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Good Practice Guide
GPG-FM-005

# Test and Evaluation

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Department of Energy
Office of Field Management
Office of Project and Fixed Asset Management

# FOREWORD

This United States (U.S.) Department of Energy (DOE) Guide is approved by the Office of Field Management (DOE HQ/FM) and is available for use by all DOE components and their contractors.

Specific recommendations for additions, deletions, or changes that would enhance this document should be sent to:

TBD
Office of Field Management
U.S. Department of Energy
Washington, DC 20585

This Guide is part of the DOE directives system and is issued to supplement information in the Project Management Overview Guide regarding the Department's expectations for fulfilling the requirements of Draft DOE Order 430.1, Life Cycle Asset Management. The Guide also provides acceptable methods for implementing these requirements.

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# 1. INTRODUCTION

Testing and Evaluation (T&E) includes the complete set of activities that verifies that the end product(s) meet the customer's requirements. This Guide presents a systematic, cost-effective approach for implementing T&E that can be used by Department of Energy (DOE) Headquarters (HQ) and field element project managers, their staffs, and their contractors. The principles and practices in this Guide should be used by the project manager to ensure that selected verification methods are complete, compatible, and non-redundant and that they add value.

This Guide should be used to implement the T&E effort on all projects undertaken within the DOE complex. DOE project managers may either assume responsibility for T&E or delegate that responsibility. DOE prime contractor(s) completing project activities are subject to this guidance, which then should be included in the contract solicitation statements of work. When multiple contractors directly support DOE on a project, an evaluation at the DOE level may be required to ensure the end product(s) integrated from the various contractors have been verified.

Quality Assurance (QA) is the umbrella DOE uses to ensure that the customer receives quality end product(s), and T&E is a project-specific extension of QA. QA representatives are responsible to approve the T&E plans and procedures. The T&E group set up for a specific project has to meet all project applicable QA requirements.

The T&E Guide is one of several guides for implementing DOE Order 430.1, Life Cycle Asset Management. The "Project Management Guide to the Guides" provides a synopsis of the information in each of the guides. Order 430.1 provides requirements for the DOE, in partnership with its contractors, to plan, acquire, operate, maintain, and dispose of physical assets.

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# 2. PRINCIPLES AND PRACTICES

This section describes the principles and practices and resulting products associated with the T&E approach shown in Figure 1. This approach can be used by the project manager to ensure end product(s) perform their specified functions and meet requirements. It is the intent that the T&E activities be implemented throughout the project life cycle as shown in Figure 2.

## 2.1 Test and Evaluation Overview

T&E is a much broader set of activities than the physical testing of component, subsystems, or systems. T&E includes:

- reviews and analysis performed during the design activities;
- inspection activities performed during manufacturing and/or construction activities; and
- testing performed during design, manufacturing, construction, and turnover activities.

T&E begins early and should continue throughout the project to ensure end product(s) perform functions and meet requirements at the project's end. end product(s) generally consist of components, subsystems and systems and can be, for example, office buildings, process plants, process systems, computer systems, engineering studies, designs, and other items, including the outputs of various operational activities. Some level of verification (i. e. T&E) should be performed on all projects, regardless of the end product(s) complexity.

## 2.2 Test and Evaluation Concepts

### 2.2.1 Input to the Test and Evaluation Process

Performance requirements are the key input to the T&E process, as shown in Figure 1. Performance requirements normally result from a systems engineering process and are documented in specification(s). The specification should define the selected architecture for the end product(s).

The performance requirements are derived from the customer needs, laws and regulations, codes and standards, and organizational policies such as DOE Orders. The complete set of performance requirements will be developed over a finite time period as a part of the

design effort. The systems engineering process may require several iterations before the final architecture and performance requirements are selected. Alternative architectures may be analyzed during the selection process.

Performance requirements as used above will be different for components, subsystems, systems or end product(s). But performance requirements are the input to T&E for each level of testing.

### 2.2.2 Acceptance Criteria

Acceptance criteria are the measures which demonstrates that the item under test meets its performance requirements. The program manager is specifically responsible for working with the contracting officer and the DOE project manager to develop or modify acceptance criteria for the stated project performance requirements. The project acceptance criteria must be allocated to the subsystems and components. Likewise, the project manager is responsible for negotiating with the contractor(s) the acceptance criteria for the items they are under contract to deliver. Acceptance criteria parameters or measures and tolerance bands should be clearly established, documented, accepted by the project, and approved by the customer. Acceptance criteria principles include:

**Measurability**. When acceptance criteria parameters cannot be established that are physically measurable within reasonable project cost and schedule constraints, the associated requirement should be questioned as to whether it is appropriate. **Requirements that cannot be measured are meaningless and should not be used**.

**Quantification**. Acceptance criteria measures and tolerance bands should be quantitative. Possible exceptions are qualitative terms, such as likely or credible, where these terms are referenced to DOE, national, or international standards, and are defined by quantitative values. Qualitative terms such as *good* or *acceptable* should be avoided in establishing measures since demonstrating compliance with such criteria is subject to individual interpretation.

**Completeness**. The set of acceptance criteria (i.e., measures) for each specific requirement should be complete. This principle is closely related to the consistency and traceability principles (below). The set of acceptance criteria for each level of test should be established such that if the complete set is met, there is reasonable assurance that the end product(s) satisfy the customer's requirements.

**Currency and Accuracy**. Change control principles and practices should be used to ensure that acceptance criteria are current and accurate and that, if project requirements are changed, the acceptance criteria are changed also.

**Consistency and Traceability**. System and technical acceptance criteria should use the same measures to define similar parameters. Acceptance criteria should also be traceable to the requirement so that the completeness of the acceptance criteria can be assured.

**Acceptance Criteria Approval**. Customer approval principles and practices should be used to ensure proper approval for the initial acceptance criteria and any subsequent changes. If changes are made to the acceptance criteria, a new agreement should be obtained. Final acceptance is accomplished in the Execution Turnover Subphase (see section 2.8).

### 2.2.3 Test and Evaluation Approach

Once acceptance criteria and requirements have been established for a project, T&E can be planned in conjunction with the project's general planning efforts. Selection of the most appropriate verification method or methods for a given requirement should be based on the following:

- the method that can be applied as early as possible in the project life cycle to demonstrate compliance,
- the method or combination of methods most effective for demonstrating compliance, and
- the methods that are most efficient when considering risk.

Correct selection of a verification (i.e. T&E) method helps ensure that end product(s) architecture remains in compliance with requirements as the project evolves. However, on a project with important performance parameters, some level of turnover testing at the end of the execution phase (See section 2.8), in addition to verification during the project, should be considered to demonstrate compliance.

If a verification activity demonstrates non-compliance, the affected area must be reassessed as early as possible to identify alternative approaches for meeting requirements with a minimum impact on project resources. Alternative approaches, which require a change to the accepted project architecture or the requirements, need to be implemented through the project change control process.

The T&E effort concludes with turnover at the end of the execution phase. The complete set of verification results should be reviewed and evaluated against performance requirements to ensure the results demonstrate compliance as part of the turnover activities. Any issues noted during this assessment must be addressed by the project team. This evaluation and any actions required by the assessment should be documented in the appropriate report. On complex projects, this may be a T&E assessment report. This report should consolidate the T&E plans, the T&E activities summary, testing results, and a discussion of how T&E activities demonstrate that the end product(s) comply with the requirements.

### 2.2.4 Innovative Approaches to Test and Evaluation

**Heuristic Method**. In some cases, the customer may not be able to set firm requirements and acceptance criteria for one or more of the following reasons.

- More than one customer is involved and they cannot agree on a common set of requirements.
- The requirements are set by an exterior force that is ambiguous or fluid.
- The objectives of the customer are general and not specific enough to measure.

In such cases, alternative approaches are required to help the customer define clear requirements. One such approach is the heuristic method. The heuristic method calls for starting the project by establishing a T&E model to define the requirements. The model is used and adjusted thereafter until a desired performance is demonstrated. The customer and the contractor should agree on the results and then, a production version of the model is used to define the main purpose of the project.

**Engineering Analysis Approach**. This approach to subsystem or component testing and analysis and system or subsystem modeling, as discussed in section 2.3.2, should be used when a full set of demonstration test cannot be performed owing to physical or cost limitations.

## 2.3 Verification Methods

### 2.3.1 Inspection

Inspection of constructed and manufactured items can be used to evaluate conformance with specified requirements and acceptance criteria. Inspection is generally nondestructive

and consists of visual examinations of actual hardware or simple, nonfunctional measurements. Typical characteristics verified through inspection include dimensions or number of units.

### 2.3.2 Testing

Testing can be used to gather data to evaluate functional characteristics and performance requirements. Items can be physically tested to determine if they perform their required functions and meets acceptance criteria. Testing data are normally recorded by precision measurement equipment or procedures and then evaluated. Analysis of test results is usually done in conjunction with testing.

The categories of tests described in the following paragraphs should be used as applicable. Testing categories should be selected as part of T&E planning. (See section 2.5.) All testing should be performed according to the instructions in approved test procedures.

**Engineering Development Tests**. Engineering development or proof of concept tests should be conducted on designs involving new technology to verify whether the design works as specified. A range of operating conditions that exceed design limits should be tested to identify marginal design features. For example, over-voltage, under-voltage, reverse polarity, over-temperature, and under-temperature engineering development tests would be used to confirm the robustness of a new electrical-based design. The thrust of the development test program should be to identify problems early so that corrective action can be taken prior to completing design and fabrication. Thus, development testing to evolve design concepts typically should not require rigorous design and test documentation, and operational hardware and software is usually not required at this stage.

**Qualification Tests**. Qualification testing should be used to confirm that the unit being tested satisfies acceptance criteria under simulated operational environmental conditions with a margin of safety. These tests are recommended whenever equipment is used in a new application or environment that has severe environmental conditions. To ensure that the unit being tested can meet the safety margins, qualification testing should be conducted at levels that exceed required performance. Qualification testing should also provide increased confidence that subsystem and software integration and segment interfaces meet design and performance requirements. Qualification test planning should cover all levels of assembly (piece-parts through system), operational phases and associated tests, handling, shipping, and storage. Implementation of the qualification test program generally affects cost significantly.

The two primary types of qualification tests are environmental and functional. Environmental testing tests the performance of the unit under the environmental conditions in which it will operate. Typical types of environmental tests include vibration, electromagnetic interference, and thermal cycling. Functional testing tests the ability of the unit to perform its specified functions. Functional tests are generally performed under normal operating conditions.

**Acceptance Tests**. Acceptance testing is used to verify manufacturing construction methods, operational modes, output performance, and support functions. Acceptance tests on the other hand should be used to screen for failures of workmanship and material quality deficiencies at all levels of assembly. Such tests should also be used to test interfaces between segments and to verify the performance of the system by testing at the required performance levels. Acceptance testing can include demonstration tests where functional characteristics are verified by go/no go criteria versus the use of elaborate measurement equipment. Examples of demonstration tests include a physical fit check and a demonstration of on/off switch. An additional acceptance test call a turnover test where the customer operations staff runs an operational test may be needed for complex end product(s).

### 2.3.3 Analysis

Analysis is used to verify the design and/or predict performance during the design effort (i.e., during the preconceptual activities). Engineering analysis, including design calculations, is used to verify that the evolving design meets specified requirements. For example, design organizations normally complete stress calculations concurrently with the design of structures or pressure vessels to ensure the design meets strength requirements. Examples of design analysis include RMA analysis, safety analysis, mass and energy balances, stress analysis, and electrical breaker coordination studies.

Verification by engineering analysis alone to predict performance capability is generally used only when an item cannot be tested to its specified limits due to either physical limitations or cost. Analysis should be used to simulate operating conditions such as process simulation and flow calculations. It can also be used to extrapolate the subsystem or component test result data, which may be used to evaluate compliance with higher level requirements.

### 2.3.4 Reviews

Reviews can be used to determine characteristics, adequacy, and conformance with specified requirements and acceptance criteria by examination of items such as engineering

drawings, analyses, flow diagrams, procedures, specifications, and computer program listings.

Verification reviews (or peer reviews) are performed to ensure correctness, completeness, and compliance with technical requirements. Verification or peer reviews should be performed by an individual who is experienced in the engineering disciplines involved but has no direct involvement with the work being reviewed. Review of design output should be a continuing activity throughout design, which generally begins during the preconceptual activities and continues into the execution phase.

## 2.4 Independent Verification and Validation

Although the T&E effort helps control system compliance with requirements, additional T&E requirements may be imposed by the customer for independent verification and validation (IV&V). There is no generally accepted industrial standard for IV&V. Therefore, when IV&V is required by the customer, the scope of the IV&V effort must be defined. This should be done in the contract or project enabling documents. When IV&V is required, the T&E plans should include provisions for an IV&V effort. Traditionally, a key method to ensure the independence of the IV&V organization is to hire an outside contractor to perform the IV&V activity.

However, on some projects, the customer may prefer, for reasons of security, coordination, etc., to have the contractor internally perform its own IV&V. To perform this function internally, a completely independent organization should be identified to perform the IV & V effort. This IV&V organization should be headed by an individual who reports directly to the customer's project manager. The IV&V organization should have a small staff and primarily draw support from specialty areas within the contractor's organization. These specialists should be experienced in the engineering disciplines involved but have no direct involvement with the project and project personnel.

The IV&V organization should prepare the portion of the overall T&E Plan that defines the project-performed IV & V activities, the T&E activities the IV&V organization will review, and the T&E activities the IV&V organization will conduct.

Since there is no standard list for the T&E activities performed by the independent IV&V organization, the customer, project manager, and IV&V organization must agree on the T&E activities the IV&V organization will perform and/or review. The following is a suggested listing of T&E activities that should be considered for the IV&V effort.

- Validate the results of the functional requirements and architecture allocation effort.
- Validate the project scope, schedule, and cost baseline.
- Review and/or accept system specification(s).
- Review and accept software specification(s).
- Participate in the Preliminary Design Review.
- Witness and/or perform key acceptance tests.
- Review and/or accept the final T&E assessment report.

If the end product(s) involve developed software, the software IV&V activities described in reference 14 of section 5 of this Guide should be considered.

**Personnel Safety Considerations**. A key area for independent verification testing may be personnel safety. Safety may be an important consideration for any end product(s) that require personnel to work in close proximity to extremely hazardous materials or operations. In these situations, the T&E Plan should require that system integration engineers conduct separate analyses to ensure personnel safety and health. It should further stipulate that these analyses undergo reviews to verify the correctness of these analyses.

## 2.5 Test and Evaluation Planning

T&E should be planned to consider various combinations of verification methods and the levels of testing necessary to ensure technical performance. The T&E plan should relate to the project's technical risks, importance of operability function, acceptance criteria, and reliability, maintainability, and availability (RMA).

### 2.5.1 Organization of T&E Activities

There are five important aspects to the effective and efficient organization of T&E activities:

- the approach to use in planning the verification activities;

- the verification methods to be used to verify compliance with a requirement;
- the measure to be used to demonstrate compliance;
- integration of verification activities into the project work breakdown scheme and Work Breakdown Structure; and
- the sequence in which testing should occur.

Management and engineering should establish the planning breakdown approach during the conceptual phase of the project to facilitate the T&E planning effort.

A recommended approach is to organize the T&E Activities by performance requirements. That is, state the requirement, specify the verification method(s) to be used to verify compliance, and identify the acceptance criteria to be used to demonstrate compliance. Generally, more than one verification method may be needed for a given requirement. For example, an important process requirement may be verified by analysis and reviews during design and by system acceptance testing during the Turnover Subphase (see section 2.8) of the project. The T&E activities completed during the design process should reduce the risk of failure in operational performance testing late in the Turnover Subphase.

All requirements for end product(s) should be addressed in T&E planning. This includes requirements for components, subsystems, and systems (including facilities) that make up the end product(s). Projects with complex end product(s) may entail a large amount of data requiring extensive maintenance to ensure the requirements are complete and current throughout the project. A number of software tools are commercially available to support this effort. Other approaches that can be used include general automated data bases or table entries in the planning documentation. The project manager should consider the use of such tools.

During T&E planning, the following issues should be given special consideration.

**Project Alternatives**. T&E planning should include continuing analysis of various verification methods and their associated effects on the project's cost, schedule, and technical parameters. This analysis should identify critical testing areas and investigate alternative verification methods that might reduce costs or shorten schedules.

**System Test Planning**. T&E planning should include input from all engineering specialties to define an effective and economical total system testing approach that takes into account the following objectives.

- Whenever practical, testing for different objectives should be combined.

- Verification of the acceptability and compatibility of human performance requirements, training, and man-machine interfaces should be integrated into system testing.

- System testing should be accomplished in a well-defined sequence.

There may be several levels of system testing. For example, testing could be accomplished at the component level, subsystem level, segment level, and system level. Such a sequence for an acceptance test program might include installation checks, leak tests, system operational testing with minimum parameters, system operation with normal parameters, and operational modes.

**Test Impact on Construction**. Construction planning should address installation of the equipment to support testing sequence requirements.

### 2.5.2 Planning Test and Evaluation Activities

The complexity of the end product(s) should be a determining factor in the level of planning and planning documentation required. On projects with limited T&E activities, the T&E planning could be documented in the Project Execution Plan. On projects requiring extensive T&E, a separate T&E Plan is recommended. In addition, if acceptance testing is used extensively as a verification method, a separate plan may be warranted. Acceptance testing warrants such special planning because, unlike reviews or inspections, which are in-line activities, acceptance testing is generally a separately scheduled activity. These in-line verification methods are generally planned as an integral part of the design or construction activity, and the scheduling is dictated by the design and construction schedule.

Any appropriate format for the T&E Plan is acceptable. However, the plan should address each requirement, the verification methods to be used, the acceptance criteria used to demonstrate compliance, the performance period for the activities, and the estimated cost if the activity is estimated separately from other project activities. Again, if testing activities are extensive, a separate plan may be warranted.

The detailed planning effort should account for the preparation of procedures to document how the various T&E activities will be completed. Generally, responsible organizations have standard procedures for standard T&E activities such as analysis, reviews, inspections, and construction verification testing. Where appropriate, use of these

standard procedures is a cost effective approach. However, it is important that the results of the verification be documented and the results assessed against the acceptance criteria. Testing procedures are generally necessary for nonstandard tests such as unique design concept verification or acceptance testing. Such procedures should, at a minimum, specify the test objective, the "how to" for completing the test, the method for recording the test data/results, and an evaluation of the results against the acceptance criteria. These procedures should be reviewed to ensure correctness, clarity, completeness, and adherence with the requirement.

### 2.5.3 Suggested Content for a Test and Evaluation Plan

T&E planning should be documented and detailed as follows to show the rationale for the kind, amount, and schedules of the T&E activities.

- Relate the T&E effort clearly to the technical risks, operational issues and concepts, acceptance criteria, reliability, availability, maintainability, and acquisition phase key decisions.

- Explain the relationship of component, subsystem, integrated system development testing, and operational testing which, when analyzed together, provide confidence that the project is ready to proceed.

- Outline the T&E management responsibilities for participating organizations, including any independent verification and validation to be performed by another agency or organizational element.

- Specify arrangements between participants for sharing physical test data.

- Specify testing periods and schedules, which should allow sufficient time to perform the testing.

For projects with limited T&E activities, the plan could be incorporated into the project execution plan. Where the T&E effort is significant, a dedicated T&E plan is recommended. Table 1 gives a suggested content for the T&E plan.

## 2.6 Test and Evaluation Documentation

Each T&E method will have its own documentation, which may be project-specific. Documentation for inspection, hardware and software testing, and demonstration often is included in manufacturing documents. Review and analysis documentation is usually

included in reports or engineering memoranda with acceptance testing documented in test procedures or reports. Control of test and analysis reports, raw test data, and other T&E documentation should be traceable, responsive to changes in requirements, and consistent with the configuration management change control requirements of the project. (See section 2.7.) These data should be identified for control purposes in a manner similar to engineering drawings.

### 2.6.1 Plans

T&E planning documents should be considered records and should contain the necessary approval signatures to ensure that T&E is integrated into the project adequately. The acceptance criteria should be clearly documented and approved. The Test and Evaluation Plan should then be integrated into the baseline change control process and the configuration management control process (See Configuration and DATA Management GPG.

### 2.6.2 Testing Procedures

Procedures should be prepared to specify how a particular physical test will be conducted. Test procedures should conform with industry standards for testing and contain information about what test is being performed, steps in performance and their sequence, test data to be recorded, acceptance criteria, performers, and equipment requirements. Procedures should flow clearly from project requirements to acceptance criteria.

### 2.6.3 Results Documentation

T&E results should be documented to provide written records of verification results and evidence the acceptance criteria were met. This documentation should include review reports, analysis reports, testing results, inspection reports, testing reports, evaluation reports, and any other documents that will form the basis of project acceptance.

## 2.7 Change Control

### 2.7.1 Project Baseline Change Control Process

T&E activities should be integrated into the baseline change control process for the project. Baseline change control requests may come from the customer or result from conditions internal to the project. The project manager is responsible for the baseline change control process and for communicating the disposition of all approved baseline changes to the project team.

### 2.7.2 Project Baseline Changes Affecting T&E

Proposed project baseline changes should be evaluated to estimate their effect on the T&E plans. This estimate should be incorporated into the cost estimate for the proposed change and approved changes should be incorporated into the T&E Plan. If the project change, requires redesign, the new design must be re-verified to ensure compliance with requirements. Re-verification should be documented and should be traceable to the approved change request. When testing is performed to demonstrate compliance, special care should be taken to ensure the need for re-testing is examined. Where necessary, re-testing should be specified, planned, executed, and the test results incorporated with previous test results to ensure compliance with requirements.

### 2.7.3 Baseline Changes Initiated Within T&E

Baseline changes could be initiated within the T&E effort to improve the effectiveness of T&E or in reaction to a verification activity that failed the acceptance criteria. Changes that can enhance the effectiveness of the T&E effort and reduce costs are encouraged. If a proposed change affects the project baseline, the change must be processed using the project baseline change control process discussed above. For proposed changes that do not impact this project baseline, the need for the change can be assessed by the project team and incorporated based on merit. If the proposed change is accepted, it should be incorporated into the T&E planning documentation, coordinated with the affected project team discipline, and implemented.

Changes initiated due to failure of a project component, subsystem, or system (including facilities) to meet the acceptance criteria must be evaluated and corrective actions undertaken by the affected project discipline as directed by project management. Again, corrective actions requiring changes to the project baseline must be processed through the project baseline change control process.

All T&E changes implemented on the project should follow good configuration management practices and be implemented through the project's configuration management process. This will ensure all affected project organizations are informed of the change and all changes are incorporated into project documentation and activities.

## 2.8 Test and Evaluation During the Project Life Cycle

DOE-sponsored projects are expected to progress as shown in Figure 2. This progression includes preconceptual activities, which occur prior to the formal start of a project, and two project phases—Conceptual and Execution. The execution phase has three

Subphases Design, Construction and Turnover. T&E activities are required at each stage of a project, as discussed below.

### 2.8.1 Preconceptual Activities

Preconceptual activities include the identification of a project need and an evaluation of that need to determine if it supports the Department's mission, goals, and objectives. During the preconceptual activities, the design concept is being developed. Specific T&E activities at this stage are as follows.

- Verify the proposed project architecture and associated design concept for the end product(s) against the requirements.
- If testing is required to verify a concept, execute the tests and evaluate and document the test results.
- Document these tests properly for use during the acceptance phase to demonstrate that the end product(s) satisfy the requirements. This approach may reduce the testing needs and testing costs during the acceptance phase of the project life cycle.

### 2.8.2 Conceptual Phase

The conceptual phase advances ideas formulated for the project architecture during preconceptual activities. During this phase, the project management team develops planning documentation. Specific T&E activities at this stage are as follows.

- At the start of this phase, develop, review, and approve acceptance criteria for each requirement.
- Once the acceptance criteria have been established, initiate T&E planning activities.
- As possible, execute initial portions of the T&E activities. Even though T&E plans, may still be in the process of development, review, and approval, these activities may be necessary to continue to verify the developing architecture against requirements and acceptance criteria.

- Plan and document the results of the verification activities for potential use during later phases of the project to demonstrate that end product(s) meet project requirements.

### 2.8.3 Execution Phase

During the execution phase, detailed design, construction, or remedial design and remedial actions take place. Specific T&E activities at this stage are as follows.

- At the beginning of the execution phase, finalize, review, and approve the remaining portions of the T&E Plan.

- Prepare and approve T&E procedures (including testing procedures), analysis, reviews, some component and subassembly acceptance testing, and inspection and construction verification testing.

- Prepare T&E plans, test procedures, and review, inspection, and testing reports.

The Execution Turnover Subphase takes the completed end product(s) to an operational mode or completes remedial actions. T&E activities generally peak during the Execution Turnover Subphase as functional and operational performance testing is completed. During this phase, in which the project manager has full responsibility for continued project functions, the focus is on transition activities requiring strong coordination between the project manager and the future operating organization and the careful delineation of responsibilities.

Specific T&E activities at this stage are as follows.

- Perform acceptance testing (operational mode, output performance, and support functions) and demonstration testing.

- Document and prepare final assessment of T&E results. To ensure that required re-work is properly reverified, the final assessment should pay special attention to any subsystems or systems that required rework to meet acceptance criteria.

The final evaluation should be documented in a form commensurate with the T&E activities. An assessment report is recommended. This report is key for the T&E effort and an important document in the turnover of the end product(s) to the customer. If end product(s) do not meet the acceptance criteria for a requirement, an evaluation should be performed to determine the causes, impacts, and candidate remedies for the discrepancy.

- Ensure all required re-work is completed and that re-worked end product(s) meet acceptance criteria and are accepted by the customer.

- Prepare final T&E documents, including testing reports and a final assessment report.

# 3. GRADED APPROACH

Because some level of T&E effort should be implemented on all projects, the question is not whether to perform T&E activities, but to what level. A graded approach should be used to ensure T&E principles and practices are incorporated commensurate with project factors, such as complexity, visibility, and risk, to ensure successful project completion. Without this minimum set of T&E activities, the project manager has no basis to demonstrate to the customer that the end product(s) meet project requirements.

To incorporate T&E into contract solicitation documents, the DOE project manager should tailor principles and practices to the specific characteristics of a project. The contractor and the Government may tailor the T&E requirements further during subsequent contract negotiations. The agreement reached on the T&E effort should be reflected in the resultant contract.

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# 4. MEASURING FOR RESULTS

Two types of T&E measures should be considered by the project team:

- metrics that measure the effectiveness of the T&E activities during the project life cycle; and

- metrics that measure the effectiveness of the T&E process as applied to all the organization's projects.

The ability of the T&E effort to demonstrate that end product(s) meet the project's requirements should be measured throughout the project. Acceptance criteria and T&E plans and procedures should be systematically reviewed for completeness, currency, and accuracy as part of the T&E process.

Table 2 lists candidate metrics that the project manager should consider using throughout the project. Type 1 metrics should be used to continuously improve T&E. Others may be more appropriate for a given project. However, the project team should actively measure the selected items, track the trends, and react to negative trends with additional actions in the T&E area to improve the T&E effort.

Type 2 metrics should be used to improve the organization’s T&E process. These measures are assessed near the end of the project and should be provided to the organizational element responsible for T&E . The measures generated from all the organization’s projects should be integrated and used to improve the organization’s T&E process.

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# 5. SUGGESTED READING

The following selected DOE Orders, guides, and national and international standards should be referenced for additional information.

1. "DOE Order 430.1, "Life Cycle Asset Management,"

2. "DOE Project Management Overview Guide," Draft

3. "DOE Project Execution and Engineering Management Planning Guide," Draft

4. "DOE Project Reviews Guide," Draft

5. MIL-SAD-499B, "Systems Engineering," Department of Defense, May 6, 1992, Draft

6. MIL-SAD-781D, "Reliability Testing for Engineering Development, Qualification, and Production," Department of Defense, October 17, 1986

7. MIL-SAD-882B, "System Safety Program Requirements," Department of Defense, March 30, 1984

8. MIL-SAD-1540B, "Test Requirements for Space Vehicles," Department of Defense, October 10, 1982

9. ANSI/ASQC Q91-1987, "Quality Systems - Model for Quality Assurance in Design/Development, Production, Installation, and Servicing," American Society for Quality Control

10. A NSI/ASQC Q92-1987, "Quality Systems - Model for Quality Assurance in Production and Installation," American Society for Quality Control

11. ANSI/ASQC Q93-1987, "Quality Systems - Model for Quality Assurance in Final Inspection and Test," American Society for Quality Control

12. IEEE P1220, "Standard for Application and Management of the Systems Engineering Process," Draft dated September 26, 1994

13. EIA/IS-632 Standard, "Systems Engineering," December 1994, Final Draft

14. "Computers Science and Technology: Planning for Software Validation, Verification, and Testing," PB83144493XSP, RN: NBSSP50098, November 1982

15. ISO 9000-9004 series (Equivalent to ANSI/ASQC Q90 through Q93)

# 6. DEFINITIONS

This Guide does not create any new terms requiring formal definitions.

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# 7. Assistance

Questions concerning this Guide may be referred to the Office of Field Management in Washington, D.C. at (202) 586-4041.

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# 8. RELATED TRAINING

No formal DOE training is available that focuses on the subject of T&E. However, general training courses on project management and systems engineering will generally address verification and/or T&E. In addition, system engineering training courses cover verification and/or testing in more detail. A number of good training courses are commercially available on these two subjects.

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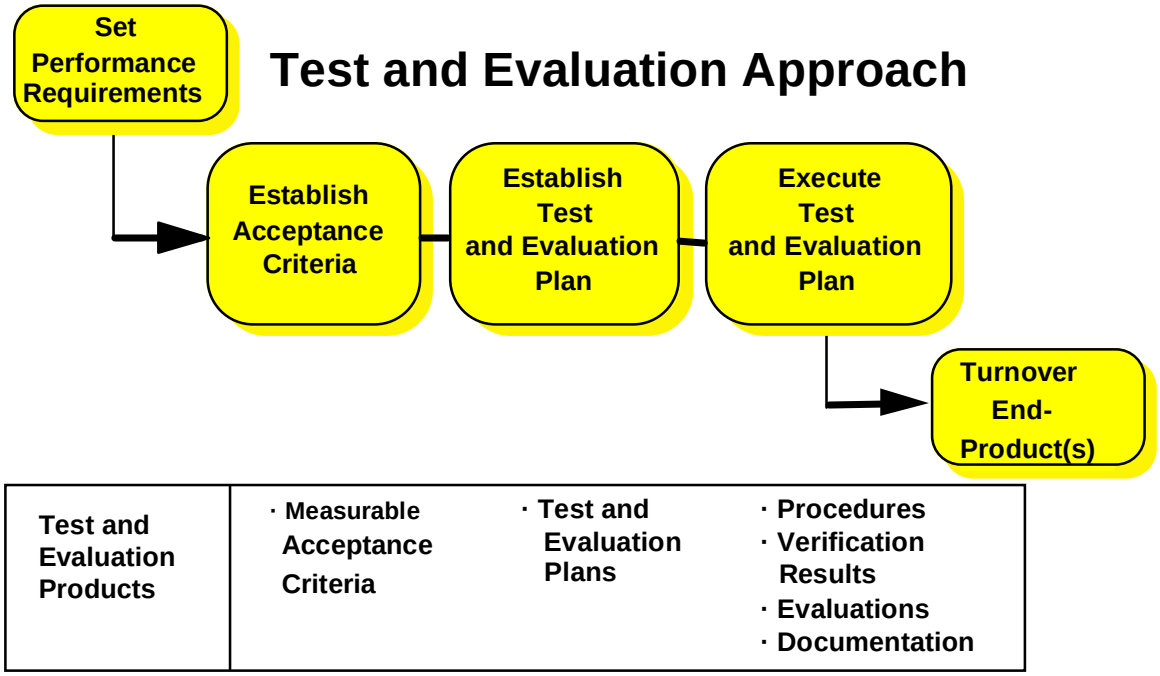
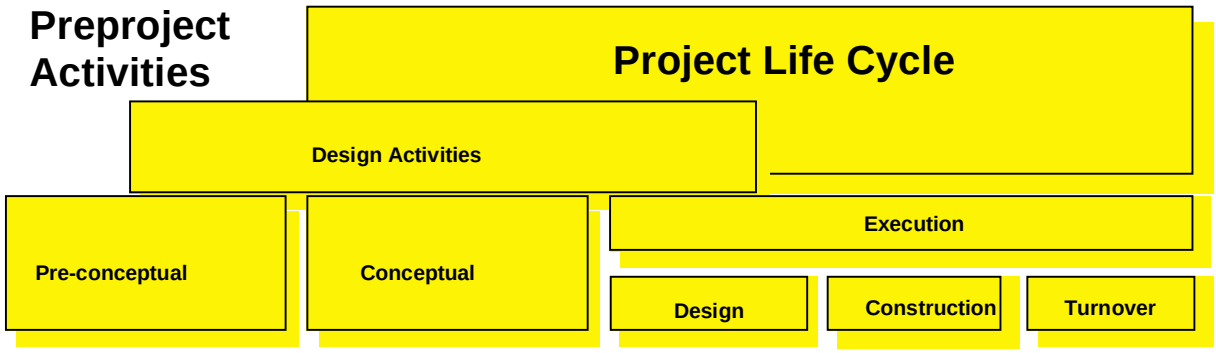



**Figure 1.** Test and evaluation approach and products.




## Test and Evaluation

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· Concept Verification Testing

· Alternative Verification Testing
· Acceptance Criteria
· Preliminary Test and Evaluation Plans

· Final Test and Evaluation Plans
· Reviews
· Construction Verification Testing
· Analysis
· Inspection

· Functional Testing
· Operational Testing
· Evaluation of Testing Results
· Documentation of Testing Results

**Figure 2.** Project life cycle and test and evaluation activities.

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**Figure 2. Project Life Cycle/Test and Evaluation Activities**.

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## Table 1. Suggested Test and Evaluation Plan Content

**T&E Approach**
- Define any subordinate T&E plans
- Specify organization responsibilities for T&E activities
- Integrate T&E effort into the project schedules

**Project Requirements, Verification Methods and Acceptance Criteria**
- Identify project requirements
- Specify the verification method(s) to be used
- Document the acceptance criteria

**Verification by Review**
- Review procedures
- Reviewer qualifications
- Review documentation
- Integration of reviews into the project design schedule

**Verification by Analysis**
- Analysis documentation
- Analysis review requirements
- Integration of analysis into the project activity schedule

**Verification by Inspection**
- Inspection procedures
- Inspection qualifications
- Integration of inspections into the project manufacturing construction schedule

**Verification by Testing**
- Testing sequence
- Testing plans
- Testing procedures
- Review and approval of testing procedures
- Documentation of review results
- Acceptance testing schedules

**Use of computer programs in T&E**
- Computer program verification
- Computer program configuration control
- Documentation of computer analysis input and output assessment of T&E effort

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## Table 2. Metrics for Measuring Results

**Type 1 Metrics - Measures to improve the application of the T&E process on a project.**

- Deficiencies on design drawings found during manufacturing or construction.
- Construction variances discovered during a following construction effort versus those found during the in-process inspection process.
- Failure of a system to function due to a design discrepancy disclosed in a system acceptance test versus failures discovered by analysis or review.
- Change rate on project requirements.
- Number of action items during project status review based on design and/or construction deficiencies.
- Ease of measurability of an acceptance criteria during a verification activity.
- The customers' level of satisfaction that the evolving project end product(s) will meet their requirements.

**Type 2 Metrics - Measures to improve the organization's T&E process.**

- The Scope of Work involved in eliminating project punch list items that are based on design and/or construction deficiencies.
- The ease of customer acceptance of the project punch list items that are based on design and/or construction deficiencies.