

The Test and Evaluation Master Plan: an Operational View

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New regulations governing defense acquisition give less guidance than ever before on what should be tested, how to plan a T&E program and how to document that planning in a Test and Evaluation Master Plan. The authors, each of whom has responsibility to recommend to the Director, Operational Test and Evaluation (DOT&E) whether planned testing is adequate, present a view of what is an adequate Test and Evaluation Master Plan in the new acquisition environment of spiral development, evolutionary acquisition, and more integrated and joint testing.

On May 12, 2003, the Deputy Secretary of Defense signed an update to DoD Directive 5000.1 that redefined the “Defense Acquisition System.” At the same time, the Under Secretary of Defense (Acquisition, Technology, and Logistics) USD(AT&L), the Assistant Secretary of Defense (Command, Control, Communications, and Intelligence) ASD(C3I), and the DOT&E reissued a modified DoD Instruction 5000.2 (DODI 5000.2) that specifies the “Operation of the Defense Acquisition System.”

The new versions of these documents are shorter and less proscriptive than any of the previous versions over the last dozen years. But they prescribe a number of acquisition concepts that could have major impact on how testing is done in the Department. The concepts include spiral development, evolutionary acquisition, integrated testing throughout development, and a new statement of the objective of Defense Acquisition, i.e., “to acquire quality products that satisfy user needs with measurable improvements to mission capability and operational support....”

Taken together these concepts ought to have a major effect on the Test and Evaluation Master Plans (TEMPs) developed during the life of a program. In the case of the first TEMP iteration under this instruction, its name has even changed. It is now called the T&E Strategy. For this article, we will consider it a first version of the TEMP although the time-lines and resources for intermediate development will be harder to define. There are also new names for the milestones and the phases between them. (Figure 1)

The T&E strategy is due at Milestone A (if the program has a Milestone A), and it must be approved by the USD(AT&L), and DOT&E. For Major Defense Acquisition Programs, Major Automated Information System (MAIS) programs, and programs on the OSD T&E Oversight list, the Program Manager must submit a TEMP for approval to support Milestones B and C and the Full-Rate Production decision.

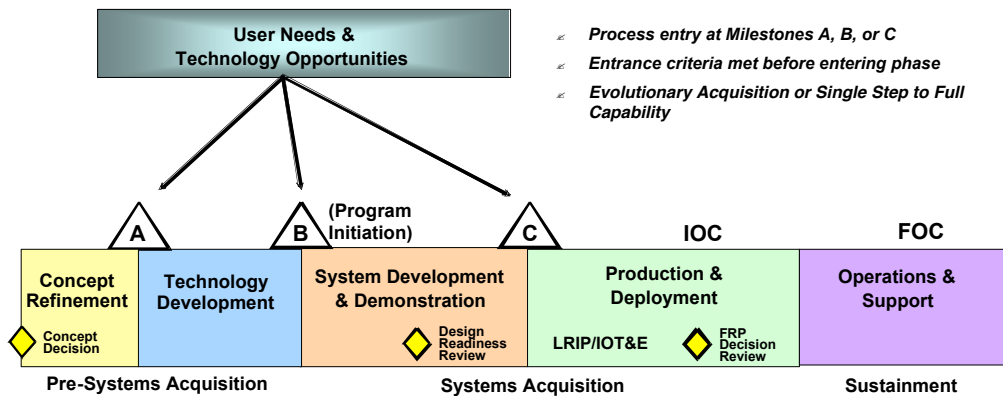


Figure 1. The Defense Acquisition Management Process

Guidance in the current version of the DoD Instruction is that “The Test and Evaluation Master Plan shall describe planned developmental, operational, and live fire testing, including measures to evaluate the performance of the system during these test periods; an integrated test schedule; and the resource requirements to accomplish the planned testing.” (DoDI 5000.2 E5.4.1) The document does not offer how to plan testing, what to plan in testing, or how to integrate the testing into a schedule for spiral development or evolutionary acquisition.

To streamline the approval process of TEMPs, the authors wish to present what they will look for and how they will approach the task of forming an approval recommendation under the new Directives and Instructions. Every TEMP approved by DOT&E is reviewed by at least two of the authors, who recommend to the Director whether or not the test plan is adequate.

The following presents a picture of what the content of the TEMP ought to be. Recognizing that every program is special and that flexibility can have its rewards, this article presents those aspects that the office of DOT&E will consider in making a recommendation about the adequacy of a TEMP.

Mission Accomplishment Is Still Fundamental

DOT&E reports on the adequacy of testing and whether a test confirmed that a system actually tested is effective and suitable for combat. Definitions are contained in the Defense Acquisition University Desk Book. DOT&E's evaluation is in the context of operational effectiveness: the overall degree of mission accomplishment. So the TEMP must describe realistic missions for which mission success can be defined.

Operational Effectiveness

The overall degree of mission accomplishment of a system when used by representative personnel in the environment planned or expected (e.g., natural, electronic, or threat) for operational employment of the system considering organization, doctrine, tactics, survivability, vulnerability, and threat (including countermeasures, initial nuclear weapons effects, nuclear, biological, and chemical contamination (NBCC) threats).

Operational Suitability

The degree to which a system can be placed satisfactorily in field use with consideration being given to availability, compatibility, transportability, interoperability, reliability, wartime usage rates, maintainability, safety, human factors, manpower supportability, logistic supportability, natural environmental effects and impacts, documentation, and training requirements.

Survivability

The capability of a system and its crew to avoid or withstand a man-made hostile environment without suffering an abortive impairment of its ability to accomplish its designated mission.

Vulnerability

The characteristics of a system that cause it to suffer a definite degradation (loss or reduction of capability to perform the designated mission) as a result of having been subjected to a certain (defined) level of effects in an unnatural (man-made) hostile environment. Vulnerability is considered a subset of survivability.

The overall degree of mission accomplishment is fundamental; everything that may degrade mission accomplishment should be part of the effectiveness determination. It would be wise to include success and failure definitions and scoring criteria as a TEMP appendix so that a shared understanding of them is possible. An Initial Operational T&E ought to confirm the success of a development effort. Operational T&E should also provide to the developer periodic operational assessments, an early warning system for problems so that they may be addressed appropriately. This early warning system should be clearly integrated into the development effort and documented in the TEMP. As we try to make Initial Operational T&E (IOT&E) more efficient, operational

testers and evaluators will depend on the information gained earlier in development.

History clearly shows that adequate testing improves the chances for a successful program. The TEMP can help from the beginning in this process by providing: a clear picture of the operational missions that will be executed in the test, the definitions of mission accomplishment, the conditions under which the system will be tested, and the interactions with other systems that will be needed for mission accomplishment.

The master testing strategy has to weave together understanding of three elements: 1. The military mission, 2. How mission translates into military system, and 3. How 1 and 2 ought to be tested. The military mission should be analyzed into essential tasks (the Universal Joint Task List provides a good place to start). Then further analyzed into interactions and actions that must be accomplished by any proposed system. Systems will perform with components using available technology. Each level of the foregoing decomposition will have a corresponding testing activity, building up to the operational test. The above process (Figure 2) allows the TEMP to begin the IOT&E planning as soon as the mission is identified, and to fill in plans for the component and technology demonstrations as the program develops.

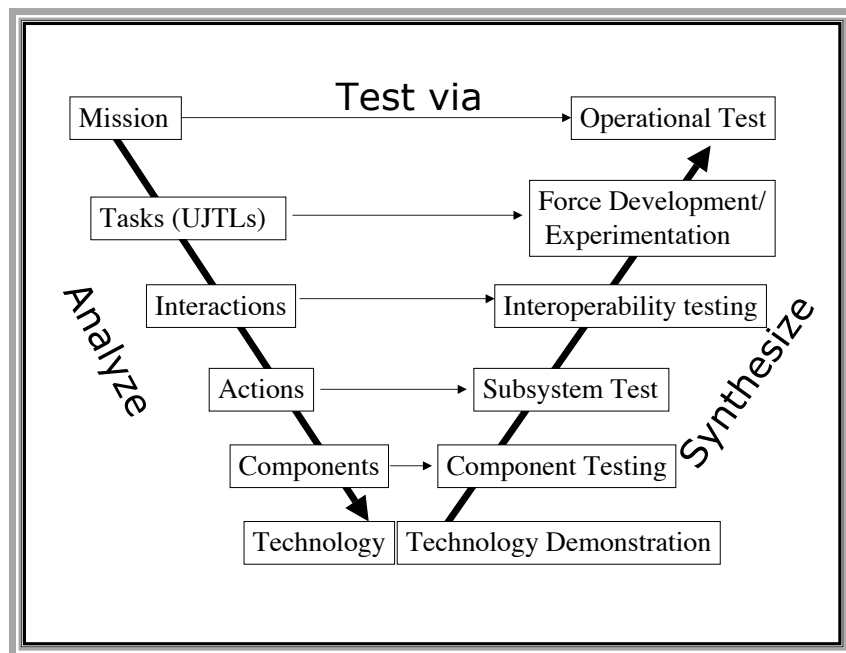


Figure 2. Analysis – synthesis model relating mission and system level to test level

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Building a successful product begins with a clear analysis of the military mission. The TEMP should provide a plan to understand everything that is known about the mission and the system in terms of mission accomplishment. The TEMP should also identify times when information should be learned from testing. The analyze-synthesize model (Figure 2) provides a framework to implement the instructions: “Test and evaluation shall be integrated throughout the defense acquisition process. Test and evaluation shall be structured to provide essential information to decision-makers...”. The TEMP is the contract between all the parties to ensure those instructions are fulfilled.

The Essential Elements of Information that T&E Provide

The essential elements of information from T&E focus on the following goals:

1. Quantify the need.
2. Assess and test the proposed solution concept.
3. Evaluate the preliminary and detailed system design.
4. Structure demonstrations at lower levels.
5. Plan experimentation to develop operational concepts.
6. Determine readiness for IOT&E (Production configuration defined, produced, and unit trained).

7. Test and evaluate the system (IOT&E and live fire test).
8. Test and evaluate logistic support.
9. Provide for life-cycle evaluation (e.g., follow-on operational testing).
10. Plan system use/deployment recording of information as part of the spiral development.

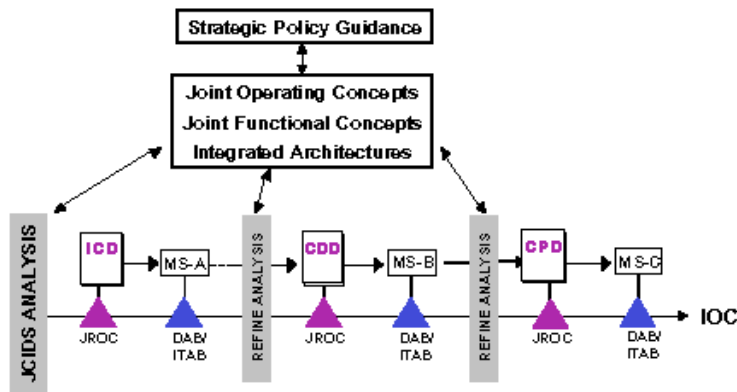
These essential elements of information are to be determined and updated. The information builds with each revision of the TEMP and there should be plans to refine the information available.

“Test and evaluation shall be integrated throughout the defense acquisition process. Test and evaluation shall be structured to provide essential information to decision-makers, assess attainment of technical performance parameters, and determine whether systems are operationally effective and suitable, survivable, and safe for intended use. The conduct of test and evaluation, integrated with modeling and simulation, shall facilitate learning, assess technology maturity and interoperability, facilitate integration into fielded forces, and confirm performance against documented capability needs and adversary capabilities as described in the system threat assessment.” (DoDD 5000.1 E1.11)

1. Quantify the Need – Operational Analysis of Mission

To fulfill the Directive to “satisfy user needs with measurable improvements to mission capability and operational support,” one must know the *current* mission capability and operational support, and how to quantify it. The TEMP formerly contained a summary of the Mission Need Statement (MNS) in the full Joint context. The Initial Capabilities Document (ICD) has replaced the MNS in a new Joint Capabilities Integration and Development System (JCIDS) (Figure 2). The ICD presents the need for a materiel solution to resolve a specific capability gap (defined in terms of the functional area, the relevant range of military operations, and appropriate measures of effectiveness). Since military units accomplish operations, the unit to use the system should be identified in the TEMP by its organization, doctrine, and tactics. If these are not well known, a plan must be made to get that information (e.g., through force development experimentation). A good analysis will also make clear what will be: the realistic stress and operational tempo; the threat representative forces, tactics, and equipment; the operationally realistic environments, terrain, signatures, targets, and countermeasures; and the interfacing systems.

JCIDS Process and Acquisition Decisions



ICD The Initial Capabilities Document, used instead of the MNS, makes the case to establish the need for a material approach to resolve a specific capability gap.

CDD The Capability Development Document provides the operational performance attributes including supportability, necessary for the acquisition community to design the proposed system, including key performance parameters (KPP) that will guide the development, demonstration and testing of the current increment. That increment will be a militarily useful and supportable operational capability.

CPD The Capability Production Document, finalized after the critical design review, narrows the performance parameters into more precise estimates for the production system.

Figure 3. Joint Capabilities Integration and Development System (JCIDS).

As a program develops, clearer notions of how the system will contribute to mission accomplishment should emerge. In this process, look at the entire mission, end-to-end. This will prevent false expectations from developing about the interaction with other systems.

Essential in the operational analysis of the mission are: a description, careful and complete, of the whole mission end-to-end; an understanding of how the equipment under test will contribute to mission accomplishment; and definition of mission success. One major cause of product failure is that the consumer uses the product in a way different from that envisioned by the developer. Early T&E involvement can minimize this risk.

2. Assess and Test the Proposed Solution while it is Still a Concept

The master plan ought to schedule frequent assessments to identify operational and technical risk. Assessment can begin with a crosswalk between existing documents, such as those mentioned earlier (e.g., the ICD) and the request for proposal or the contract specifications. More than consistency, assessment should determine whether the documents work toward the development of a system that gets the mission done. Making the “translation” between mission needs and engineering specification is complex. The assessment should inform the analysis of alternatives or the engineering trade-offs, as well as identifying the proposed system’s technical and operational challenges. Early

operational assessments (EOAs) of systems that exist only on paper can be significant to the design effort. A second assessment should systematically examine the factors that will drive the design. Once these drivers are defined, a test strategy can be devised at a detailed level.

3. The TEMP Should Present the Test Concept

The TEMP is the plan to provide the essential information for decision makers and the contract on the delivery of that information. The DoD Directive identifies the most essential piece of information - Does the product satisfy user needs with a measurable increase in mission capability?

Once the mission is clearly defined, the early drafts of the T&E strategy should begin defining the operational test. The IOT&E definition will determine what resources are needed to acquire targets, develop special instrumentation, and identify the number of systems required. If the system is a candidate for live fire test and evaluation, then the TEMP should also contain the live fire strategy and resources.

At the end of many system developments, expectations for the system's contracts or requirements have not been met. Despite the system's failure to meet user requirements, the system often *does* provide an improvement in mission capability. This information generally proves vital to the production decision. The best way to provide quantified, objective information on this fact is through a test (or in some cases an evaluation) comparing the new system's mission accomplishment to the current way the mission is accomplished. This comparison test approach also calibrates the test and offers evidence of the test's validity. Having a direct answer to the question of whether or not the proposed system is an improvement helps decision makers in these cases.

The TEMP should revisit this question over the development process. Early on, evaluating the proposed solution against the baseline will highlight what is limiting the baseline. Later, assessments focus on the proposed solution and its technical and operational risks, and uncertainties. It is even worth considering including a draft of the TEMP in the Request For Proposal so that the contractor would have some idea of the concerns operational evaluators have. There should be a plan to iterate the answers, for example, at design reviews.

The TEMP should not deal only with system-level testing. It is never too early to plan the initial demonstrations of component or subsystem capability to support mission accomplishment. Much could be done in realistic testing of components. For example, sensors can be tested in a realistic environment before full integration onto the final platform.

Evaluations Associated with Test Concepts

Each demonstration should plan an evaluation that puts the results in terms of end-to-end performance. Even component testing can be evaluated in a mission context. Thus, tests in System Integration Laboratories, Hardware-in-the-Loop facilities, with brass board or prototype systems could focus on whether the system is on track to satisfy mission needs. Reliability, Availability, and Maintainability (RAM) demonstration results should be compared with a RAM rationale or logistic support model for the mission. Knowledge of design margins can be gained from testing components to failure or comparing stress to realistic mission environments.

It is necessary to identify realistic endgame conditions for live fire test & evaluation planning. These can come from operational or engineering considerations. The TEMP should include how the live fire results will be used to inform the operational test results, and vice versa.

One of the failures in the acquisition process is that, although testing gives information about problems, however the feedback loop has no enforcement mechanism to insure that something is done about the problem once discovered. One tool that would serve the acquisition process well is for evaluators to have failure-consequence modeling. On the program management side there should be a failure-mode review board, but in the absence of that, a tester's responsibility is to clearly articulate the operational implications of test results. Such an effort requires resources that ought to be identified and provided at the beginning of the acquisition process.

Items such as mission and logistic support modeling, as well as instrumentation requirements, are appropriate for the TEMP because planning for them and developing them often take more time than is available after detailed test planning begins.

The Scope of OT Test Concepts

The scope of an OT&E event can be characterized by: the unit or unit slice to be tested, the number and type of "missions" to be attempted, and the sample size; where the event will be conducted and the threat portrayal; and measures to be used, the instrumentation required, and the way in which readiness to test will be established.

It is best to have a data source matrix for the complete operational evaluation showing where the information is to be obtained. Some of the information needed may be produced during developmental test, and should be identified. Evaluation criteria must be included; usually a measure and criterion for operational effectiveness (mission level) and a measure with criterion for suitability. While there may be many lower level criteria, the overarching one is expressed in the new acquisition Directive 5000.1 - measurable improvements to mission capability. For most systems, if the current mission capability has not been quantified, the TEMP must plan to make it so.

The adequacy of the test event will be judged on the realism of the combat-like conditions: whether the challenge is at the edge or the “heart of the envelope”; whether the missions tested are complete (i.e., end-to-end); and whether contractor involvement meets the requirements of the law. Also critical is that typical units and personnel are used, not “golden crews” and that there are properly trained soldiers, crews, and units supported by typical support personnel and units. It is important that the unit in test is the proper size. This is necessary because the military gives missions to units. The production configuration should be defined and certified ready for IOT&E. It should be a total system evaluation with documentation and training. There should be pretest predictions of results as part of the determination of readiness to test. During planning, modeling the mission and the expected results should be part of the sizing effort for the IOT&E.

Good preparation eventually leads to an IOT&E that should address the most frequently asked question about new systems (especially when they don’t meet all requirements) namely, “Is it better than what we have now?” The tester should be able to provide proof of this essential element of information.

The test plan must identify the concept to determine operational effectiveness and suitability. One of the best contributors to this is through comparative testing. That approach has saved many programs that did not meet user requirements but offered measurable improvements to military capability.

4. Evaluation at Preliminary and Detailed Design

By the time of the preliminary design review, the TEMP should identify key components and environments. The TEMP should also be able to reference (under DoDI 5000.2 instruction) a model of mission level performance that could be used in an early operational assessment to show that the concept for the system can resolve the needs identified in the Initial Capabilities Document (ICD). At the same time, the special test facility requirements (HIL, SIL, Trainers, Environments) should be clear. Finally there should be a plan for the necessary component vulnerability/lethality testing and component qualification.

The TEMP should contain a plan for an EOA to accompany the Preliminary Design Review. An essential element of information needed from each design review is whether the design is complete. For example, the deferral of a piece of the review is often a sign that there is some trouble with that component. This frequently occurs with software. The operational evaluation is always from the mission perspective, so part of the answer must be whether all the interface and interoperability issues are resolved. In fact, the design review offers the first opportunity to identify specific technical risks associated with the program. If those are significant, TEMP revision may be appropriate. Reducing uncertainty by adding tests is part of responsible risk management.

One of DoD's biggest problems is that systems come to test before they are ready and prove it by doing very poorly on reliability measures. One survey had 80 percent of the systems failing to meet even 50 percent of the reliability requirement the first time they went to operational test. The preliminary design review should include a full life-cycle look. This will include the logistic support concept and embedded training and instrumentation.

During the design reviews an assessment should be made of the vulnerability of the system to information warfare attack to determine the amount of information assurance (IA) testing warranted. IA is not an add-on or evolutionary requirement; it is fundamental to the design. Experience has shown that systems cannot be protected at the boundary. The IA must be designed in from the beginning, and it must include operational procedures and safeguards as well as software.

5. Structure Demonstrations at Lower Levels: What The TEMP Should Say about System Development and Demonstration

Operational assessments during design reviews ought to identify what testing on components needs to be done and how it should be done in terms of the potential for safe and effective mission accomplishment. For example, a new technology ought to be assessed in operational environments as quickly as possible. New components should be tested for reliability under stressful environmental conditions. The essential information required is the evaluation of the technological maturity and potential to integrate that technology into a system that increases the degree of mission accomplishment.

6. Plan any Needed Employment Experimentation

An adequate OT&E requires realistic operational concepts, tactics, and doctrine. If these are not clear, the TEMP should have a plan for experimentation to determine them. These employment experiments can also test training and human factors. The essential element of information from these operational assessment activities is that the system will be tested with realistic and reasonable tactics, techniques, and procedures.

7. Plan for the System Test and Evaluation

IOT&E planning, as already discussed, is a benefit to the program in and of itself. It makes clear the mission, threat, environmental conditions, the resources required, measures of effectiveness, and failure definitions and scoring criterion. The same benefit comes from early planning for live fire testing and logistics supportability testing. As early as possible criteria should be established so that the start of OT is event based and not schedule driven. Criteria should include system maturity, design stability and the

manufacturing of the OT test articles. They should be production representative. In summary: “Buy what you test and test what you buy.”

If warranted by analyses, the IOT&E should include realistic Red Team capabilities for information attack and the evaluation should include an assessment of information assurance.

Production representative system
An article off production line.
Has both the hardware and software.
Uses production materials and process.
Logistics system / Operator & Maintenance Manuals / Technical Orders.

8. Test and Evaluation Logistic Support

The system level test also will provide RAM on production representative systems and should provide (through the safety release) evidence that the system is safe to be deployed with our armed forces. An adequate OT with respect to suitability is only as good as the suitability analyses and assessments done early in the process. These identify the risks associated with new technologies, operational concepts, or support concepts, and allow for follow-up testing of corrections.

Over the last fifteen years the experience with systems brought to OT is that they have significant reliability problems. Fixing problems during system level testing is expensive and slow. Designing-in reliability and finding the problems in lower-level testing (discussed earlier) is really the key to more reliable systems. For reliability, this lower level testing includes highly accelerated life testing (HALT), highly accelerated stress screening (HASS), and testing of components, even commercial-off-the-shelf ones, in representative operational environments.

Timing is Important

TEMP and Acquisition Strategy in an Integrated Schedule

A TEMP must inform the reader about what the evaluator wants to know and when. The TEMP must be designed so that the acquisition strategy and the T&E strategy support each other in terms of schedule. We believe we test to learn, not just confirm. The TEMP should identify what information is needed at a given engineering, contractual, or bureaucratic milestone, and what the contribution of testing will be to that information. The TEMP shall relate program schedule, test management strategy and structure, and required resources to all of the following: major decision points, COIs, critical parameters, and operational performance parameters derived from the user, evaluation criteria, ICD, or CDD. For example, DODI 5000.2 instructs that a project “shall exit Technology Development when...the technology for that increment has been demonstrated in a relevant environment...”. The TEMP should define that environment, the measure and its criteria, and the demonstration to be done. Operational evaluation

should track maturity issues to determine whether a system is ready to proceed to its next phase/event.

Adequate time and resources must be planned for pre-test predictions, the test itself, and post-test analysis for all major test events. The danger of rushing was made clear in a well documented accident report: “In an effort to recover cost and schedule, the conditions to be tested were reduced.” The adequacy will depend on whether the T&E strategy will produce all the information needed and is fully funded. All capabilities expected in the IOT&E should have been demonstrated successfully in developmental test.

The Interplay of Test Design and Acquisition Style

9. Plan for Future Spirals: System Use/Deployment and Post Production Product Improvement

The new spiral development and evolutionary acquisition styles have produced an additional element of information - prioritization of potential upgrades with respect to their operational impacts. The new acquisition requirements of spiral development will make it more and more important for the operational testers to report what changes to the system might have the most significant increase in mission accomplishment. This should be clearly separate from the system “as tested.” Databases on fielded performance to help decisions on future improvements, spiral development, and evolutionary acquisition are needed and should be resourced in the TEMP.

With respect to Information Assurance, there needs to be planning for post-full-rate production and fielding activity. The vulnerability to information warfare attack changes rapidly and all systems need to be reviewed periodically. This, in turn, suggests establishment of a deficiency tracking system to insure “fix” or “follow-up” and an organized and institutionalized lessons learned activity.

10. Testing Increments of an Evolutionary Acquisition Program

Evolutionary acquisition programs should conduct adequate testing for each new incremental capability including: provide for early involvement of the Service operational test agency and JTC in DT&E and test planning; evaluate, at a minimum, the increment of mission accomplishment and survivability required, plus whether or not performance previously demonstrated by the previous increment has been degraded; perform an independent operational assessment prior to release of each successive increment to the user; and support the intended schedule for reporting to the Secretary of Defense and Congressional defense committees. (c.f., DODD 5000.2 E5.12)

Building a good TEMP also Builds Commitment

The TEMP is a contract that has many levels. At one level it is a contract between the developer and the Service test agencies about service to be rendered. At another level, it is a contract between the Service and the Office of the Secretary that the testing will be adequate and fully funded.

The process of developing an adequate TEMP is not easy, but the process itself provides an opportunity to do considerable good for a program. It provides a forum where developers, users, and testers can be sure they share the same vision about the system and the mission in which the system will be used. Generally, the difficulties of communication make drafts of the TEMP or T&E strategy the best way to start.

There probably is no one “best” T&E strategy. One suggestion has been to outline and compare alternative strategies before making the final recommendation. That gives all players a chance to discuss and revise. That process serves to get the best commitment from everyone. Most important throughout the development process is to identify deliverables, not just dates. That is, identify what will be demonstrated and how.

TEMP Format

The content of the test program has been the subject up to now. How to present that content in a TEMP was, in previous versions of the DoDI 5000.2, included in a section on the format of the TEMP. That section has been removed. Most of it may become available on the Web as part of a “Best Practices” site (<http://dod5000.dau.mil/>).

The removal of a specified format may have reflected a view that TEMPs could become “hollow” by following a format without thinking deeply enough about the content. The authors want to reinforce the primacy of content over form.

On the other hand, consistent formatting among TEMPs serves an important function. A consistent format is an aid to those who see many TEMPs, so that they can quickly and consistently find information. In light of that, it is probably best, to the extent possible, to follow the format in the “best practices”: that is, include chapters on the system, the integrated test program, developmental test and evaluation, operational test and evaluation, and resources for testing.

Summary

The primary responsibility of the reviews of TEMPs that the authors conduct is to ensure that the OT&E will be adequate. The very first strategic plan (or TEMP) should have the

OT&E described and resourced. For the TEMP to be adequate from this point of view it has to describe:

- The missions to be tested (scenarios/units).
- The sample size (test matrix - conditions/controls).
- The measurements and evaluation measures.
- The resources to do the above.
- The steps to be sure the system will be ready to test.

If the first TEMP (or T&E strategy) presents and justifies itself with respect to each of those, it is probably adequate.

The rest of the TEMP should plan to implement the DODI to provide essential elements of information to decision makers through T&E that is integrated throughout the defense acquisition process. During development, the most important element of information is: knowing clearly where the system is on its path to providing an operationally effective and suitable system. That is the task of unquestionable operational T&E implications.

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