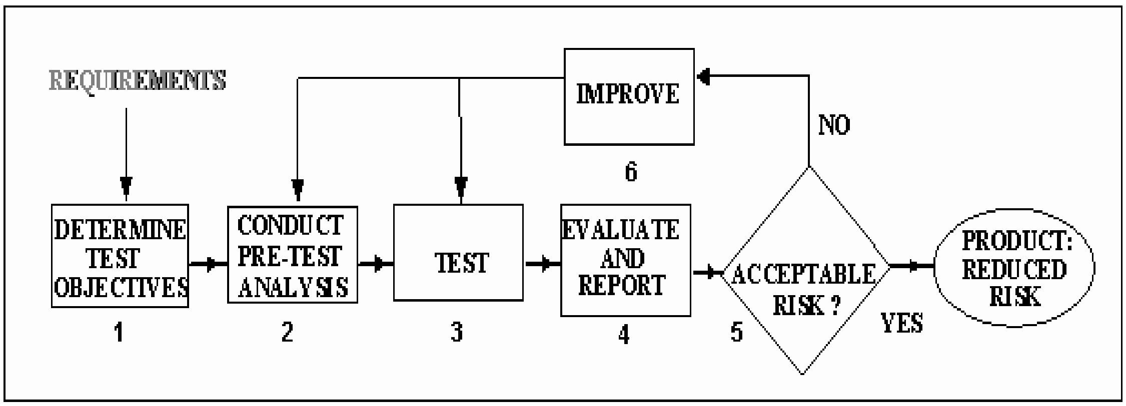
Attachment 5

THE C4I T&E PROCESS CHECKLIST

A5.1. Overview. Complete the first two steps of the checklist as the initial test planning actions, then use the checklist as appropriate throughout the C4I T&E Process (**Figure A5.1.**) to assist in identifying and initiating action to avoid or solve problems. Even though the checklist is organized in a time/event sequence, it can be used at any point in executing the test process to give the test manager a "how-goes-it" on current issues. For more information, see *The Air Force Test Plan Preparation Guide*, December, 1993 and *Templates For Certification of Readiness For Dedicated Operational Test and Evaluation (OT&E)*, September 1993.

NOTE: This checklist is provided merely as a guide and is not intended to be all inclusive. Also some questions listed below may not apply to all types of C4I T&E.

Figure A5.1. The C4I T&E Process.



A5.1.1. STEP 1--DETERMINE TEST OBJECTIVES.

<u>**YES**</u>	<u>**NO**</u>	
		Have you contacted the SFTC office for early test planning guidance?
		Have you formed a Test Planning Working Group (TPWG)?
		Are you using the plan-predict-test-compare philosophy documented in this manual and AFI 99-103, *AF T&E Process*, as the foundation for T&E planning?
		Are test objectives based on performance and mission requirements?
		Have you determined what information is required by the decision makers?
		Have you determined critical performance issues that must be addressed?
		Have you reviewed DOD 5000.1/5000.2, AFI 99-103, DODD 4630.5, DODI 4630.8, CJCSI 6212.01, and Joint Interoperability and Engineering Organization (JIEO) Circular 9002?

YES	NO	
		Do you know the type of acquisition strategy (e.g., grand design or evolutionary) the C4I acquisition program is going to use?
		Are you aware there are testing requirements for nondevelopment items (NDI) planned for use in/as C4I systems?
		Are you aware that all DOD C4I systems for the warfighter, including Automated Information
		Systems, require interoperability testing and certification before being declared operational?

A5.1.2. STEP 2 --CONDUCT PRE-TEST ANALYSIS.

YES	NO	
		Have you identified DT&E facility and instrumentation requirements?
		Have you determined what specific test assets are needed to collect the data?
		Have you determined the types and amounts of data required?
		Have you predicted the expected test results?
		Do you plan to maximize the use of models and simulation in T&E before going to real world environment T&E?
		Is a Digital System Model (DSM) being developed for the system to be tested?
		Do the test requirements correlate with documented user/customer requirements?
		Has a responsible test organization (RTO) been designated for DT&E?
		Have you made plans to observe/review and archive the test and evaluation results?
		Do you have a test data management plan?
		Have test scenarios been developed and agreed upon?
		Will the test item be instrumented to collect required data?
		Have you considered using a combined (DT&E & OT&E) test approach for your program/system?
		If Interoperability Certification is a requirement, have you started working with the JIEO,
		Joint Interoperability Test Center, and other sources in preparation for required testing?
		For Air Force Procedural testing, has certification testing been scheduled with the AF Participating Test Unit (PTU) at Langley AFB, VA?
		Do you know the function of every agency in associated working groups (e.g., Test

YES	NO	
		Planning Working Groups, etc.) and do you understand why they are there?
		Have you planned for appropriate levels of software T&E?
		Have you documented requirements and requested approval for all needed frequencies?
		Have tests been designed to include a countermeasures environment?
		Have human factors objectives been included?
		Have the requirements for pre-operational spares during T&E been provided, and have provisions been made to accumulate data on their usage?
		Have you planned for personnel to operate the test item(s)?

A5.1.3. STEP 3--TEST.

YES	NO	Are appropriate C4I T&E resources being used to conduct the test?
		Is information required by the decision makers being collected and analyzed?
		Are the tests being conducted stressing the system?
		Are you using the plan-predict-test-compare philosophy documented in this manual and
		Are you using the plan-predict-test-compare philosophy documented in this manual and AFI 99-103, AF T&E Process, as the foundation for ongoing T&E efforts?
		If a current DSM being used with the program/system to be tested?
		Is the RTO independent of the developer for the program/system to be tested?
		Have all needed/required frequencies been authorized and allocated?
		Have you included maintenance testing?
		Has testability been designed into the test item?
		Was a testbed(s) acquired? Where is it located?
		Are technical/maintenance data available for T&E?
		Have enough test items been programmed to support timely tests?
		Was all required software testing scheduled?
		Was all scheduled software T&E accomplished?
		Has regression testing been accomplished?

A5.1.4. STEP 4--EVALUATE AND REPORTING.

YES	**NO**	
		Did post-test analysis compare predicted outcomes to test results?
		Were expected results achieved?
		Is information being reported to the proper decision makers?
		Have you made provisions for deficiency reporting?
		Do you have a procedure established and organizations/facilities designated to archive all information/ data that results from the C4I T&E Process?
		Is the information/data in the Test Process Archive current and accessible?
		Has interoperability certification been obtained?

A5.1.5. STEP 5--ACCEPTABLE RISK DECISION.

YES	**NO**	
		Were technical and operational risks reduced to acceptable levels?
		Did the system meet the mission requirements stated in the ORD?
		Is the product ready to move ahead to the next phase?

A5.1.6. STEP 6--IMPROVE.

YES	**NO**	
		Was the test flawed (e.g. planning, conduct, instrumentation, etc)?
		Do problems exist in the system design?
		Have you determined what must be changed or refined?
		Have you determined who will make the necessary change(s) or refinement?
		Is re-test necessary?