DEPARTMENT OF DEFENSE

SCIENTIFIC TEST AND ANALYSIS TECHNIQUES IN TEST AND EVALUATION

IMPLEMENTATION PLAN

January 2012

Deputy Assistant Secretary of Defense for Developmental Test and Evaluation

COORDINATION

We endorse this Scientific Test and Analysis Techniques in Test and Evaluation Implementation Plan.

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EXECUTIVE SUMMARY

In early 2011, the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L)) and the Deputy Assistant Secretary of Defense for Developmental Test and Evaluation (DASD(DT&E)) were tasked by the Secretary of Defense to find efficiencies in defense acquisition. Based on the Director of Operational Test and Evaluation (DOT&E) design of experiment (DOE) efforts in operational testing (OT), inputs from the Services, and successes in industry, the DASD(DT&E) believes that the use of scientific test and analysis techniques (STAT) will generate test and evaluation (T&E) efficiencies; provide rigorous, defensible T&E strategies and results; and improve the level of knowledge for developmental test (DT) planning, execution, and analysis process.

When used in the proper context, STAT will enable the program managers (PMs) to make better informed decisions based on acceptable risk thresholds. DOE is one of the methodologies resident in STAT.

This implementation plan provides guidance for developing and implementing a Department of Defense (DoD)-wide scientific-based T&E planning, execution, and analysis capability that will generate defensible T&E strategies and results and improve the level of knowledge for DT planning, execution, and analysis process. This plan is implemented with the assumptions that funding for a STAT T&E Center of Excellence (COE) is sustainable, that it will take approximately 7 years to realize the desired impact, and that the Office of the Secretary of Defense (OSD) and the Component T&E Executives will champion the effort. The multipronged, phased effort will feed into the DOT&E 2-year test science road map.

The STAT in T&E effort will be executed in three phases. Phase 1 (Initiation Phase, FY 2012–2014) will last 3 years with the goal of facilitating the transition to scientifically based test and analysis. The Initiation Phase focuses on developing policy and guidance, identifying training opportunities and software for the current workforce, and developing case studies by targeting pilot programs. Development of a STAT T&E COE is critical to the success of this phase. The COE will work on pilot programs identified by the Components to demonstrate the benefits of a scientifically based approach to test and analysis. This phase will create the momentum needed to fully integrate scientific test design and analysis into T&E.

Phase 2 (Expanded Phase, FY 2015–2016) will last 2 years with the goal of expanding the depth and breadth of programs using scientific approaches to T&E. Phase 2 expands upon the implementation completed during Phase 1 and leverages lessons learned and best practices.

Phase 3 (Institutionalize Phase, FY 2017–2018) will last 2 years with the goal of completing the STAT in T&E implementation, realizing the vision by the end of FY 2018. Specific tasks will be dictated by the results garnered in Phase 2.

The STAT T&E COE is a reachback T&E capability that will provide advice and limited assistance, promote collaboration and use of best practices in the employment of STAT in both developmental test and evaluation (DT&E) and operational test and evaluation (OT&E) to enable defensible results.

The STAT T&E COE provides direct value to the program executive officers (PEOs)/PMs through assistance provided to the designated T&E key leadership positions and program T&E leads in the development and review of T&E strategies. The STAT T&E COE will provide an additional layer of experience and knowledge during the development of the program's test and evaluation master plan (TEMP), with the goal of increased efficiencies and effectiveness within availability of resources.

The STAT T&E COE, organized in terms of warfare areas (land, sea, air, space, and information systems), will consist of statistical/T&E subject matter experts (SMEs) with broad knowledge of DoD T&E. Their qualifications will include experience with DoD T&E planning, execution, and assessment; statistical expertise; and access to the research communities. The STAT T&E COE support will be independent of DASD(DT&E) or DOT&E involvement in support of the T&E working-level integrated product teams (WIPTs).

The STAT T&E COE, which is envisioned to provide a long-term T&E capability for the acquisition community, will attain limited capability in April 2012 with full operational capability in 4th quarter FY 2012. The DASD(DT&E) plans to fund the STAT T&E COE for Phase 1 (FY 2012–2014). Funding for FY 2015 and beyond will be determined before the end of Phase 1 by the DASD(DT&E) and the Component T&E Executives.

The STAT T&E COE will support a select number of acquisition programs from across the Components. Available funding will dictate the specific number of programs. It is envisioned that the STAT T&E COE should support approximately 20 programs, with one SME supporting five programs, per year.

This effort is a continually evolving process that requires management of the overall direction while adjusting for new developments to achieve the objectives. Senior T&E leadership will review, assess, and redirect, as appropriate, actions that will enhance the efforts to institutionalize scientific and statistical rigor in T&E within the DoD. Key stakeholders and enablers with roles and responsibilities include the DASD(DT&E), DOT&E, Component T&E Executives, and STAT in T&E Implementation Panel.

1.0 BACKGROUND

In February 2009, the DOT&E hosted a meeting of operational test agency (OTA) technical and executive agents from the Army Test and Evaluation Command (ATEC); the Commander Operational Test and Evaluation Force (COMOPTEVFOR); the Air Force Operational Test and Evaluation Center (AFOTEC); and the Joint Interoperability Test Command. The meeting enabled DOT&E and experts in DOE from the National Institute of Standards and Technology to discuss the applicability of DOE principles to support OT&E efforts. DOE is a structured process for analysis and decision making that provides scientific and statistical methods needed to rigorously plan and execute tests across the entire acquisition development cycle and evaluate their results. The group endorsed the use of DOE as a discipline to improve the planning, execution, analysis, and reporting of integrated testing. As a result, DOT&E and the Component OTA commanders signed a memorandum of agreement in February 2009 to use DOE for OT&E. The October 19, 2010, DOT&E Memorandum, "Guidance on the use of Design of Experiments (DOE) in Operational Test and Evaluation," directed the inclusion of DOE for the planning of OT in DoD.

In January 2011, the DASD(DT&E) chartered a scientific test and evaluation design (STED) committee to determine the best practices for implementing STAT within DT&E. The committee is chaired by the DASD(DT&E)'s Deputy Director for Capabilities Development and includes representatives from the stakeholder community and scientific test design methodology SMEs. Committee membership includes the following:

- Deputy Director for Capabilities Development, DASD(DT&E) (Chair).
- Representatives from DASD(DT&E).
- Representatives from DOT&E.
- Representative from each of the Component T&E Executives.
- SMEs from systems engineering and field activities.
- Federally Funded Research and Development Center advisors.

In early 2011, the USD(AT&L) and the DASD(DT&E) were tasked by the Secretary of Defense to find efficiencies in defense acquisition. Based on DOT&E DOE efforts in OT, inputs from the Services, and successes in industry, the DASD(DT&E) believes that the use of STAT in T&E will generate T&E efficiencies; provide rigorous, defensible T&E strategies and results; and improve the level of knowledge for the DT planning, execution, and analysis process. When used in the proper context, STAT in T&E will enable the PMs to make better informed decisions based on acceptable risk thresholds. DOE is one of the methodologies resident in STAT.

In June 2011, the DASD(DT&E) directed the STED Chair to develop a STAT in T&E implementation plan. This modified the original requirement for a deliverable, as stated in the STED Charter, from a report to an implementation plan.

The DASD(DT&E) and the DOT&E are working with the Components to apply STAT as an integral part of a program's integrated T&E process. The goal is to make the best use of

contractor and Government DT beginning early in a program's life cycle to ensure successful OT and support system evaluation.

2.0 PURPOSE

This implementation plan provides guidance for developing and implementing a DoD-wide scientific-based T&E planning, execution, and analysis capability that will generate defensible T&E strategies and results and improve the level of knowledge for the DT planning, execution and analysis process.

2.1 ASSUMPTIONS

This plan is implemented with the following assumptions:

1. Funding for a STAT T&E COE is sustainable.

2. Achieving the desired impact will take approximately seven years.

3. OSD and the Component T&E Executives will champion the effort.

3.0 APPROACH

STAT in T&E implementation will be a multipronged, phased effort (see Figure 1). It will feed into the DOT&E 2-year test science road map. Institutionalizing the STAT capability in T&E will require a cultural change. This change will be facilitated by developing guidance and policy, establishing appropriate education and training, establishing a STAT in T&E Implementation Panel, identifying appropriate software for the workforce, conducting analyses and case studies, and proliferating lessons learned through multiple means, including the Defense Acquisition University (DAU) Website.

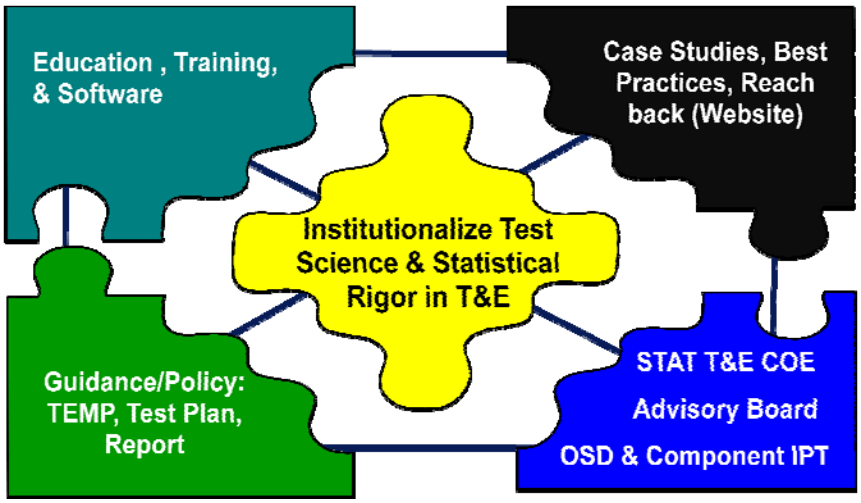
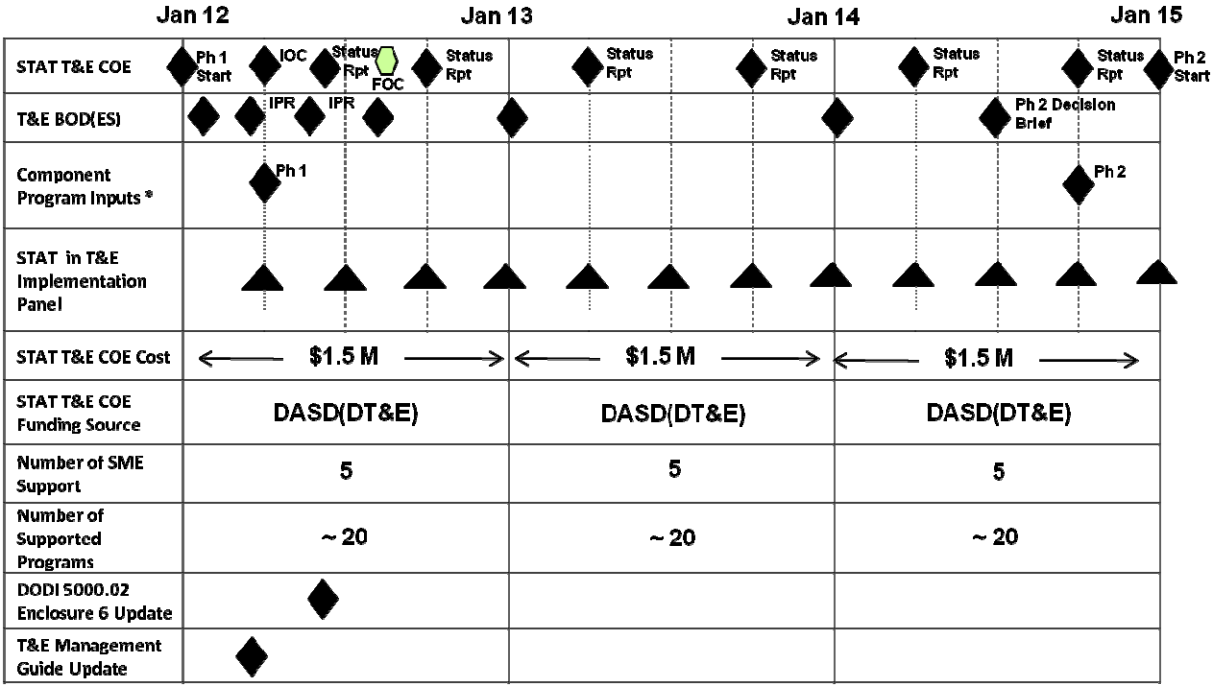


Figure 1. The multipronged, phased effort

STAT in T&E implementation will be accomplished in three phases.

Phase 1 (Initiation Phase): FY 2012–2014 (3 years). The goal of the first phase is to facilitate the transition to scientifically based test and analysis. The Initiation Phase focuses on developing policy and guidance, identifying training opportunities and software for the current workforce, and developing case studies by targeting pilot programs. Development of a STAT T&E COE is critical to the success of this phase. The STAT T&E COE will work on prioritized pilot programs submitted by the Components to demonstrate the benefits of a scientifically based approach to test and analysis. The schedule is shown at Figure 2.



Schedule details are provided at Appendix A.
* The Component T&E Executives can adjust, as appropriate, the prioritized list of pilot programs, when warranted.

Figure 2. STAT in T&E Implementation Plan Phase 1 Schedule

Phase 2 (Expanded Phase): FY 2015–2016 (2 years). The goal of the second phase is to expand the depth and breadth of programs using scientific approaches to testing. This phase expands upon the implementation completed during the first phase and leverages lessons learned and best practices. Case studies will be conducted, as appropriate, and additional specific tasks identified in the first phase will be completed.

Phase 3 (Institutionalize Phase): FY 2017–2018 (2 years). This phase will complete the STAT in T&E implementation, realizing the vision by the end of FY 2018. Specific tasks will be dictated by the results garnered in Phase 2.

Although all three phases are discussed in this implementation plan, the focus is on Phase 1 activities. As various tasks are executed, the results from those efforts will be incorporated into or identify new implementation opportunities for later phases. This plan is considered a living document, subject to change throughout its 7-year implementation plan horizon.

3.1 PHASE 1 (INITIATION PHASE): FY 2012–2014 (3 YEARS)

Phase 1 will include the following actions:

- Update guidance/policy (DoD Instruction (DoDI) 5000.02, T&E Enclosure; T&E Management Guide; and T&E in Contracting Guide) to reflect emphasis on STAT in T&E.
- Components begin to expand knowledge base of the T&E workforce.
- Establish a STAT T&E COE at a capability level permitted by available resources.
- Work with the acquisition community to submit a limited number of programs to serve as pilot programs by the Component T&E Executives. Establish and charter a STAT in T&E Implementation Panel that will meet regularly to review progress and identify additional tasks, as appropriate, for future phases. The STAT in T&E Implementation Panel will provide an annual report to the DASD(DT&E) and T&E Board of Directors (Executive Secretariat) (BOD(ES)).
- Provide case studies, best practices, and lessons learned, as available, to the acquisition community (particularly the PMs).
- Develop sample wording for incorporating STAT inT&E into requests for proposal, statements of work, and TEMPs.
- Update training courses (TST 203 - Intermediate Test and Evaluation; CLE 035 - Introduction to Probability and Statistics; ACQ201A - Intermediate Systems Acquisition, Part A).
- Identify software for use to support STAT in T&E.
- Develop DAU T&E Website capability.

The Entrance Criteria for Phase 1 are:

- Implementation Plan is approved.
- STAT T&E COE funding is approved.

The Exit Criteria for Phase 1 are:

- Phase 1 actions are completed.
- STAT T&E COE provided annual reports.
- Phase 2 initiation decision has been made.
- STAT T&E COE funding is identified beyond FY 2014.

3.1.1 GUIDANCE/POLICY

The following guidance/policy activities are planned during Phase 1.

3.1.1.1 DoDI 5000.02

DoDI 5000.02, "Operation of the Defense Acquisition System," is in the revision process to address "fact of life" changes. The revised DoDI 5000.02 will require elements of a STAT in T&E approach to be reviewed during the approval process for TEMPs and associated DT and OT test plans. Information about the STAT in T&E approach will need to be included in the TEMP (i.e., Part III and IV). The T&E Enclosure of DoDI 5000.02 provides specific guidance on the required content in the TEMP for a particular milestone. The approved version of DoDI 5000.02 is expected in 3rd quarter FY 2012.

3.1.1.2 T&E Management Guide

The DASD(DT&E) and DOT&E collaboratively worked with the Components to update the T&E Management Guide. The updated guide will encompass new and recent T&E processes, procedures, and best practices. The updated guide will become a valuable tool to T&E personnel within DoD. The approved version is expected in 2nd quarter FY 2012.

3.1.1.3 T&E in Contracting Guide

The DASD(DT&E) directed an update to the guide, "Incorporating Test and Evaluation into Department of Defense Acquisition Contracts." The update provides guidance with regard to DT&E involvement in OSD peer reviews and an emphasis on T&E verbiage to ensure that proposals adequately address the scientific T&E design methodologies. The guide, with updates from the Federal Acquisition Regulation Part 15.2, was released in November 2011.

3.1.2 STAT T&E COE

The STAT T&E COE is critical to the success of this implementation plan. The STAT T&E COE will provide PMs with a reachback T&E capability that will provide supported programs with test planning, execution, and analysis assistance and share STAT in T&E best practices in both DT&E and OT&E to provide robust and defensible results.

The STAT T&E COE will consist of statistical/T&E SMEs with broad knowledge of the DoD acquisition process and program management. Their qualifications will include experience with DoD T&E planning, execution, and assessment; statistical expertise; and access to the research communities. The STAT T&E COE, organized in terms of warfare areas (land, sea, air, space, and information systems), will provide the following capabilities:

- Provide PMs and T&E organizations with recommendations and best practices regarding test planning, execution, and analysis, focused on optimizing return from test resources.
- Provide engagement and mentorship to T&E practitioners.
- Support development of case studies.
- Provide liaison service with the Components to assist and share lessons learned.

- Collect and promote best practices for the use of statistical design and analysis within T&E.
- Advise OSD and the Components on statistical methods in T&E.
- Develop and maintain a central repository (website) for case studies, best practices, and published work.
- Support responses to questions from DAU's "Ask A Professor" on scientific and statistical rigor in TEMP development.
- Provide a feedback loop to the STAT in T&E Implementation Panel.
- Assist in the development of DAU training materials, as required.
- Assist in the development of guidance on use of statistical methods in T&E, as requested.

The STAT T&E COE will support a select number of acquisition programs from across the Components. Available funding will dictate the specific number of programs. It is envisioned that the STAT T&E COE should support approximately 20 programs, with one SME supporting five programs, per year. The STAT T&E COE will provide semiannual reports to the STAT in T&E Implementation Panel.

As part of Phase 1, a DASD(DT&E) memorandum will be distributed to the Component T&E Executives/Component Acquisition Executives in the February 2012 timeframe requesting submission of their prioritized list of programs by April 2012. The memorandum will include the selection criteria and format for submission.

The process for submission of acquisition programs for STAT T&E COE assistance will be as follows:

- The DASD(DT&E) releases a memorandum requesting Component and Defense Agency submissions of acquisition programs for STAT T&E COE assistance. The memorandum will include the selection criteria and format for submission.
- T&E Executives submit their prioritized list of programs for STAT T&E COE support to the DASD(DT&E).
- The STAT in T&E Implementation Panel reviews Component and Defense Agency program submissions and provides recommended modifications to the BOD (ES).
- The STAT in T&E Implementation Panel provides a list of selected programs to the STAT T&E COE with direction and guidance.
- The STAT T&E COE initiates dialogue with selected programs.

The STAT T&E COE SMEs will have the credentials to establish credibility with T&E practitioners. The STAT T&E COE concept of operations (CONOPS) will lay out the process to provide confidential and independent support. STAT T&E COE SMEs will <u>not</u> function as DASD(DT&E)/DOT&E action officers (AOs), and SME actions will be independent of DASD(DT&E) or DOT&E involvement in support of the T&E WIPTs.

The STAT T&E COE will attain limited capability in April 2012 with full operational capability in 4th quarter FY 2012. It is envisioned that the STAT T&E COE will provide a long-term T&E capability for the acquisition community. The DASD(DT&E) plans to fund the STAT T&E COE for Phase 1 (FY 2012–FY 2014). Funding for FY 2015 and beyond will be determined before the end of Phase 1 by the DASD(DT&E) and the Component T&E Executives.

A plan of action and milestones (POA&M) is provided at Appendix A.

3.1.3 EDUCATION, TRAINING, AND SOFTWARE

The DASD(DT&E) has worked with the Components to determine what STAT training capabilities already exist. Based on the initial list, the DASD(DT&E) and the Components will determine how best to train the T&E workforce, as well as others impacted by acquisition decision making, including PMs, systems engineers, requirements officers, and contracting and logistics personnel. The DASD(DT&E) is coordinating with the functional integrated product team (FIPT) leads for each of the aforementioned communities to incorporate STAT discussions in their DAU curricula. Appendix B lists the existing STAT-related training available in DoD.

The DASD(DT&E) is also coordinating with the Components to understand and share the capabilities of several statistical software packages that are available for use by the T&E workforce. Their advantages and disadvantages and approval for use by various Components are provided at Appendix C. The decision about which software to use and at what level of the T&E organizations is the responsibility of the Components.

3.1.4 DAU T&E WEBSITE

DAU hosts a T&E webpage on the DAU Website. Policies, regulations, directives, certification guidance, and best practices relating to T&E are available at that site. A glossary of STAT in T&E terms was recently added to the DAU T&E webpage. In the future, STAT in T&E case studies and lessons learned will be posted on the webpage.

An "Ask A Professor" icon, see Figure 3, provides an avenue for an individual to ask T&E-related questions (not just those related to STAT) and obtain responses from SMEs provided by the STAT T&E COE.

Figure 3. "Ask A Professor" on Defense Acquisition Portal

3.2 PHASE 2 (EXPANDED PHASE): FY 2015–2016 (2 YEARS)

Phase 2 will expand upon the implementation completed during Phase 1 and leverage lessons learned and best practices. Additional case studies will be conducted, as appropriate, and additional specific tasks identified in the first phase will be completed. This phase will include the following actions:

- Update guidance/policy, training courses, and online help, as required.
- Assess Phase 1 "pilot programs."
- Components continue to expand knowledge base of the T&E workforce.
- Leverage lessons learned and case studies from Phase 1.
- Continue to collect case studies, best practices, and lessons learned and socialize them with the acquisition community (particularly the PMs).
- Expand Phase 1 pilot programs to include more programs.
- Maintain operations and capability of the STAT T&E COE, as permitted with available resources.
- Implement STAT T&E COE Phase 1 lessons learned.

The Entrance Criteria for Phase 2 are:

- Favorable Phase 2 initiation decision obtained in Phase 1.
- Phase 1 actions have been completed.
- Ready to proceed to Phase 2.
- Review of STAT T&E COE Phase 1 lessons learned has been completed.
- STAT T&E COE funding has been identified.

The Exit Criteria for Phase 2 are:

- Phase 2 actions have been completed.
- STAT T&E COE has provided annual report.
- STAT T&E COE funding has been identified.

3.3 PHASE 3 (INSTITUTIONALIZE PHASE): FY 2017–2018 (2 YEARS)

Phase 3 will complete the implementation, realizing the vision by FY 2018. Specific tasks will be dictated by the results garnered in Phase 2.

4.0 MANAGEMENT AND OVERSIGHT RESPONSIBILITIES

This effort is a continually evolving process that requires management of the overall direction while adjusting for new developments to achieve the objectives. Management will review, assess, and redirect, as appropriate, actions that will enhance the efforts to institutionalize statistical rigor in T&E within DoD.
Key stakeholder roles and responsibilities are outlined in the following sections.

4.1 DASD(DT&E) AND DOT&E

The DASD(DT&E) and DOT&E shall:

- Maintain overall responsibility for the process and promote collaboration across the entire Department.
- Provide guidance, emphasis, and persistent focus on use of STAT in T&E activities.
- Disseminate information on available STAT training across the Department and promote awareness and participation.
- Disseminate best practices and case studies to the T&E community through the STAT T&E COE, DAU, and other websites.
- Provide an overview of the STAT T&E COE to DASD(DT&E) and DOT&E AOs.

The DASD(DT&E) will designate the Chair for the STAT in T&E Implementation Panel.

The DOT&E will designate a representative for membership on the STAT in T&E Implementation Panel.

4.2 COMPONENT T&E EXECUTIVES

Component T&E Executives shall:

- Maintain overall responsibility for the process and promote collaboration within their Components.
- Designate representatives for membership on the STAT in T&E Implementation Panel.
- Work with their Components to:
  - Champion the STAT in T&E implementation effort.
  - Submit a prioritized list of pilot programs.
  - Adjust, as appropriate, the prioritized list of pilot programs, when warranted.
  - Use existing training venues to train the T&E workforce.
  - Gauge the implementation process and provide feedback.
- Share lessons learned, best practices, and case studies with the T&E community.
- Provide an overview of the STAT T&E COE to AOs.

4.3 STAT IN T&E IMPLEMENTATION PANEL

Because the STED Working Group Charter ended in January 2012, the DASD(DT&E) will charter the STAT in T&E Implementation Panel. It is envisioned that this panel will be composed of the same membership as the recent STED Working Group and the DOT&E-chartered Test Science Committee. Industry will be invited, as needed. The STAT in T&E Implementation Panel will be charged with monitoring the STAT T&E implementation initiative to include establishment of the STAT T&E COE. The STAT in T&E Implementation Panel shall:

- Advise the DASD(DT&E), DOT&E, and the T&E BOD(ES) with recommendations on those areas outside their control.
- Meet on a regular basis to discuss progress and issues. Provide a collaborative venue for maintaining progress status and vetting issues.
- Provide an annual report to the DASD(DT&E) and T&E BOD(ES).
- Develop a communications plan to market the value of using STAT during T&E strategy development and the value of the STAT T&E COE.
- Provide guidance to the STAT T&E COE staff.
- Review and upload lessons learned, best practices, and case studies into the OSD repository (TBD).
- Maintain open communication with the Components on progress to plan, via the Board of Directors (Executive Secretariat Support) (BOD(ESS)) and T&E BOD(ES).

5.0 CHALLENGES

5.1 CULTURE CHANGE

Changing the way in which DoD plans and conducts T&E is difficult. Change must be reinforced with leadership, sound guidelines, accountability, and communication. The change has begun with OT, with the February 2009 memorandum of agreement by the OTAs to use DOE and the October 19, 2010, DOT&E memorandum.

Change can be smooth when there is a thorough understanding of the desired end state. STAT offers a framework from which PMs may make well-informed decisions on resource allocation and scope of testing required for an adequate test. The T&E workforce, as well as the other acquisition workforce communities, must be educated to understand that STAT further provides a valuable tool to identify and mitigate risk in test activities.

To increase the probability of success, we must clearly communicate the vision for change to the T&E workforce as well as those in other functional areas that interface with T&E. We need to create early successes by engaging the STAT T&E COE with pilot programs early on. Showing improvements over the status quo will have a positive impact on cultural change. The STAT

T&E COE is critical for creating success stories that leadership can promote to all T&E organizations.

The STAT in T&E Implementation Panel will develop a communication plan to socialize the value of this initiative and of the STAT T&E COE. Additionally, as the opportunity arises, the STAT in T&E initiative will be presented to T&E forums within Components and external audiences with the intent of disseminating the value and benefits of this effort.

5.2 SENIOR-LEVEL CHAMPIONS

Successful use of STAT in T&E will require a cadre of personnel within each test organization with professional knowledge and expertise in applying these methodologies to military test activities; however, the new ways of doing T&E will not maintain or gain traction without senior-level champions.

The senior-level champions (i.e., the DASD(DT&E), DOT&E, and Component T&E Executives) will ensure that the endeavor is heard and supported at the highest levels of leadership. These champions will clearly define the objectives, build senior leader rapport and support, set their expectations, build credibility, seek buy-in, ensure that funding is provided for successful execution, and promote the effort via speaking engagements and site visits. The senior-level champion can significantly influence the implementation and success of each phase by communicating the reasons behind the effort and establishing a sense of urgency.

5.3 RESOURCE MANAGEMENT

In this resource-constrained fiscal environment, finding programming dollars to execute the plan will be a primary challenge. It is more difficult since the programming actions must be accomplished before seeing the added value of the STAT T&E COE as a T&E capability. The DASD(DT&E) plans to fund the STAT T&E COE for Phase 1 (FY 2012–2014). Funding for FY 2015 and beyond will be determined before the end of Phase 1 by the DASD(DT&E) and Component T&E Executives.

5.4 TRAINING

Professional development is an enabler to this effort. Training and knowledge sharing need to be embraced. Training is available through various means as listed in Appendix B. Each Component is responsible for managing, mentoring, and training its workforce, and each individual must take on the challenge to maintain proficiency and to obtain new skills to address the needs of the mission. There will be schedule and funding constraints to overcome. Early and continuous focus on getting the appropriate training will add value to subsequent testing and ultimately to the Warfighter.

The STAT in T&E Implementation Panel will coordinate with the T&E FIPT for review, upgrade, and addition of the T&E curriculum to better train/educate today's T&E workforce. The STAT T&E COE annual lessons learned will be one catalyst for upgrade/modification of the T&E curriculum.

5.5 STAT T&E COE

As mentioned earlier, the STAT T&E COE is critical to the success of this implementation plan. Without the STAT T&E COE, successful implementation would be difficult to attain because the Components lack an adequate number of practitioners possessing the technical and analytic skills required to successfully execute STAT in T&E. The STAT T&E COE will bridge that capability gap until the Components grow their organic capability.

It is critical for the STAT T&E COE to establish credibility and gain trust with the PMs/PEOs and the T&E practitioners. The STAT T&E COE must show added value as a T&E capability and justify continuing funding support.

It is planned that the STAT T&E COE SMEs will have the credentials to establish credibility with the PMs/PEOs and the T&E practitioners. The STAT T&E COE CONOPS will lay out the process to provide confidential and independent support. STAT T&E COE actions will be independent of DASD(DT&E) or DOT&E involvement in support of the T&E WIPTs.

5.6 WORKFORCE COMPETENCY

Based on the increasing complexity of systems, as well as a need to develop more efficient and rigorous T&E design methodologies, the DASD(DT&E) revised the core certification standards for the T&E acquisition workforce. The aim is to advance the overall intellectual proficiency in T&E.

There must be a concerted effort to develop a workforce that is versed in STAT. The Components are responsible for determining and resourcing the appropriate mix of expertise within various levels of the test organizations.

APPENDIX A

PLAN OF ACTION AND MILESTONES (POA&M)

Jan 4, 2012 Principal Deputy, DASD(DT&E) socializes STAT in T&E Implementation Plan with Component T&E Executives.

Jan 18, 2012 Final presentation (collectively) to DASD(DT&E).

Jan 24, 2012 DASD(DT&E) releases letter requesting designation of STAT T&E COE

Jan 24, 2012 Present STAT in T&E Implementation plan to the T&E BOD(ES) and obtain coordination signatures.

Feb 1, 2012 DASD(DT&E) signs & releases STAT in T&E Implementation Plan.
DASD(DT&E) charters STAT in T&E Implementation Panel.
DASD(DT&E) provides funding for STAT T&E COE

Feb 6, 2012 DASD(DT&E) releases letter to Component T&E Executives requesting their prioritized program list for STAT T&E COE assistance.

Feb 17, 2012 STAT in T&E Implementation Panel kick-off meeting. Draft Measures and Metrics.

Mar 8, 2012 Component T&E Executives provides their prioritized program list to DASD(DT&E).

Mar 9, 2012 STAT in T&E Implementation Panel reviews Component program list and prepares recommendations for T&E BOD (ES). Refine measures and metrics.

Mar 20, 2012 STAT in T&E Implementation Panel develops presentation for T&E BOD (ES) (Measures & Metrics and recommended program submission).

Mar 23, 2012 STAT in T&E Implementation Panel presents program recommendations and draft measures & metrics to T&E BOD (ES)

Apr X, 2012 STAT T&E COE attains limited capability (that is, Initial Operational Capability).
Program list submitted to STAT T&E COE.
Provide overview of STAT T&E COE to DASD(DT&E) and DOT&E action officers. (Provision for Component action officers as well.)
STAT in T&E Implementation Panel monthly meeting.

May X, 2012 STAT in T&E Implementation Panel monthly meeting.

May 24, 2012 STAT in T&E Implementation Panel presents updates on measures & metrics to

T&E BOD (ES).

June X, 2012 STAT in T&E Implementation Panel monthly meeting.

July X, 2012 STAT T&E COE attains full operational capability.
STAT T&E COE provides semi-annual status report to STAT in T&E Implementation Panel.
STAT in T&E Implementation Panel monthly meeting.

July 26, 2012 STAT T&E COE status presented to DASD(DT&E) and T&E BOD (ES).

Aug X, 2012 STAT in T&E Implementation Panel monthly meeting.

Sep X, 2012 STAT in T&E Implementation Panel monthly meeting.

Oct X, 2012 STAT in T&E Implementation Panel monthly meeting.

Nov X, 2012 STAT T&E COE provides annual status report.
STAT in T&E Implementation Panel reviews and assesses lessons learned for initiation during FY 2013.
Overview of STAT T&E COE and Implementation presented to DASD(DT&E) and T&E BOD(ES).
DASD(DT&E) provides FY 2013 funding to STAT T&E COE.
STAT in T&E Implementation Panel monthly meeting.

APPENDIX B

EXISTING AND PLANNED STAT IN T&E TRAINING VENUES

DAU Courses

ACQ201A - Intermediate Systems Acquisition, Part A

AQ201A is a computer-based training course. Its purpose is to prepare mid-level acquisition professionals to work in integrated product teams by providing an overview of systems acquisition principles and processes. There is no cost and the student has 60 calendar days to complete this course.

The DASD(DT&E) provided a short overview of STAT and its value added to systems acquisition into the ACQ201A course.

TST 203 – Intermediate Test and Evaluation

TST 203 is a 5-day resident course, administered by DAU. It is a Core Certification Standards functional training course required for T&E Level II Defense Acquisition Workforce Improvement Act certification. Course sign up is on line via the DAU website. There is no cost for the course. However, other costs associated with course attendance will be paid by the student's organization.

The DAU TST 203 residence course has been updated to include the addition of a DOE block of instruction and should be part of the classroom training by 1QFY 2012.

CLE 035 - Introduction to Probability and Statistics

The current CLE 035 Introduction to Probability and Statistics Continuous Learning Module is being revised. CLE 035 will provide an introduction into the subject of probability and statistics; with enough depth to provide an adequate base for the student to take courses in DOE. It will be a no-cost 6-hour on-line course.

DASD (DT&E) directed an initiative to update the DAU's CLE 035. The update provides an increased awareness and application of statistics within T&E. The updated course is expected to be available by 3QFY 2012.

DAU courses can be found at:
http://www.dau.mil/Training/default.aspx

U.S. Army Test and Evaluation Command (ATEC) Test and Evaluation Basic Course

The U.S. Army Test and Evaluation Command (ATEC) Test and Evaluation Basic Course consists of Computer Based Training (CBT) and a Resident Seminar (RS) CBT which takes approximately 40 hours to complete. RS is a 4.5 day class consisting of briefings, guest speakers (Deputy Under Secretary of the Army for Test & Evaluation; DOT&E; Commanding General, ATEC; Technical Director, ATEC; etc.) and nine Practical Exercises. The CBT consists of eight modules addressing all aspects of T&E. Module 7 of the CBT is entitled "Probability and Statistics" and addresses aspects of experimental design.

The POC for the training is:

Robert G. Malone
Human Resources Specialist (HRD)
US Army Test and Evaluation Command
G1, Human Resources Directorate
2202 Aberdeen Boulevard, 3W117
Aberdeen Proving Ground, MD 21005
COMM 443-861-9766
DSN 848-XXXX
robert.g.malone.civ@us.army.mil

U.S. Air Force (46th Test Wing and 53rd Wing) DOE residence courses

The U.S. Air Force (46th Test Wing and 53rd Wing) DOE residence courses are listed below:

Course (Hrs)	Course Title	Target Audience
TW 105 (1-2)	Executive Overview of the Science of Test (aka DOE)	Center, Flag and SES audiences
TW 110 (4)	Leaders' Introduction to the Science of Test (aka DOE)	Wing, Group, Sqdn CC, DO, and CA
TW 211 (16)	DOE for Software-Intensive Systems	SPO, Test and Software Engineers
DOE for Aircrew (4)	DOE for Aircrew	Aircrew and Unit Project Officers
TW 210 (16)	Introduction to DOE	Test/Project Engineers, Project Managers
TW 310 (40)	Statistical Foundations for DOE (DOE 0)	SPO Engineers, Oversight action officers, DOE Practitioners and Test Design Engineers
TW 311 (40)	DOE for the General Factorial (DOE I)	DOE Practitioners and Test Design Engineers
TW 410 (40)	DOE for Fractional Factorials and Response Surfaces (DOE II)	DOE Practitioners and Test Design Engineers
TW 411 (40)	Advanced Topics in Design of Experiments (DOE III)	Invitation only – advanced practitioners

POCs:

Gregory T. Hutto, DAF
Wing Operations Analyst, 46 Test Wing
46 TW/OA
Room 211 Building 1
101 West D Street
Eglin AFB, Florida 32542-5000
850-882-5349 (office)

James R. Simpson, DAF
Group OA, 53d Test Management Group
Eglin AFB FL, 32542
Office (850) 882-0619
Fax 850-882-5644
DSN 872-0619
james.simpson@eglin.af.mil

Course Registration Information

Air Armament Academy (A3) via AFKN CoP

DOE training opportunities are scheduled through the A3 – College of Test and Evaluation at the following link:
https://afkm.wpafb.af.mil/community/views/home.aspx?Filter=OO-ED-AA-A2
Click on "TE - College of Test & Evaluation" link in the middle of the page

Air Armament Academy via AF Portal

Log into A3 from the Air Force Portal by selecting URL https://www.my.af.mil

- Once logged in, select WORKSPACE found at the top left
- On the WEB FAVORITES tab, select the EDIT button
- On the EDIT WEB FAVORITES pop-up, select CREATE NEW FAVORITE found at the top right
- Link name can be whatever you choose (A3 Outside Mil Domain, Cool DOE Links, etc.)
- Under URL input the following link:
  https://wwwd.my.af.mil/afknprod/ASPs/CoP/OpenCoP.asp?Filter=OO-ED-AA-A2
- Select SUBMIT
- Close the pop-up and your workspace page should reload with your recently named link
- You should now be able to access the A3 website by logging in through the AF Portal

53d WG via AFKN CoP

53d WG personnel can register for courses at the 53d WG Cop by using this link:
https://afkm.wpafb.af.mil/ASPs/CoP/OpenCoP.asp?Filter=OO-TE-AC-56

53d WG via SharePoint

53d WG personnel can register using the 53 TMG TR Share Point site by using this link:
https://eglin.eis.af.mil/53tmg/tr/TTI/default.aspx

53d WG via AFKN CoP

53d WG personnel can register for courses at the 53d WG Cop by using this link:
https://afkm.wpafb.af.mil/ASPs/CoP/OpenCoP.asp?Filter=OO-TE-AC-56

53d WG via SharePoint

53d WG personnel can register using the 53 TMG TR Share Point site by using this link:
https://eglin.eis.af.mil/53tmg/tr/TTI/default.aspx

Non-46TW/53WG Personnel Training

DoD personnel (military or civilian outside the 46th TW or 53d WG) are eligible to attend DOE courses on a space-available basis. Advisory and Assistance Support (A&AS) contractors, with their clients' approval, may also attend the courses. Travel and text books are funded by the student's unit. We supply course slides, software to load for training purposes, and free instruction.

- Slides and course data files, reading, and support material may be downloaded from the USAF DOE Community of Practice (CoP) at:
  https://afkm.wpafb.af.mil/community/views/home.aspx?Filter=OO-TE-MC-79
- Students should register on the A3 website from any .mil domain.

Executive Overview of the Science of Test (aka DOE)

Target: Center, Flag, and SES audiences; general base acquisition, science, and engineering students wanting an introductory overview of DOE.

Pre-requisite: NONE.

Description: This introductory course demonstrates a powerful methodology for test and evaluation: design of experiments (DOE). The case for DOE begins with a presentation of the central challenge of test – how to draw enough samples to make the correct fielding decision, while simultaneously testing across a broad battle-space. DOE answers four fundamental questions: how many trials, under what conditions, executed in what order, and what are defensible conclusions? DOE history is discussed along with a series of case studies to illustrate how it works. The course features test examples showing DOE often reduces testing cost by 30-80% while increasing knowledge; conversely the course discusses several cases where tests had too few assets and should have been augmented. The concluding portion of the course addresses challenges of leading change that must be dealt with to successfully alter the way an organization typically conducts tests.

Duration: 1-2 Hours.

Objectives: Personnel who complete this training will:

- Understand the central challenge of test and the basic DOE process.
- Understand leadership's critical role in deploying the DOE concept throughout an organization.
- Understand the potential of implementing DOE to "right size" each test.
- Understand barriers which must be overcome to successfully conduct testing.

Leader's Introduction to the Science of Test (aka DOE)

Target: Wing, Group, Squadron Leaders.

Pre-requisite: NONE

Description: This introductory course demonstrates a powerful methodology for test and evaluation: design of experiments (DOE). The case for DOE begins with a presentation of the central challenge of test – how to draw enough samples to make the correct fielding decision, while simultaneously testing across a broad battle-space. DOE answers four fundamental questions: how many trials, under what conditions, executed in what order, and what are defensible conclusions? DOE history is discussed along with a series of case studies to illustrate how it works. The course features test examples showing DOE often reduces testing cost by 30-80% while increasing knowledge; conversely the course discusses several cases where tests had too few assets and should have been augmented. The concluding portion of the course addresses challenges of leading change that must be dealt with to successfully alter the way an organization typically conducts tests.

Duration: 4 Hours.

Objectives: Personnel who complete this training will:

- Understand the central challenge of test and the basic DOE process.
- Understand leadership's critical role in deploying the DOE concept throughout an organization.
- Understand the potential of implementing DOE to "right size" each test.
- Understand barriers which must be overcome to successfully conduct testing.

DOE for Aircrew

Target: Test Aircrew and Unit Project Officers.

Pre-Requisites: None.

Description: DOE for Aircrew describes the process and principles of test design from a test aircrew/execution perspective to promote effective test team interaction and understanding. Along with an introduction to statistical fundamentals, the course emphasizes the need to understand the problem under test, how to map the test item process, and brainstorming techniques to determine factors and response variables.

Duration: 4 hours.

Objectives: Personnel who complete this training will:

- Understand DOE from an aircrew/execution perspective.
- Be able to promote effective test team interaction and understanding of test design.

Introduction to DOE

Target: Test/project engineers, and test project managers leading a team conducting a designed experiment. While graduates will not be practitioners of DOE, they will be conversant with unique features of DOE tests and able to facilitate discussions among practitioners and experts. Scientists, and Engineers wanting to explore whether DOE holds promise in their area of expertise will also benefit from this course. Other students who may profit include technical supervisors of R&D, test and evaluation, product qualification, or digital simulation.

Pre-Requisite: Some familiarity with how experiments or tests are usually conducted is helpful, but not required.

Description: This course introduces a powerful methodology for test and evaluation. It shows how DOE uniquely solves the twin challenges of test – varying test conditions to explore a broad battle space, while controlling the risks of making incorrect fielding decisions. It addresses the DOE history, compares designed experiments to other popular test strategies, and describes a four stage process to apply DOE to any test problem by using several in-class experiments. Developing the simple analysis follows a method originated by Air Academy Associates of Colorado Springs. Students should be seeking a broad understanding of how designed experiments work and their basic justification for success. Recently added are ideas from Resampling to further illustrate the difficult-to-grasp concepts of statistics including testing errors and sample size.

Duration: 16 Hours.

Objectives: Students will understand:

- The definition of a designed experiment, its purposes, and effects.
- DOE's 80 year history in science and industry.
- Why designed experiments are more powerful and efficient than other strategies for experimentation.
- How DOE can both accelerate and reduce the cost of testing.
- A systematic, process-based design and analysis methodology which can be applied to literally any discipline where tests are conducted.
- How to create simple factorial test matrices (designs) and appreciate more complex designs.
- Simple statistics-free analyses of two-level designs and understand the features of a more complete analysis.

DOE 0 – Foundations for Statistical Design of Experiments

Target: Test/project engineers and test project managers leading a team conducting a designed experiment; additionally, students may include technical supervisors of R&D, test and evaluation, product qualification, or digital simulation.

Prerequisite: An academic degree with a minimum of four courses in mathematics or supervisor recommendation. A previous course in statistics is helpful but not required.

Description: Satisfying the need for statistics to deal with variation in test data and the concepts of the scientific method (hypothesis testing), this course introduces multifactor designs for varying multiple test conditions simultaneously while retaining the ability to link cause-to-effect. It explores design options with factors at two or more levels, including strategies for running a fraction of these combinations, designs for nonlinear response spaces (response surface methods), and a number of design augmentation schemes to resolve ambiguities in test outcomes. Students become familiar with the powerful statistics program Design Expert 8 (**www.statease.com** for free 45-day download) used in the Practitioner DOE series. The course material is conveyed through the use of lecture, group discussion, student exercises, group laboratories, and electronic reading materials.

Duration: 40 Hours.

Objectives: Personnel who complete this training will:

- Understand need for statistics in test and evaluation.
- Understand hypothesis testing, error types, and how to design defined-risk tests.
- Understand the mechanics and benefits of two-level factorial designs.
- Understand the efficiencies of and approach to testing using fractional factorial designs.
- Be able to analyze factorial and response to surface designs.
- Be able to develop response surface designs understand reasons for selecting these designs.
- Be able to plan, design, execute, and analyze a test using statistically based designed experiments.
- Be familiar with special-use design options such as split plot and optimal designs.

DOE I – Design of Experiments for the General Factorial

Target: Test project engineers, test engineers, scientists, and mathematicians.

Prerequisite: DOE 0 or consent of instructor (advanced undergraduate, 1st year graduate).

Description: This is the second of three courses in DOE, building up to the general factorial with any number of variables at any number of levels. Students learn basic techniques and processes needed to create a statistically rigorous test in the physical sciences. A well-designed experiment can lead to reduced development lead time for new processes and systems, more rigorous test and evaluation, and systems that have superior function and reliability. Using examples from military T&E and the student's own problem field, the course has a strong applied flavor and is intended to graduate practicing experimentalists. Both design and statistical analysis issues are discussed. Opportunities to use the principles taught in the course arise in all phases of engineering work, including new product design and development, process development, and test and evaluation. Applications from various fields of engineering (including chemical, mechanical, electrical, materials science, industrial, etc.) will be illustrated throughout the course. Computer software packages (Design Expert 8 www.statease.com for free 45 day download) to implement the methods presented will be illustrated extensively, and you will have opportunities to use it for seat assignments and group lab projects.

Duration: 40 Hours.

Objectives: Personnel who complete this training will:

- Use Design Expert 8 to design, graph, analyze, and report on data sets.
- Use good experimental technique in designing and executing experiments.
- Have a solid grasp of the assumptions and methods of ANOVA.
- Design and analyze factorial and blocked factorial designs.
- Be aware of other schools of DOE including Taguchi, response surfaces, and optimal designs.
- Be able to develop response surface designs and understand reasons for selecting these designs.
- Be able to plan, design, execute, and analyze a test using statistically based designed experiments.
- Be familiar with special-use design options such as split-plot and optimal designs.

Important Info:

The required text for DOE I and II is Montgomery's *Design and Analysis of Experiments*, 7th edition. Textbooks are NOT provided for students outside the 53d Wing. All other personnel please obtain your own copy or one will be provided during the class only. A recommended site for purchasing the book is: http://www.bestwebbuys.com/books/search?isrc=b-compare-srchbox&t=ISBN&q=0201775700 . There is some pre-course reading. An email will be sent to all class participants before the course containing a syllabus.

DOE II – Design of Experiments for Fractional Factorials and Response Surfaces

Target: Test project engineers, test engineers, scientists, and analysts.

Prerequisite: DOE I or consent of instructor (advanced undergraduate, 1st year graduate).

Description: This course picks up where DOE I leaves off and introduces variations on two level designs (the 2k model) including blocking and confounding in the 2k model. The course then introduces two days of work on fractional factorials, design resolution, and aliasing patterns. The student is then taught 10 ways to break alias chains among the confounded effects including the fold over in several variations. The course continues by introducing response surface methods to model nonlinear behavior in the test envelope including several variations of the central composite design. Both the fractional factorial and response surface topics culminate in group lab exercises to illustrate the concepts involved. The course concludes with a survey of advanced DOE topics including nested and split plot designs, shortcomings of the three-level family of designs, fixed versus random effects analysis of variance (ANOVA), the analysis of covariance (ANCOVA), and the multivariate analysis of variance (MANOVA). Finally, the course points toward an advanced DOE III course covering the general linear model, more details on response surfaces, nested and split-plot designs, and the topic of optimal design to include orthogonal arrays.

Duration: 40 Hours.

Objectives: Personnel who complete this training will:

- Understand how to block and confound in the 2k model.
- Be able to fractionate two-level designs, identify design resolution, and resolve aliases.
- Use Design Expert to design, examine, and analyze factorials and fractional factorials.
- Be able to state, test for violations, and remedy violations of the four assumptions underlying classical statistics.
- Be able to create, examine, and analyze simple response surface designs.
- Be able to develop response surface designs and understand reasons for selecting them.
- Appreciate a list of variations on classical DOE and know when to seek help.

Important Info:

The required text for DOE I and II is Montgomery's *Design and Analysis of Experiments*, 7th edition. Textbooks are NOT provided for students outside the 53d Wing. All other personnel please obtain your own copy, or one will be provided during the class only. There is some pre-course reading. An email will be sent to all class participants prior to the course containing a syllabus. A recommended site for purchasing the book is: http://www.bestwebbuys.com/books/search?isrc=b-compare-srchbox&t=ISBN&q=0201775700 .

DOE III – Advanced Topics in Design of Experiments

Target: Energized practitioners with reasonable experience who successfully completed DOE 0, I, and II.

Prerequisite: DOE II or consent of instructor (advanced undergraduate, 1st year graduate).

Description: This course covers methods seasoned DOE practitioners require to handle testing aberrations. The content is geared towards equipping students with tools for attacking the more challenging problems, where either the variable composition or underlying response surface is complex, or violations of our standard assumptions and principles occur. The intent is to dig deeper into the characteristics and qualities of the experimental designs and explore the possibilities engaging computer generated algorithms to assist the analyst in building or augmenting designs for a specific purpose. A second objective is to discover alternative methods of empirical model building and analysis, when the data is messy. The final objective of this course is to provide a testing strategy for test conduct environments with hard-to-change factors. The format of the course will blend lecture, case studies along with extensive use of analytical software. Both Design Expert and JMP software will be used. Format will be lecture with example problems, small team assigned problems, reading for seat and laboratory formulations.

Duration: 40 Hours

Important Information:
Loaner textbooks are provided for students during class. The primary text is Myers, Montgomery, and Anderson-Cook's *Response Surface Methods*, 3rd edition for this course. Wu and Hamada's *Experiments: Planning, Analysis, and Parameter Design Optimization* is an alternate reference. An email will be sent to all class participants prior to the course containing a syllabus. A recommended site for purchasing the book is:
http://www.bestwebbuys.com/books/search?isrc=b-compare-srchbox&t=ISBN&q=0201775700

Air Force Institute of Technology (AFIT) courses

Science of Test (SOT) Course Descriptions:

Hours	Course Name	Target Audience
2 to 4	Executive Overview of the Science of Test (DOE)	General Officer, SES, Wing, Group, Squadron leadership
16	Introduction to Science of Test Experimental Design and Analysis	Test/Project Engineers, Project Managers
36	Science of Test Experimental Design and Analysis I	DOE Practitioners and Test Design Engineers
36	Science of Test Experimental Design and Analysis II	DOE Practitioners and Test Design Engineers

POC:

Dr Darryl Ahner
Center for Operational Analysis
937 823 9278
http://www.afit.edu/en/COA/

Executive Overview of the Science of Test (DOE)

Target Audience: **General Officer** and **SES audiences; Wing, Group and Squadron leadership.**

Description: This introductory 2 hour course for senior executives introduces them to this powerful methodology for test and evaluation: design of experiments (DOE). Recent guidance from OSD has required DOE to be addressed in all Test and Evaluation Master Plans. The case for DOE begins with a presentation of the central challenge of test – how to draw enough samples to make the correct fielding decision, while simultaneously testing across a broad battle-space. DOE supplies scientific and objective answers to four fundamental questions faced by each test: how many trials, under what conditions, executed in what order, and what are defensible conclusions? Over the past decade, numerous test organizations have begun using this method including ACC's 53d Wing, AFFTC, TPS, AFOTEC, AEDC and now the 46 TW and AAC. The history of DOE is discussed along with a series of case studies to illustrate how DOE works. The course features test examples showing that DOE has often reduced the cost of testing by 30-80% while increasing knowledge gained; conversely the course discusses several cases where tests had too few assets and should have been augmented. The concluding portion of the course addresses the challenges of leading change that must be dealt with to successfully alter the way an organization typically conducts tests.

Objectives: Personnel who complete this training will:

- Understand the central challenge of test and the basic DOE process.
- Understand the critical role of leadership in to deploying DOE concept throughout an organization.
- Understand the potential of implementing DOE to "right size" each test.
- Understand barriers that must be overcome to successfully conduct testing.

Who should attend: This training is open to all personnel but primarily designed for **senior leadership** across the acquisition and test community.

SOT 210: Introduction to Science of Test Experimental Design and Analysis

Target: **Acquisition Leaders, Project Engineers** and **Project Managers.**

Description: This two-day course will introduce Design of Experiments --a powerful methodology for test and evaluation that OSD requires be present in every test program. We show how DOE is critical in the planning, design, execution, and analysis of test. DOE uniquely solves the twin challenges of test – how to vary test conditions to explore a broad battlespace, while controlling the risks of making incorrect fielding decisions. We describe general methods for determining the correct number of test runs to ensure sufficient power and allow results to be reported with confidence. We address the history of DOE, compare designed experiments to other popular strategies of test, and describe a four-stage process to apply DOE to any test problem. We discuss how to construct and analyze the most useful designs, factorial and fractional factorials. We will conduct several in-class experiments to demonstrate each of the four steps. Of particular interest are the numerous examples of DOE applied to Air Force systems. Students should be seeking a broad understanding of how designed experiments work and the basic justification for the success of a designed experiment.

2.1

2.2 **Objectives**: Students will understand:

- A definition of a designed experiment, its purposes, effects, and history.
- Understand the applicability of DOE to planning, design, execution, and analysis of Air Force tests.
- Why designed experiments are more powerful and efficient than other strategies for experimentation.
- How DOE can both reduce the cost and accelerate the schedule of test programs.
- A systematic, process-based design and analysis methodology that can be applied to literally any discipline where tests are conducted.
- How process flow and fishbone diagrams decompose a process into its causal factors and responses.
- How to use course software to create test matrices (designs) with the right number of runs, factors, and settings.
- How to execute a test with randomization and blocking.
- How to gain insight to system performance through statistical analysis methods to include regression and Analysis of Variance.

Who Should Attend: Test/project engineers, and test project managers leading a team conducting a designed experiment. While graduates will not be practitioners of DOE, they will be conversant with unique features of DOE tests and able to facilitate discussions among practitioners and experts. Scientists, and Engineers wanting to explore whether DOE holds promise in their area of expertise will also benefit from this course. Other students who may

profit include technical supervisors of R&D, test and evaluation, product qualification, or digital simulation.

Prerequisites: Familiarity with basic statistics and how experiments or tests are usually conducted is helpful, but not required.

SOT 310 : Science of Test Experimental Design and Analysis I

Target: **Squadron DOE Gurus** and **Practitioners** and **SPO Engineers**.

Description: The four and a half day foundations course in designed experiments teaches students basic techniques and processes needed to create a statistically rigorous and defensible test for military weapon systems. Based on Douglas Montgomery's text *Design and Analysis of Experiments* (7th Edition), the course is taught at the advanced undergraduate or first year graduate level for non-statisticians. All experiments conducted by engineers and scientists are *designed* experiments; some of them are poorly designed, and others are well-designed. Well-designed experiments allow you to obtain reliable results faster, easier, and with fewer resources than with poorly-designed experiments. You will learn how to plan, conduct and analyze experiments efficiently in this course. A well-designed experiment can lead to reduced development lead time with fewer tests required, provide greater insight to system performance, and ultimately lead to fielding better, more reliable systems.
Using examples from military T&E and the students' own test experiences, the course has a strong applied flavor and is intended to graduate practicing experimentalists. This course emphasizes classical design principles teaching required background statistical knowledge just-in-time. Students will understand a disciplined approach to clearly define the true test objectives, measures of effectiveness/performance, appropriate input factors that impact the MOE/MOPs, and the recommended settings for these factors to effectively span the battlespace. Students will design powerful tests through appropriate sample size computations, construct efficient test run matrices, develop statistical models, test models for assumptions, and quantify the uncertainty of test results. Two-level full and fractional factorial designs are the primary test matrices used throughout this course. In class projects and exercises will reinforce learning objectives. Computer software packages (Design Expert 8…www.statease.com for free 45 day download) to implement the methods presented will be illustrated extensively, and you will have opportunities to use it for class assignments and group lab projects.

Objectives: Personnel who complete this training will:

- Know how to apply a disciplined process to identify test objectives, responses, factors, settings, assumptions and constraints for any test.
- Be able to construct test designs to appropriately span the battlespace with sufficient power and sample size to protect against erroneous conclusions.
- Understand statistical foundations and have a solid grasp of the assumptions and methods of analysis of variance and regression.
- Interpret software output to identify important factors and develop models to predict performance throughout the test region.
- Use Design Expert 8 to design, graph, analyze and report example test scenarios.
- Be aware of other useful designs including response surfaces and optimal designs.

Who should attend: This training is designed **for test project engineers**, **test engineers**, **scientists**, and **mathematicians**.

Important Information: Textbooks are NOT provided for students and are highly recommended although a course textbook is currently being developed. The primary source is

Douglas Montgomery's *Design and Analysis of Experiments*, 7th edition for this course. **Laptop computers are required** and trial versions of Design Expert software along with data sets will be available to all participants. Coordination with local IT protocol is necessary.

SOT 410: Science of Test Experimental Design and Analysis II

Target: **Squadron DOE Gurus** and **Practitioners.**

Description: This four and a half day course reinforces the fundamentals from DOE I, looks more closely into what makes good designs across a variety of metrics, introduces new classes of designs, and provides advanced modeling and analysis methods. Design evaluation topics include power, sample size, optimality, and aliasing criteria. Students will learn additional design approaches for realistic Air Force test issues such as constrained test regions, multiple factor levels, categorical factors, nuisance factors, and random effects. Sequential design is highlighted with augmentation methods. The course continues by introducing response surface methods to model nonlinear behavior particularly when the test objective is to optimize performance; several variations of the central composite design are presented. The course concludes with a survey of advanced DOE topics tailored to the organization's requirements including nested and split plot designs, fixed versus random effects ANOVA, the Analysis of Covariance (ANCOVA), designs for software intensive systems and simulations, and multiple response optimization.

Objectives: Personnel who complete this training will:

- Understand the relevance of and how to compute power and sample size for all types of designs.
- Know and understand what makes a good design.
- Understand how to block and confound in the 2k model.
- Be able to fractionate 2 level designs, identify design resolution and resolve aliases.
- Use Design Expert to design, examine, and analyze factorials and fractional factorials.
- Be able to state, test for violations, and remedy violations of the four assumptions underlying classical statistics.
- Be able to create, examine, and analyze simple response surface designs.
- Appreciate a list of variations on classical DOE and now when to seek help.

Who should attend: This training is designed for **test engineers, project engineers, scientists**, and **operations analysts.**

Prerequisite: SOT 310—Foundations of Design of Experiments.

Important Information: Textbooks are NOT provided for students and are *highly recommended* although a course textbook is currently being developed. The primary source is **Douglas Montgomery's *Design and Analysis of Experiments*, 7th edition** for this course. **Laptop computers are required** and trial versions of Design Expert software along with data sets will be available to all participants. Coordination with local IT protocol is necessary.

Air Force Flight Test Center (AFFTC) courses

In the area of Statistics, the Air Force Flight Test Center (AFFTC) offers a 3-course introduction (each course is 8 weeks; meet twice a week for 1.5 hrs each meeting). The purpose of these classes is to make engineers and flight test practitioners better "consumers" of statistics (not to make them statisticians). The statisticians are available for consulting on any/every problem. The R software and Excel spreadsheets are used in the course.

The first course covers statistics/probability, drawing statistical inferences, t-tests, comparison of means of two or more groups, simple linear regression and assumptions that are associated with the analyses.

The second course covers multiple regression, how to use it, how to select models, inferences using multiple regression, variable selection, model checking and refinement, analysis of variance and how to deal with test conditions with data that is serially correlated.

The third course covers repeated measures, multivariate responses, logistic regression/odd ratios, experimental design, factorial treatment and blocking.

AFFTC is developing "stand alone" versions of these three courses for the Test Pilot School.

AFFTC courses POC:

Bill Kitto, 812 TSS/CL, William.kitto@edwards.af.mil, DSN 527-4684, comm. (661) 277-4684.

Naval Postgraduate School (NPS) DoE courses

Course Title: Design of Experiments for Joint Interoperability Information Technology System Testing

Course Description: This course was customized for JITC by the NPS Operations Research Department and is currently evolving to include more emphasis on Information Technology (IT) systems and joint interoperability test and evaluation. This is a five-day course that introduces design of experiments (DOE) from a statistical perspective and emphasizes applications of interest IT systems and joint interoperability testing. The first part of the course is devoted to building an understanding of statistical inference on which DOE builds its methodological foundation. Topics covered include estimation, confidence intervals, and hypothesis testing. DOE is then presented as a technique for collecting experimental data so that statistical inference can be conducted in a resource-efficient manner. Classical experimental designs including full factorial, partial factorial, optimal designs, covering arrays, and space-filling designs are introduced. In interoperability testing of IT systems, for example, such experiments often entail configuring the levels of multiple factors for which testing every possible combination of levels is not feasible. The course explores strategies for conducting such tests efficiently while at the same time maintaining good statistical power. The statistical software package JMP is used to illustrate the application of statistical and DOE concepts to real data.

Course Title and NPS Course Number: Design of Experiments, Operations Analysis (OA) 4101

Course Description: This is an introductory course on the design and analysis of experiments that is taught on-site at NPS every other quarter.
The course will teach the student how to plan and conduct an experiment, analyze the data, and make valid and objective conclusions.
The course will begin with basic statistical concepts, followed by a review of the ANOVA (analysis of variance). The student will then learn the foundations of experimental design, factorial analysis, and fractional factorial analysis. The latter part of the course will include mixture experiments, computer experiments, response surface methods, and optimal design.

POC: Professor Robert Koyak, Operations Research Dept, Naval Postgraduate School, 1411 Cunningham Road, Monterey, CA 93943-5219, (831) 656-2688.

APPENDIX C

SOFTWARE OPTIONS

Software Packages – Overview
There are many software packages available for performing statistical analyses. The ones highlighted here are selected because they provide comprehensive statistical design and analysis tools and a user friendly interface.

SAS
SAS is arguably one of the most comprehensive packages in terms of statistical analyses. However, the individual license cost is expensive. Primarily, SAS is a macro based scripting language, making it challenging for new users. However, it provides a comprehensive analysis ranging from the simple t-test to Generalized Linear mixed models. SAS also provides limited Design of Experiments capability. SAS supports factorial designs and optimal designs. However, it does not handle design constraints well. SAS also has a GUI available: SAS Enterprise, however, it has limited capability. SAS is a good program to purchase if your organization conducts advanced statistical analyses or works with very large datasets.

R
R, similar to SAS, provides a comprehensive analysis toolbox. R is an open source software package that has been approved for use on some DoD computer (contact AFFTC for details). Because R is open source its price is very attractive (free). However, the help guides are not user friendly. R is primarily a scripting software with notation similar to MatLab. R's GUI: R Commander provides limited DOE capabilities. R is a good language to download if you can get it approved for use and you have analysts with a strong programming background.

MatLab w/ Statistical Toolbox
MatLab has a statistical toolbox that provides a wide variety of statistical analyses. The analyses range from simple hypotheses test to complex models and the ability to use likelihood maximization. The capability is limited compared to SAS and R but sufficient for the majority of analyses that the DoD T&E community will use. MatLab does not have a DOE capability, thus making it primarily an analysis package and not one to be used for test design. If your organization already has MatLab adding the statistical toolbox is a relatively affordable method for getting a basic statistics package. However, since it has no DOE capability it may not fully meet your organizations statistical needs.

Design Expert
Design Expert a Design of Experiments package. It has the largest library of built-in designs and the capability of constructing optimal designs. It also provides a user friendly interface and lots of graphical tools. It is one of the best packages available for experimental design. However, the analysis tools available in Design Expert are limited to analyzing data from designed experiments. Also, it performs poorly in handling complex data forms (non-normal data, random effects). Design Expert is a good package for your organization to buy if they are new to DOE and need a user friendly package that provides guidance on best practices.

JMP
JMP is a SAS product that provides a user friendly GUI. It provides both comprehensive DOE tools through its custom design platform and a wide variety of analysis techniques. JMP provides the most comprehensive DOE tools available for handling restricted randomization. It also has good reliability analysis tools and limited reliability growth capabilities. JMP is a good package for your organization to buy if you want one package that is both good at DOE and statistical analysis. JMP is less user friendly than design expert in terms of designing experiments but the tutorials they provide can decrease the learning curve.

Minitab
Minitab provides a user friendly GUI. It is commonly used in introductory statistics courses because it is user friendly. Minitab provides both strong DOE tools and a wide variety of analysis techniques. It also has good reliability analysis tools. Minitab is a good package for your organization to buy if you want one package that is both good at DOE and statistical analysis.

Statistica
Statistica provides a user friendly GUI. It provides both limited DOE tools if the expanded quality control package is purchased. It provides a wide variety of basic analysis techniques, but is limited in the complex analyses based on the level of the package purchased.

Best Packages for Designing Experiments:
1. Design Expert
2. JMP
3. Minitab
4. Statistica
5. R – commander
6. SAS

*Note: MatLab does not have any Design of Experiments Capability
Best Packages for Statistical Analysis:
1. SAS or R (if you can use scripting languages)
2. JMP or Minitab
3. MatLab (w/ Statistics Toolbox)
4. Statistica
5. Design Expert

Other packages that may be useful to T&E practitioners outside of the packages highlighted above include:
- SPSS – geared towards social scientist research. Provides a wide variety of statistical analysis tools; however, does not provide any design of experiments capabilities.
- WinBUGS – Open source Bayesian analysis package using Markov Chain Monte Carlo (MCMC).
- Reliasoft – Provides tools for lifetime data analysis and reliability growth analysis.

		Software Tool							
	Topic	**Design Expert**	**JMP**	**Minitab**	**SAS**	**R**	**Statistica**	**Excel**	**ACTS/FireEye**
	Vendor	**StatEase**	**SAS**	**Minitab**	**SAS**	**Public Domain**	**StatSoft**	**Microsoft**	**NIST**
	Approx Comm Cost	$ 1,000.00	$ 1,450.00	$ 1,000.00	$6,200	$ -	$2,000	$149 (resample)	Free
	Approx Gov Cost	$ 680.00	$ 400.00	$ 800.00		$ -	$2,000	$99	Free
	Approved for Gov. Use	Yes	Yes	Yes	No	Yes	Yes	Yes	Unk
	Process Decomposition (responses)	manual	manual	manual	manual	manual	manual	manual	manual
	Process Decomposition (Factors/Levels)	manual	manual	manual	manual	manual	manual	manual	manual
	Supports Cont/Categoric/Binary Response	no	yes	no?	scripts	scripts	no	yes	no
	Supports Cont/Categoric/Binary Factors	yes	yes	yes?	scripts	scripts	no	yes	yes
Use/Teaching	Interface Enforces Sound Analysis/Warnings	yes	no	no	no	no	no	no	no
	Safe to Use by Novices	yes	no	no	no	no	no	no	no
	Help Facility and Website References	Excellent	Spotty	Good	Hard to Use	mixed	Spotty	yes	?
	Enforces Good Residual Checking	Superb	by hand	Good	no	no	Good	no	N/A
	User Interface Easy to Teach and Learn	Very Simple	Very Complex	Complex	no	Complex	Complex	Simple	Moderate
Classic Designs Supported	General Factorial	yes	yes	yes	yes	yes	yes	no	N/A
	2^(k-p) Class Designs	yes	yes	yes	yes	yes	yes	no	N/A
	Response Surface Designs	yes	yes	yes	yes	yes	yes	no	N/A
	Mixture Designs	yes	yes	yes	yes	yes	no	no	N/A
	D- and I- Optimal Designs	yes	yes	yes	yes	yes	no	no	N/A
	Space Filling Designs	no	yes	no	yes	unk	no	no	N/A
	Taguchi OAs	yes	yes	yes	unk	yes	yes	no	N/A
	Strength 2 S/W Arrays (pairs)	no	yes*	no	unk	unk	no	no	yes
	Strength N S/W Arrays (all)	no	yes*	no	unk	unk	no	no	yes
	Sequence Covering Arrays	no	no	no	unk	unk	no	no	yes
Designs with Restrictions in Randomization	Split-Plot	yes	yes	yes	yes	yes		no	N/A
	RCBD	no	unk	unk	yes	yes		no	N/A
	Latin Square	no	unk	unk	yes	yes		no	N/A
	Greeko-Latin Square	no	unk	unk	yes	yes		no	N/A
Design Metrics	Statistical Power Calcs	yes	yes	yes	yes	yes	no	manual	N/A
	Orthogonality of Model Terms (X'X)	yes	yes	yes	yes	yes	yes	no	N/A
	Prediction Error Estimates	yes	yes	yes	yes	yes	no	no	N/A
	Compares Designs	yes	yes	yes	yes	yes	yes	no	yes
Analysis Tools	One sample Tests (Z, t, chi, etc.)	no	yes	yes	yes	yes	yes	yes	N/A
	Paired T-test	no	yes	yes	yes	yes	yes	yes	N/A
	Test of proportions	no	yes	yes	yes	yes		yes	N/A
	ANOVA	yes	yes	yes	yes	yes	yes	yes (one factor)	N/A
	Simple Linear Regression	yes	yes	yes	yes	yes	yes	yes	N/A
	Multiple Linear Regression	yes	yes	yes	yes	yes	yes	no	N/A
	Logistic Regression	not well	yes	yes	yes	yes		no	N/A
	Generalized Linear Model	no	yes	yes	yes	yes	yes	no	N/A
	Linear Mixed Model	no	yes	yes	yes	yes		no	N/A
	Generalized Linear Mixed Model	no	no	no	yes	yes		no	N/A
	Nonlinear Models	no	yes	yes	yes	yes		no	N/A
	Nonlinear Mixed Models	no	no	no	yes	yes		no	N/A
	Hierarchical Linear Models	no	no	no	yes	yes		no	N/A
	Bayesian HLM	no	no	no	yes	yes	no	no	N/A
	Nonparametric Methods	no	some	some	yes	yes	no	no	N/A
	Multivariate Analyses	some	some	some	yes	yes	no	no	N/A

* script code req'd

\+ claimed

Additional Software Tools: Reliasoft, Matlab, Hexawise, Stata, SPSS

APPENDIX D
DOT&E OCTOBER 2010 MEMORANDUM

OPERATIONAL TEST AND EVALUATION

OFFICE OF THE SECRETARY OF DEFENSE
1700 DEFENSE PENTAGON
WASHINGTON, DC 20301-1700

OCT 19 2010

MEMORANDUM FOR COMMANDER, ARMY TEST AND EVALUATION COMMAND
COMMANDER, OPERATIONAL TEST AND EVALUATION FORCE
COMMANDER, AIR FORCE OPERATIONAL TEST AND EVALUATION CENTER
DIRECTOR, MARINE CORPS OPERATIONAL TEST AND EVALUATION ACTIVITY
COMMANDER, JOINT INTEROPERABILITY TEST COMMAND
DEPUTY UNDER SECRETARY OF THE ARMY, TEST & EVALUATION COMMAND
DEPUTY, DEPARTMENT OF THE NAVY TEST & EVALUATION EXECUTIVE
DIRECTOR, TEST & EVALUATION, HEADQUARTERS, U.S. AIR FORCE
TEST AND EVALUATION EXECUTIVE, DEFENSE INFORMATION SYSTEMS AGENCY
DOT&E STAFF

SUBJECT: Guidance on the use of Design of Experiments (DOE) in Operational Test and Evaluation

This memorandum provides further guidance on my initiative to increase the use of scientific and statistical methods in developing rigorous, defensible test plans and in evaluating their results. As I review Test and Evaluation Master Plans (TEMPs) and Test Plans, I am looking for specific information. In general, I am looking for substance vice a 'cookbook' or template approach - each program is unique and will require thoughtful tradeoffs in how this guidance is applied.

A "designed" experiment is a test or test program, planned specifically to determine the effect of a factor or several factors (also called independent variables) on one or more measured responses (also called dependent variables). The purpose is to ensure that the right type of data and enough of it are available to answer the questions of interest. Those questions, and the associated factors and levels, should be determined by subject matter experts -- including both operators and engineers -- at the outset of test planning.

Elements of experimental design that I am looking for when I approve TEMPs and Test Plans include the following:

- The goal of the experiment. This should reflect evaluation of end-to-end mission effectiveness in an operationally realistic environment.

- Quantitative mission-oriented response variables for effectiveness and suitability. (These could be Key Performance Parameters but most likely there will be others.)

- Factors that affect those measures of effectiveness and suitability. Systematically, in a rigorous and structured way, develop a test plan that provides good breadth of coverage of those factors across the applicable levels of the factors, taking into account known information in order to concentrate on the factors of most interest.

- A method for strategically varying factors across both developmental and operational testing with respect to responses of interest.

- Statistical measures of merit (power and confidence) on the relevant response variables for which it makes sense. These statistical measures are important to understand "how much testing is enough?" and can be evaluated by decision-makers on a quantitative basis so they can trade off test resources for desired confidence in results.

Design of Experiments is a structured process to identify the metrics, factors, and levels that most directly affect operational effectiveness and suitability and that should be reflected in detailed test plans. DOT&E is working with other members of the test and evaluation community to develop a two-year roadmap for implementing this scientific and rigorous approach to testing. I am looking for as much substance as possible as early as possible, but each TEMP revision can be tailored as more information becomes available. That content can either be explicitly made part of TEMPs and Test Plans, or referenced in those documents and provided separately to DOT&E for review.

J. M. Gil

J. Michael Gilmore
Director

cc:
DDT&E

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ACRONYMS

AAC	Air Armament Center
ACQ201A	Intermediate Systems Acquisition, Part A; DAU course
AEDC	Arnold Engineering Development Center
AFFTC	Air Force Flight Test Center
AFIT	Air Force Institute of Technology
AFIT/LS	AFIT School of Systems and Logistics
AFOTEC	Air Force Operational Test and Evaluation Center
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
AO	action officer
AST	ATEC System Team
ATEC	Army Test and Evaluation Command
BOD(ES)	Board of Directors (Executive Secretariat)
BOD(ESS)	Board of Directors (Executive Secretariat Support)
CBT	Computer Based Training
CLE 035	Introduction to Probability and Statistics; DAU course
COE	Center of Excellence
COMOPTEVFOR	Commander, Operational Test and Evaluation Force
CONOPS	Concept of Operations
DASD(DT&E)	Deputy Assistant Secretary of Defense for Developmental Test and Evaluation
DAU	Defense Acquisition University
DISA	Defense Information Systems Agency
DoD	Department of Defense
DoDI	Department of Defense Instruction
DOE	Design of Experiment
DOE 0	Statistical Foundations for Design of Experiments; Air Force (46th Test Wing and 53rd Wing) course
DOE I	Design of Experiments for the General Factorial; Air Force (46th Test Wing and 53rd Wing) course
DOE II	Design of Experiments for Fractional Factorials & Response Surfaces; Air Force (46th Test Wing and 53rd Wing) course
DOE III	Advanced Topics in Design of Experiments; Air Force (46th Test Wing and 53rd Wing) course
DOT&E	Director of Operational Test and Evaluation
DT	developmental test
DT&E	developmental test and evaluation
FIPT	functional integrated product team
FY	fiscal year
GUI	Graphical User Interface
HRD	Human Resources Specialist
IPT	integrated product team
IT	integrated test
JMP	Software Package

MOE	measure of effectiveness
MOP	measure of performance
OSD	Office of the Secretary of Defense
OT	operational testing
OT&E	operational test and evaluation
OTA	operational test agency
PEO	program executive officer
PM	program manager
POA&M	plan of action and milestones
R	Software Package
RS	Resident Seminar
SAS	Software Package
SME	subject matter expert
SOT	Science of Test
SOT210	Introduction to Science of Test: Experimental Design and Analysis; AFIT course
SOT310	Science of Test: Experimental Design and Analysis I; AFIT course
SOT410	Science of Test: Experimental Design and Analysis II; AFIT course
SPO	System Program Office
STAT	scientific test and analysis techniques
STED	scientific test and evaluation design
T&E	test and evaluation
TEBC	Test and Evaluation Basic Course
TEMP	test and evaluation master plan
TPS	Test Pilot School
TST 203	Intermediate Test and Evaluation; DAU course
TW	Test Wing
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics
WIPT	working-level integrated product team
WKSP0110	Experimental Design and Analysis: Executive Overview; AFIT course

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