The ITEA Journal

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Association

T&E at the Speed of Need

NACMAST Cyber Test Range

EWA is the primary component of the Army Research Lab (ARL) *Network Attack Characterization Modeling and Simulation Testbed*, NACMAST Enterprise. NACMAST facilitates testing and development of modeling and simulation tools to detect and characterize network attacks in near-real time and provide software solutions to mitigate attacks. It also establishes a testing environment to certify network protection tools. Developed with ARL and a consortium of universities, our laboratory focuses on computer network intrusion detection and provides a unique test range for immediate testing and implementation of new computer network defense (CND) technologies. EWA maintains a customized training and certification program on intrusion detection techniques for all test range participants, and we invite additional DOD, academia, and industry networks to participate.

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Test Instrumentation Workshop

May 15 – 18 / Las Vegas, Nevada

Two and a half days of Subject Matter Experts together to focus on Testing in the Integrated Battle Space to examine emerging technologies and collaboration of people, processes, tools, and products to turn the promise of solutions into reality.

Annual Technology Review

July 25 – 27 / Memphis, Tennessee

Two days of technical tracks intended to showcase technologies that present challenges for the T&E community and expose new capabilities and approaches to evaluate them. With a focus on Strategic Partnering, ITEA has partnered with the Systems testing Excellence Program of the University of Memphis at the FedEx Institute of Technology.

Directed Energy T&E

August 6 – 9 / Albuquerque, New Mexico

ITEA, in partnership with the Directed Energy Professional Society (DEPS) will host this eleventh annual conference to continue the exchange of insights, experiences and ideas regarding directed energy in test and evaluation.

ITEA Annual Symposium

September 17 – 20 / Huntington Beach, California

Agility, flexibility and accelerated testing will be increasingly demanded of our T&E workforce and testing facilities. With the theme, 'Testing at the Speed of Need,' the premiere T&E event of 2012 will focus on answering the question, "How will DoD and other government T&E leaders, in cooperation with industry and academia, develop the workforce and evolve the T&E resources to met the future needs?"

Test and Evaluation to Meet the Advanced Persistent Threat Conference

November / Baltimore, Maryland

Check the ITEA website for a description of this event. The topics include MRTFB Developments to support Cyber T&E, Live Fire Testing, M&S of Cyber Threats, Cyber R&D: Getting to the left of day zero, and more…

Our Vision

To be recognized as the premier professional association for the international test and evaluation community.

Our Mission

To advance the field of test and evaluation worldwide in government, industry, and academia.

2012

Connect to ITEA to Learn, Share, and Advance!

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TECHNICAL ARTICLES

DEPARTMENTS

On The Cover: "T&E at the Speed of Need" has been demonstrated repeatedly by all the Services in the current conflict. Both government and industry have found ways to rapidly deliver new capabilities that perform correctly and safely to our warfighters. However, as Guest Editor Brian Simmons asks, "Are we prepared to take the rapid T&E lessons learned from the current conflict and employ them within our programs of record?" On the cover of this issue: **Top:** At sea aboard USS Blue Ridge (LCC 19) Aug. 20, 2002, Machinist's Mate 3rd Class Lauren Del Ricci sets the timer on her oxygen breathing apparatus (OBA) during a General Quarters drill. Blue Ridge is underway in support of the exercise, Ulchi Focus Lens 2002. Ulchi Focus Lens is a computer modeling and simulation command post exercise designed to test, evaluate, and improve combined and joint communications, coordination, procedures, plans, and systems needed to conduct contingency operations by the Republic of Korea and the United States. (U.S. Navy photo by Photographer's Mate Airman Kerri Ackman.) This photo is a work of a sailor or employee of the U.S. Navy, taken or made during the course of the person's official duties. As a work of the U.S. federal government, the image is in the public domain and available from wikimedia commons, images. **Middle:** A Platoon Leader uses Rifleman Radio display device to maintain situational awareness and location of fire teams while conducting MOUT Operations during the Army Network Integration Evaluation 12.1. (Photo was provided by the U.S. Army Test and Evaluation Command, Aberdeen Proving Ground, Maryland.) **Bottom and background:** U.S. Border Patrol at Algodones Sand Dunes, California, USA. The fence on the U.S. Mexican border is a special construction of narrow, 15 feet tall elements, that are movable vertically. This way they can be lifted on top of the ever shifting sand dunes. Photo taken by the U.S. Border Patrol and is the work of a U.S. Department of Homeland Security employee, taken during the course of the person's official duties. As a work of the U.S. federal government, the image is in the public domain and available from wikimedia commons, images.

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■ For over thirty years the International Test and Evaluation Association (ITEA), a not for profit education organization, has been advancing the exchange of technical, programmatic, and acquisition information among the test and evaluation community. ITEA members come together to learn and share with others from industry, government, and academia, who are involved with the development and application of the policies and techniques used to assess effectiveness, reliability, interoperability, and safety of existing, legacy, and future technology based weapon and non weapon systems and products throughout their lifecycle. ITEA members embody a broad and diverse set of knowledge, skills, and abilities that span the full spectrum of the test and evaluation profession. All of which is shared with others through the ITEA Journal the industry's premier technical publication for the professional tester and at ITEA's Annual Symposium, regional workshops, education courses, and local Chapter events. Join the thousands of ITEA members your peers in the industry in contributing to the ITEA Journal and participating at ITEA events so that you also can benefit from the opportunities to learn from others, share your knowledge, and help advance the T&E industry.

■ *The ITEA Journal* (ISSN 1054 0229) is published quarterly by the International Test and Evaluation Association at 4400 Lakes Court, Suite 104, Fairfax, Virginia 22033 3899. Single issue cover price for *The ITEA Journal* is $25. ITEA offers annual membership for individuals, full time students, and any organization interested in advancing the test and evaluation profession. Annual membership dues are $60 for individuals ($80 if located outside of the U.S.) and $25 for full time students. Annual Corporate Membership dues are $500 for small organizations (less than 50 employees), and $1,000 for large organizations (50 or more employees). Corporate Memberships include three (3) Individual Memberships for small organizations and five (5) Individual Memberships for large organizations. Annual dues include a one year subscription to *The ITEA Journal*. The annual subscription rate for libraries and other organizations providing timely reference material to groups is $75. All overseas mail (air mail or AOA) requires an additional $20. *The ITEA Journal* serves its readers as a forum for the presentation and discussion of issues related to test and evaluation. All articles reflect the individual views of the authors and not official points of view adopted by ITEA or the organizations with which the authors are affiliated.

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The premiere T&E event of 2012

Testing at the Speed of Need

Agility, flexibility, and accelerated testing will be increasingly demanded of our T&E workforce and our testing facilities. Declaring this as a challenge is easy; doing it is difficult. How will DoD and other government T&E leaders, in cooperation with industry and academia, develop the workforce and evolve the T&E resources to meet the future needs? The solution probably relies on a combination of policy, process, and facility changes, making partnering and integrated test commonplace, and developing the current and future workforce equipped to scientifically test faster. We encourage you to participate in the Symposium to engage with, learn from and influence our T&E community in these challenging times within our industry.

New: Best Paper Award for Early Career Professionals

In order to encourage a new generation and our future workforce to participate in the symposium, ITEA will make a cash award for Best Paper presented by a young professional, those who have been practicing in the field of T&E for five years or less, and first and second place in Poster Paper presentations. We challenge you to entice the young professionals in your organization to participate!

Meeting Location

Hyatt Regency Resort and Spa
21500 Pacific Coast Highway, Huntington Beach, CA 92648 / 888-421-1442

ITEA has a room block available to all of our attendees, at the prevailing government per diem rate of $125. Deadline for this rate is **Friday, August 24, 2012**. You are encouraged to make your reservations early.

Rosh Hashanah begins at sundown on Sunday the 16th, and our host hotel will be able to provide information on local Synagogues for our Jewish members to plan accordingly.

Visit www.itea.org for all the details

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September 17–20, 2012

President's Corner

ITEA Journal 2012; 33: 1

The world is changing at a dramatic pace. We have become accustomed to yearly (or more frequent) upgrades to software and computers; "apps" that update weekly; new car models being rolled out annually; and other changes that occur at an ever increasing pace. To use an old adage, "the only constant is change." Behind every upgrade, every innovation, or any new product is test and evaluation. The test community makes sure that all these innovations that we take for granted work satisfactorily.


Mark Brown, Ph.D.

While the consumer market and government market may differ in their approach to testing, it is a core element of providing capabilities (products). In an age where the "speed of need" continues to increase while budgets decrease, the test community must adapt to meet the consumers needs - whether that consumer be a young marine going into harm's way or a young mother taking children to school in a minivan - both rely on testing to know their equipment will work and get them there and back safely. Testing crosses all domains and all industries. We must develop test capabilities, methodologies, and a test workforce that can adapt to this rapid acquisition environment. A great example of a success story for test and evaluation adapting to this increased tempo is the U.S. Army Network Integration Evaluation (NIE). The NIE is addressing the challenges of rapid acquisition by making sure networked systems are operational prior to deployment. Twice a year, the NIE fields systems at varying levels of maturity to conduct an assessment of their suitability for fielding and to identify improvements needed in the systems being evaluated prior to fielding. It provides an early look at emerging technologies while allowing mature systems to be evaluated in an operationally realistic systems-of-systems environment. As the NIE moves into the future, test environments and the systems being evaluated will continue to grow in complexity. But the rapid test environment will accelerate the ability to get systems from the laboratory to the field.

So how does ITEA fit into this rapid "speed of need" test environment?

ITEA's membership is at the heart of this changing environment. Our members span the frontier from systems developers to test capability development, to range support and operations, to test policy and oversight. ITEA is an education organization. Our primary focus is on equipping the workforce with the skills and knowledge they need to be successful in this changing environment. I always find it amazing to read *The ITEA Journal* and see similar topics in other trade magazines. If you look at the plethora of trade magazines today you will find topics on agile systems/software development, rapid acquisition, and streamlined processes. All topics you will find in this issue of the *Journal*. So what is the difference? These other magazines are focused on how to develop and provide the material solution where ITEA is focused on how we test systems developed to meet "the speed of need" and ensure the products delivered meet the needs of the consumers.

Our membership also crosses both the commercial and government domains. There are lessons that the government test community can learn from commercial ventures, where test teams are integral to the systems development process from the beginning to make sure that discovery occurs early in the development process as the system matures. And there are lessons and capabilities that commercial ventures can leverage from the government test community, including access to test facilities and ranges. At the end of the day, we are one community. The core of what we do is to make sure that the young marine and the young mother can both trust their vehicles and equipment to perform without issue no matter how quickly they went from concept to the field.

Issue at a Glance

ITEA Journal 2012; 33: 2

T&E at the Speed of Need. Dr. Steven Hutchison, Department of Defense Principal Deputy, Developmental Test and Evaluation, conceived the phrase *T&E at the Speed of Need* when he was Test and Evaluation (T&E) Executive at the Defense Information Systems Agency (DISA). The speed of need is the time between definition of a user need and initial operation of the capability. The demands of war have shortened the timeline on requirements for military systems. Rapid acquisition and rapid fielding initiatives arising from urgent operational needs have created an entire industry in the defense community. Commensurately hastened is the pace at which transportation security and border protection measures need to be deployed. We see information technology (IT), especially software, change with a frequency of months not years. T&E must be responsive to the acquisition timelines. The Federal Aviation Administration, Border Patrol, law enforcement and many other organizations have adapted to the changing speed of need. This issue takes a candid look at agile software development processes, defense IT acquisition reform, rapid acquisition and fielding, reconfigurable test capability, testing on demand, reuse and other ideas for streamlining the T&E process in support of accelerating deployment of new products, services and capabilities.

Brian Simmons, Executive Technical Director and Deputy to the Commander, US Army Test and Evaluation Command, uses the *Guest Editorial* to illustrate how T&E assists rapid delivery to our warfighters, and the inroads made that allow testers to review in-theater performance once initial deployment has occurred. Mr. Simmons then issues the imperative that we need to be prepared to take rapid acquisition lessons learned to our programs of record, because going faster is a reality for T&E. Dr. James Welshans, ITEA Historian and chair of the ITEA History Committee, documents in *Historical Perspectives* the speed of need epitomized in Britain's response to the German V-1 attacks, defending against an entirely new kind of weapon.

Army Major General Heidi Brown, Director for Test for the Missile Defense Agency (MDA), uses the platform of an *Invited Article* to describe the rate of ballistic missile threat development and proliferation and evolving threats, and the MDA response in the form of a *test as we fight* approach to developing and fielding the ballistic missile defense system. Randy Herrin and Neil Barrett of the DISA Joint Interoperability Test Command present the DISA solution to speed of need, embodied in implementing agile software development; attracting and retaining staff; and fostering collaboration among all major DoD T&E organizations. Agile is intrinsically collaborative, involving all stakeholders in its processes. Jana Gallatin, also of the Joint Interoperability Test Command, presents agile processes to help integrate vendor and government testing.

Charles Wentz shares lessons learned from joint urgent operational needs programs and recommendations for improved integration and testing. Alan Jenkins of the Naval Air Systems Command advocates for a closer relationship between program management and test and evaluation teams for the benefit of both. Dr. John Colombi of the Air Force Institute of Technology and Captain Christopher Cobb of the Air Force Distributed Missions Operations Center review the current state of practice in the live-virtual-constructive test and training community. Dr. Haydee Cuevas *et al.* make the case for a multidisciplinary approach in the test and evaluation of operator performance of military systems. The multidisciplinary approach offers an effective and timely means for integrating technological innovations, addressing complexity and advancing the understanding of and improving human performance. Daniel Carlson and P. Travis Millet of the Air Force 412th Test Engineering Group at Edwards Air Force Base present the problem of efficient use of test resources as manifested through optimal planning of test points in a flight test program. They propose using a genetic algorithm and treating the problem as a constrained optimization, rapidly surveying a large parameter space and producing a near-optimum ordered set of test points.

Guest Editorial

ITEA Journal 2012; 33: 5–8

T&E—The Speed of Need

Brian Simmons
Executive Technical Director/Deputy to the Commander,
U.S. Army Test and Evaluation Command
Aberdeen Proving Ground, Maryland

The March ITEA Journal *theme (the speed for need) is a reality in today's acquisition business. Getting equipment to the field quickly has been demonstrated repeatedly by all Services in the current conflict. Both government and industry have found ways to efficiently deliver new capability. In Test and Evaluation (T&E) we have learned how to verify system safety; check basic system performance; help shape user tactics, techniques, and procedures; and assist rapid delivery to our warfighters. We have also found inroads so that we can review in-theater performance once initial deployment has occurred plus efficiently orient our stateside testing to replicate and solve problems uncovered.*

But, are we prepared to take the rapid T&E lessons learned from the current conflict and employ them within our programs of record? We'd better be. Because going faster is also a reality for T&E!

With the nation's deficit reduction plans emerging, doing less with less should be anticipated across the Department of Defense acquisition program as a whole. Within the Army, getting more efficient in T&E is a mandate. The T&E community has to more closely manage speed (time for test execution and for producing the evaluation) and cost (which is related to test duration but also includes facilities, instrumentation, contracts, etc.). I contend that the schedule and cost implications of test programs have been our secondary focus and that designing adequate test programs to verify effectiveness, suitability, and survivability has been primary. Given the budgets ahead, it's time to more thoughtfully balance T&E effectiveness with efficiency.

Brian Simmons

Shortening the time from development to fielding is a goal shared by all in acquisition. When a program schedule is constructed, much of the time (typically years) preceding Milestone C is test time. In actuality, test time is usually a combination of initial inspections, configuration management, contractor shakedown testing, and then various execution phases of developmental testing (DT) leading toward operational testing (OT) to support the milestone decision.

In each of these phases, test time is programmed to account for system repairs and downtime as well as corrective action periods for contractors to implement system fixes. History has shown us that for complex new systems, the system availability for testing at our test ranges averages only about 50 percent. So, a first look for reducing test time should be given to ensuring that the contract language specifies an adequate number of test assets, spare parts provisioning, number of contractor field service representatives at the test range, and also provides the availability expected for the system while being tested. System readiness for testing must start before test assets are delivered to the test range.

> *History has shown us that for complex new systems, the system availability for testing at our test ranges averages only about 50 percent.*

Government participation in contractor testing needs increased support from both partners. A real scenario that can occur is for the government to repeat tests similar or identical to those performed by the contractor simply because there was no government participation before the contractor test results were shared with the government. Contract language needs to include having a government voice in designing test

plans, instrumentation, data collection methodology, and verification of results. Getting the product perfect while still at the contractor facility isn't as important as having a solid design for a reliable program in place. The Army places much more value on the reliability growth projection than any current point estimate of performance. Early failures are allowable, expected, and if accompanied by good reliability management strategies, are not show stoppers. Government T&E participation is essential for contractor test data to be creditable and as a method for not performing redundant testing. We simply cannot afford to relearn the same information more than once in any test program.

The test culture has long been to ensure that most system failure modes are identified early in program development based on the logic that finding failures early reduces system life cycle costs. In fact, we know the relationship between reliability and life cycle costs is inversely proportional. If taken to an extreme, getting a system to "perfect reliability" could prevent it from ever being fielded.

Government T&E participation is essential for contractor test data to be creditable and as a method for not performing redundant testing.

For complex and expensive weapons systems, getting to high reliability performance early is as important as fixing problems discovered later in the program that may require extensive re-engineering and be cost prohibitive. For some systems, however, such as automotive systems, information technology systems, or military/commercial dual-use items, increasing reliability through engineering change proposals or upgrading parts' quality during maintenance allows for spiraling in improved performance later in the acquisition schedule. Therefore, a method of decreasing the time to field, for selected systems, could be to incrementally increase the reliability requirement over time, perhaps hitting maturation after the initial operation test and even beyond Milestone C. This may require performing additional DT after Milestone C: programming research, development, T&E funds late in the program, and exercising smaller initial procurement quantities. This method would also proportionately reduce the test time required in advance of getting new capabilities to the field.

Perhaps the most applicable lesson learned from those systems that were rapidly fielded to our traditional programs of record is this: If the new capability is a known improvement to today's capability, and the system is safe to operate, take more acquisition risk and test less before fielding.

Too often those in T&E talk in terms of risk to the program or to the warfighter based on what has not been demonstrated through test. Ownership of acquisition risk is not the responsibility of the testers or the evaluators. This belongs with the Services and with the Department of Defense acquisition leaders. The T&E role is to quantify system performance against requirements, verify the increased mission capability, articulate warfighter proficiencies and concerns, identify training and logistics issues, and design test opportunity options to obtain the information to quantify the risk, including schedule and cost implications of the options.

Within the Army Test and Evaluation Command (ATEC), many changes have occurred within the last year to increase our efficiency as we enter a period of declining resources. Schedule and cost are at the forefront of every T&E conversation regarding the Army's upcoming acquisition programs.

We have made great progress in planning our OT by working backward to the earliest point in the developmental test program. The missions and tasks of the warfighter now get primary emphasis at the earliest evaluation strategy discussions for all new systems. We have been successful in identifying what we can learn in DT that does not have to be relearned in OT. But we still have a long way to go within our command to fully exploit integrated test opportunities. For major acquisition programs, there will always be dedicated DT to understand the system technical performance in a controlled, repeatable environment. Similarly, there will always be dedicated OT to verify system performance under simulated combat conditions. The opportunities that exist between pure DT and pure OT, however, are many, fertile, and form the basis for where we continue to press for efficiencies.

The missions and tasks of the warfighter now get primary emphasis at the earliest evaluation strategy discussions for all new systems.

We continue to push for onboard instrumentation for new weapons programs. Where this has been employed, there is a natural sharing of data between the system contractor, the program manager, the developmental and operational testers, the testers and trainers, and the sustainment community. All have visibility of the same data, instrumentation is not added downstream in the acquisition process, and real usage versus expected usage shows valuable insight into overall system performance. Onboard instrumentation coupled with accurate parts usage data is a key to measuring true system performance in theater and not having to later repeat testing back on the test range. Detailed, accurate data collection and sharing from actual combat employment should be a basis for

Figure 1. The U.S. Army Operational Test Command's Rifleman Radio test team in action for NIE 12.1.

mitigating risk in traditional test planning and for strengthening continuous evaluation.

Similarly, we continue to emphasize the goodness of having high-fidelity physics-based models for systems under test. This is the norm in some weapons commodities and yields significant T&E efficiency when resourced. For example, most missile programs come complete with a six degree of freedom flight model to include targeting and terminal effects. Our nondestructive hardware in the loop testing is then used to validate and verify the models. Live missile firings still occur, but with far fewer missiles.

In partnership with the Training and Doctrine Command and major acquisition program managers, ATEC has initiated extensive T&E Master Plan reviews. These reviews are intended to challenge user requirements, associated test requirements, and resulting program schedule and cost implications. Additionally through the Army's Configuration Steering Board process, there is an annual opportunity to adjust requirements based on schedule, cost, or performance. Testing off ramps could be identified in this process, as is needed additional testing. The Configuration Steering Board process puts T&E schedule and costs at full visibility to Army leadership.

Within the Network Integration Evaluation biannual events at Ft. Bliss and White Sands Missile Range, ATEC has partnered with Training and Doctrine Command's Brigade Modernization Command as well as the Assistant Secretary of the Army for Acquisition, Logistics, and Technology to conduct concurrent operational tests for programs of record as well as user evaluations for other nonmajor programs. We have combined the test expertise and instrumentation from our developmental test ranges as well as our Operational Test Command and have now executed two truly integrated events that unite the Army's acquirers, trainers, and testers to expeditiously mature and acquire tactical networks and communications equipment based on extensive usage by soldiers (Figure 1).

As further evidence of our recognized need to increase T&E efficiency, ATEC is leading a formal Lean Six Sigma continuous process improvement program. From our commanders, to our evaluators, to our test directors, training is well underway leading to Black Belt certification for all ATEC senior leaders. We have reduced headquarters' operating costs significantly through a reorganization which consolidated staffs from two subordinate commands into one unified Headquarters' structure. We have merged two test organizations at Ft. Huachuca (one DT organiza-

tion and one OT organization) into a consolidated command with an integrated DT/OT mission. We are reviewing our footprint to determine where we really need to be located and what test facilities must be retained. We are practicing smarter test design with our evaluation staff with increased developmental test expertise and use of statistical methods. We are consolidating contracting, instrumentation, data centers, policy, and across the board business management practices to execute our resources as an enterprise.

2011 was a year of proactive change within Army T&E with great emphasis on finding schedule and cost efficiencies within our structure and our processes. 2012 is already interesting, and the challenges for 2013 will be immense. T&E will continue to influence every acquisition program, no matter how severely the budgets change. Will we test more systems less or less systems more? I submit that the schedule and cost to perform T&E directly influences the answer to this question. A good technical product coming from T&E will always be needed. A good technical product that is also efficiently derived will be even more so. ❑

Brian Simmons was appointed to the ATEC Executive Technical Director/Deputy to the commander position on 12 March 2010. In this capacity he oversees the technical execution of all ATEC test plans and reports, as well as the command's evaluation strategy and analyses. He is also responsible for integrating the command's instrumentation, policy, modeling and simulation, and continuous business improvement projects.

He is responsible for ensuring that Army and OSD senior leaders have the essential information required before weapons and equipment are placed into the hands of soldiers and throughout the lifecycle of those systems. He directs the test and evaluation for over 400 weapons programs through a 10,000 person workforce and a $2B budget.

Mr. Simmons began his Army career in 1980 at the U.S. Army Ballistic Research Laboratory. At the U.S. Army Materiel Systems Analysis Activity in 1984, he was an evaluator for infantry anti-armor weapons systems. In 1988, he was the Chief of Test Business Operations for the U.S. Army Test and Evaluation Command. Mr. Simmons also worked at the Pentagon for the Headquarters, Department of the Army Secretariat, as the Deputy Director for Plans, Programs, and Resources, from 1996 through 1997.

Mr. Simmons joined the Army's Senior Executive Service in 1998 as the Deputy to the Commander/Technical Director, U.S. Army Developmental Test Command. Prior to his current assignment, Mr. Simmons was the Director of the Army Evaluation Center. He received Presidential Rank Awards in 2007 and in 2011. Mr. Simmons has loved every challenge and job the Army has offered him.

He holds an associate of arts from Harford Community College, a bachelor of science from the University of Maryland, and a master of science from the Johns Hopkins University. He is a Harvard University Senior Executive Fellow, a graduate of the U.S. Army War College, and a certified member of the Army Acquisition Corps.

ITEA Journal 2012; 33: 9–10

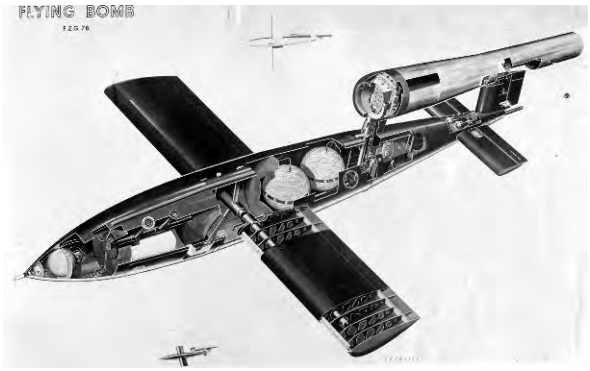
"V" Is for Vengeance … "V" Is for Victory

Jim Welshans, Ed.D.
Teledyne CollaborX, Navarre, Florida

In this issue, we define the "speed of need" as the time between the definition of a user need and the initial operation of the capability. Implicit in this characterization is one of the test and evaluation community's fundamental challenges: to determine whether the capability actually meets users' needs. In layman's terms, we answer two key questions: (a) Does the thing work as advertized? and (b) Does it produce the desired operational outcomes?

Probably the most demanding "speed of need" test and evaluation requirement occurs when a new capability is first introduced into operational wartime service. The story behind how Nazi German engineers targeted Hitler's V-1 flying bomb vengeance weapons against England during World War II illustrates this phenomenon. Moreover, these historical lessons highlight the fundamental importance of valid and reliable data sources, even when your decision-makers need immediate results.

The first V-1s fell on London in June 1944. From then until March 1945, they left approximately 6,000 dead and 40,000 injured in raids throughout Europe. A predecessor to today's modern cruise missiles, the V-1 was one of the first "fire and forget" weapon systems, enabled by an internal guidance system. Sufficiently accurate for area bombing, the V-1 used a vane anemometer on the nose as a rudimentary odometer to determine when the target area had been reached. Adjusting for prevailing forecast wind conditions, launch crews set the odometer to count down to zero upon target area arrival. As the missile flew and airflow turned the vane anemometer propeller, the odometer counted down 1 unit for every 30 revolutions, arming the warhead and programming the attack.



Cutaway drawing of a V-1 showing fuel cells, warhead, and equipment. (U.S. Air Force photo, available from http://www.nationalmuseum.af.mil/shared/media/photodb/photos/090928-F-1234S-010.jpg)

While airborne, and when the odometer count reached zero, two detonating bolts fired to release spoilers on the elevator and sever the linkage between the elevator and rudder servos. This configuration set the rudder in neutral and pitched the V-1 into a steep dive while simultaneously stopping the engine and its distinctive "buzz" sound. As a boy, I recall my father's stories about these weapons. He had deployed to England in preparation for the D-Day invasion and was living with an English family. After hearing one of the weapons cruise overhead, the sudden silence alerted listeners to the impending impact.

To adjust and correct settings in the V-1 guidance system, the Germans needed to know where the V-1s were landing. Because Royal Air Force fighters prevented any aerial reconnaissance of London, the Germans had to rely on other means to generate damage assessment reports. Two independent mechanisms were explored for generating this operational performance data, with widely differing outcomes. First, German intelligence solicited impact data from their espionage agents in Britain. For example, in June 1944, German intelligence agents Garbo, Brutus, and Tate were asked about V-1 impact sites. But all of these individuals had become British double agents (aka the Double Cross system). This posed somewhat of a dilemma for the British. If given the correct

impact site data, the Germans would be able to adjust their aim and correct subsequent V-1 launches.

The most deadly V-1 attack of the war in London occurred early in the campaign, in June 1944, when a V-1 killed 58 civilians and 63 military personnel at the Royal Military Chapel, Wellington Barracks. The British deception policy to divert V-1 impacts away from central London was initially controversial. Understandably, the War Cabinet was reluctant to authorize measures that would likely increase casualties in any area, even though casualties were reduced by greater amounts in the dense urban areas. With Churchill away at a conference, the British Home Defense Executive took the initiative to start the deception using the double agents, lest the Germans discover the truth about their V-1 impacts.

There was no plausible reason why the agents could not supply accurate data to the Germans, as major impacts were common knowledge among the English population and reported in the press, which the Germans could ready access through neutral nations. During the early V-1 flying bomb attacks against London, the British noticed that the weapons were falling 2 to 3 miles short of Trafalgar Square. In order to make the Germans continue aiming short, the British used the double agents to exaggerate the number of V-1s falling in the north and west of London and not report those impacting to the south and east. The British eventually decided to have their double agents report V-1 impact damage fairly accurately; but by emphasizing those strikes generally located northwest of London, the agents gave the Germans the impression that they were overshooting the intended target area. The Double Cross deception also caused retargeting from London, beyond just inaccurate aiming. For example, when the Germans received a false V-1 report of considerable damage in Southampton which had not been a V-1 target the V-1s were temporarily aimed at the south coast ports. These reports also downplayed the effect these weapons had on civilian morale.

The other German effort to secure accurate V-1 performance data used more technical means. The officer in charge of the V-1 offensive ordered a number of the weapons fitted with small radio transmitters that reported their flight profiles. The radio transmitters clearly demonstrated a tendency for the V-1s to fall short. But when comparing the data gathered by the transmitters with the double agents' intelligence reports, the Germans assumed that the agents were completely reliable and the radio transmitters were faulty. It was later calculated that if the Germans had relied on the radio transmitter data and made the correct adjustments to the V-1 guidance systems, British casualties might have increased by 50 percent or more. ❑

James S. Welshans, Ed.D., is a former active-duty U.S. Air Force fighter pilot, instructor, and war planner. Currently an independent scholar, he is employed as a senior requirements engineer with Teledyne CollaborX, advising the Air Force Research Laboratory on military C2 projects and technology transition. A founding member of the Air Force Operational Command Training Program, Dr. Welshans taught strategy and operational assessment to military officers worldwide during major command and control exercises. Dr. Welshans received a bachelor of science degree in international affairs and history from the U.S. Air Force Academy in 1977, a master of science degree in management in 1985, and a doctor of education in curriculum and instruction and educational leadership in 2008. He serves on the executive board of the Society of Phenomenology in the Human Sciences and on this journal's Publications Committee as The ITEA Journal historian.

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Invited Article

ITEA Journal 2012; 33: 11–14

The Ballistic Missile Defense System Approach: The Test As We Fight Challenge

Major General Heidi V. Brown
Missile Defense Agency, Fort Belvoir, Virginia

The mission of the Missile Defense Agency (MDA) is to develop, test, and field an integrated, layered, ballistic missile defense system (BMDS) to defend the United States, its deployed forces, allies, and friends against all ranges of enemy ballistic missiles in all phases of flight. Unlike traditional military acquisition programs, the MDA has been directed to field BMDS capabilities as soon as technically possible to provide defense against the evolving threat of our enemies. The need to test these capabilities under operationally realistic conditions presents a significant challenge to developmental and operational testers alike.

Brown

Until weapon systems are battle tested, warfighters live with capability uncertainty as a by-product of the military acquisition process, especially where one-of-a-kind weapon systems are procured. Reducing this uncertainty and increasing warfighter confidence in the BMDS is not only critical prior to fielding new or upgraded capabilities but is also a cornerstone of the MDA's test program. This challenge has required the MDA to adopt a test as we fight approach to developing and fielding the BMDS, which is predicated in the following:

- Employing realistic and feasible ballistic missile defense scenarios and threats
- A rigorous modeling and simulation (M&S) verification, validation, and accreditation program to provide M&S that are accredited to assess the performance of the BMDS
- Introducing tactical BMDS element hardware and software
- Establishing operational communication networks connecting operational assets or operationally representative test articles or surrogates
- Accommodating Combatant Command (COCOM) Command and Control (C2) structure and providing for active warfighter participation in the test program
- Augmenting flight and ground testing with warfighter exercises and wargames

BMDS

The missile defense technology being developed, tested, and deployed by the United States is designed to counter ballistic missiles of all ranges: short range ballistic missiles (SRBMs), medium range ballistic missiles (MRBMs), intermediate range ballistic missiles (IRBMs), and intercontinental range ballistic missiles (ICBMs). Given the unique characteristics of enemy ballistic missiles based on range, speed, size, and performance, the BMDS is an integrated, layered architecture that provides multiple opportunities to destroy ballistic missiles and their warheads. The BMDS capabilities presented in *Figure 1* form the defense against adversary ballistic missiles targeting the U.S. Home land, U.S. deployed forces, friends, and allies. The BMDS architecture includes the following:

- Networked sensors and ground- and sea-based radars for target detection and tracking
- Ground- and sea-based interceptor missiles for destroying a ballistic missile using either the force of a direct collision, called "hit-to-kill" technology, or an explosive blast fragmentation warhead
- A command, control, battle management, and communications (C2BMC) network providing the warfighter with the needed links between the sensors and interceptor missiles

Operational realism in our test program

Testing is an evolutionary process that encompasses both developmental and operational activities. The test process begins with comprehensive testing of individual elements and components, progressing to end-to-end testing of the integrated system as a combination of interceptor and sensor systems linked by a sophisticated command and control architecture. As the test program evolves, each test builds on knowledge gained from

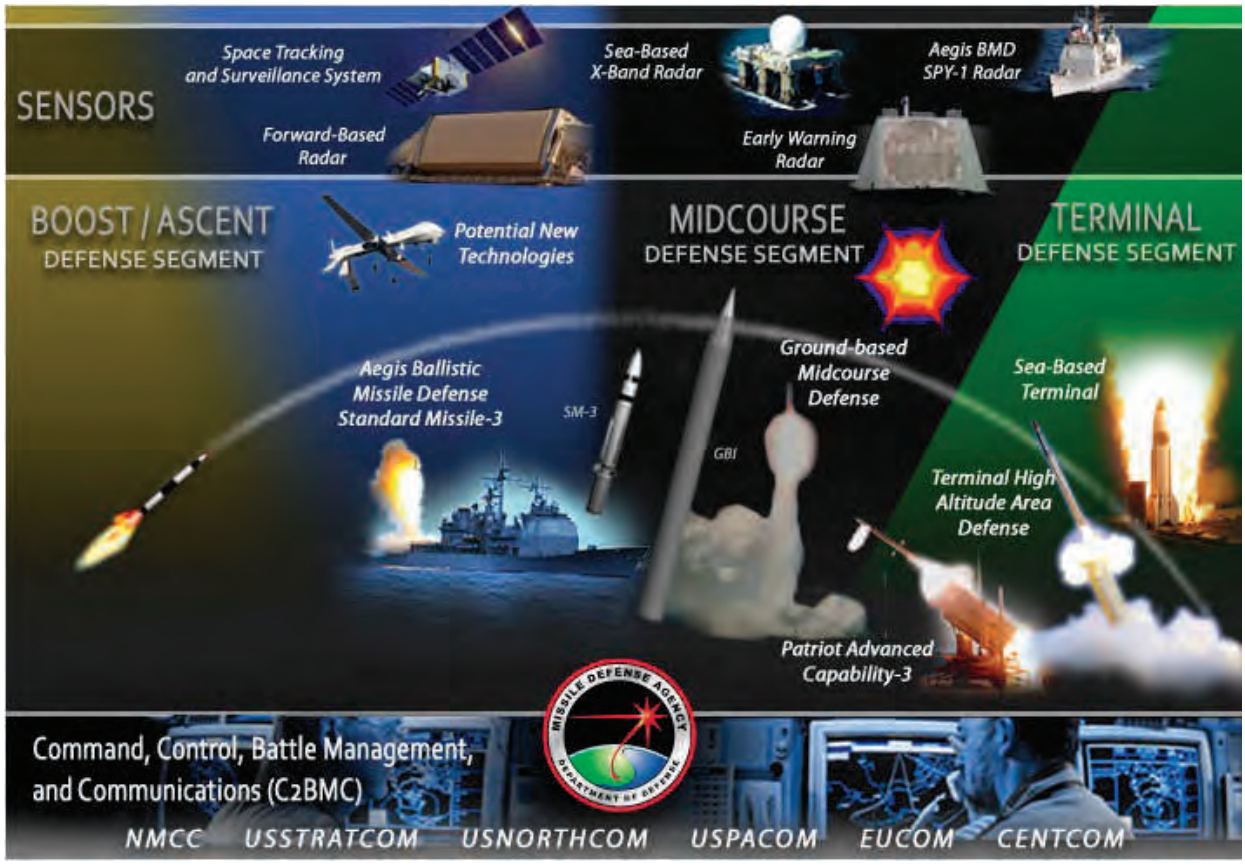

Figure 1. Ballistic Missile Defense System (BMDS) Architecture.

previous tests, adds increasingly challenging objectives, and becomes more operationally realistic.

Flight and ground testing are the principal venues for achieving the test as we fight objective. By exposing the warfighter to the to-be-fielded hardware, software, and communications under operationally representative conditions, the warfighter will be better prepared to execute the Active Defense mission should deterrence fail *(Figure 2)*. BMDS tests are conducted in partnership with the Director of Operational Test and Evaluation and with the Army, Navy, and Air Force Operational Test Agencies (OTA) to embed operational test and warfighter requirements in the test program.

Ground tests combine element hardware-in-the loop, operator-in-the-loop, and high fidelity threat simulations to test BMDS capabilities across a wide range of threats and environments that cannot be affordably replicated in flight tests. Ground tests are also the warfighter's primary venues for shaping warfighting doctrine and tactics, techniques, and procedures (TTPs). Alternatively, flight tests use assets in their operational configuration against a diverse inventory of targets to assess all aspects of BMDS performance under a variety of trajectories and profiles. The flight test program will culminate with an operational flight test that will be designed, planned, and orchestrated by the BMDS OTA Team. Finally, exercises and wargames support Joint Staff, COCOM, service components, and allies in preparation of doctrine, concepts of operations, TTPs, and requisite training on current and evolving BMDS capabilities.

The BMDS test as we fight approach

As previously described, MDA's test as we fight approach is based on utilizing M&S that are accredited to simulate realistic scenarios, tactical elements, operational communication networks, and COCOM C2 structure and warfighter participation.

The use of realistic and feasible ballistic missile threats and scenarios extends beyond threat missile type and launch point/aim point modeling to encompass high fidelity modeling of threat characteristics, including infrared and radar signatures, environmental factors and conditions, and adversary employment strategies. Wherever possible, actual adversary missile airframes and targets are employed in BMDS flight tests to further increase operational realism.

Figure 2. A Standard Missile-3 (SM-3) is launched from the USS O'KANE in a Joint Missile Defense Agency and U.S. Navy test conducted April 15, 2011. The SM-3 successfully intercepted a realistic and feasible target missile launched from the Reagan Test Site, located on Kwajalein Atoll in the Marshall Islands. Operational crew personnel prosecuted the mission.

The test program uses cost-effective M&S to assess system configurations, engagement conditions, and target phenomena. M&S allows repeated assessments of performance and provides a statistical determination of effectiveness. The MDA initiated an aggressive campaign to define flight tests that yield credible data for anchoring ground test models and simulations in order to increase warfighter confidence in the fielded capability, the desired end state.

The test program M&S is validated by executing either an Element post-flight reconstruction or a System post-flight reconstruction for every flight test. The results of the post-flight reconstruction events are compared to actual flight test data to validate the M&S and to support accreditation of the M&S to simulate realistic scenarios and to assess the performance of the BMDS.

Foundational to achieving this end state is the introduction of tactical hardware and software in flight and ground tests. Placing the warfighter on the to-be-fielded sensor, weapon, and command and control capabilities ensures warfighter performance expectations

Figure 3. Ground-based Midcourse Defense Soldiers from the 100th Missile Defense Brigade prosecute their mission of defending the U.S. Homeland from ballistic missile threats.

are realistically shaped, and TTPs reflect the capabilities and limitations of a BMDS delivery.

Also central to MDA's test as we fight approach is employing data and voice communication networks used in real world operations. When deemed practical without degrading the operational mission, this includes establishing terrestrial and satellite data and voice links that carry mission critical information between BMDS communication nodes, sensors, and shooters.

At its genesis, the hallmark of MDA's test as we fight initiative has been integrating and accommodating the needs of the warfighter community, which not only includes placing warfighter operators on console during tests but also includes establishing the multi-echelon, command and control structure that governs how execution-level warfighters execute the Ballistic Missile Defense mission. This allows the warfighter to operate in accordance with the same doctrine and TTPs in ground tests as they would during real world operations *(Figure 3)*. In flight tests, range safety factors must be considered that may constrain certain TTP actions.

Augmenting testing with warfighter exercises and wargames is critical because no test and evaluation program can satisfactorily address all factors and conditions across the spectrum of threats, environments, or operational scenarios. Therefore, MDA leverages additional venues to better inform the warfighter of BMDS capabilities and limitations, including concept of operations, TTP development/refinement exercises, and BMDS wargames. These venues contribute to the overarching objective of equipping the warfighter to efficiently and effectively fight with current and future planned BMDS capabilities.

Summary

In summary, as the rate of ballistic missile threat development and proliferation increases, a robust and effective ballistic missile defense capability has taken on greater urgency. With the advent of ballistic missile defense technologies, the U.S. has developed and is continuing to improve upon the means to defend against evolving threats. It is the MDA's mission to develop, test, and evaluate BMDS capabilities to accomplish this critical National Security objective. Central to our enterprise is integrating the warfighter and the independent BMDS OTA Team into the BMDS acquisition and fielding process early on to provide key development, test, and operational insights. The MDA's test as we fight approach supports the end state, which is to be able to deter, and should deterrence fail, defeat an adversary's aim of achieving victory through coercion and warfare. ❑

Major General (MG) Heidi V. Brown is the Director for Test for the Missile Defense Agency (MDA). She is responsible for planning, programming, budgeting, staffing, and managing a comprehensive Ballistic Missile Defense System (BMDS) test program to characterize ballistic missile defense capabilities and support fielding of an integrated and effective capability to the warfighter. In addition to directing the BMDS test program, she ensures the optimal allocation of resources, responsibilities, and functions within the Test Functional Area workforce, including test design and execution.

MG Brown, graduated from the United States Military Academy at West Point in 1981. Over the course of her military career, she has served in a variety of command and staff positions, including: platoon leader, executive officer, and commander, C Battery, 6th Battalion, 52nd Air Defense Artillery Regiment, 32nd Army Air Defense Command; executive officer and later commander, 2nd Battalion (Patriot), 43rd Air Defense Artillery Regiment, 108th Air Defense Artillery Brigade; assistant executive officer to the Deputy Chief of Staff for Operations and Plans; commander, 31st Air Defense Artillery Brigade, III Corps; chief of staff and deputy commander of the U.S. Army Air Defense Center and assistant commandant of the U.S. Army Air Defense School at Fort Bliss, Texas; Deputy Commanding General (Sustainment) at Fort Lewis; Deputy Commanding General (Sustainment), Multi National Corps – Iraq; and most recently, Director of Integration, Office of the Deputy Chief of Staff, G8.

As Commander of the 31st Air Defense Artillery Brigade, General Brown was the first female to command and lead an Air Defense Artillery brigade into combat and has the added distinction of being the first female general in the Air Defense Artillery branch.

MG Brown's awards include the Legion of Merit with four Oak Leaf Clusters (OLC), the Bronze Star Medal with one OLC, the Defense Meritorious Service Medal, the Meritorious Service Medal with six OLC, the Army Commendation Medal with five OLC the Joint Services Achievement Medal, and the Army Achievement Medal with four OLC. She is also authorized to wear the Parachutist Badge, the Air Assault Badge, the Joint Chiefs of Staff Identification Badge, and the Army Staff Identification Badge.

MG Brown holds a Bachelors Degree from the United States Military Academy, a Masters of Education Degree in Student Personnel Services, University of South Carolina, and a Masters in Strategic Studies, the Army War College. Her military education includes the Air Defense Artillery Officer Basic and Advanced Courses, Combined Arms and Services Staff School, Army Command and General Staff College, and the Army War College.

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Interoperability Testing at the Speed of Need

Randon R. Herrin and Neil L. Barrett
Defense Information Systems Agency (DISA)—Joint Interoperability Test Command (JITC),
Fort Huachuca, Arizona

Agile systems development and testing activities continue to accelerate at exponential speeds in industry and academia, with commercial vendors competing for market shares of "testing as a service (TaaS)" strategies, protocols, and standards. The Department of Defense (DoD) has continued working the National Defense Authorization Act (NDAA) Section 804 information technology (IT) system acquisition reform guidelines, with the integration of agile processes and procedures being a key tenet. Some elements of the Section 804 recommendations will likely be integrated into ongoing rewrites of the DoD 5000 series documents. A persistent challenge for the DoD is the lag in its agile policy development, while industry and academia continue to develop, establish, and execute agile methodologies and systems. If empirical evidence demonstrated for decades holds course, commercial vendors will drive agile best practices and protocols while the DoD works to finalize agile transformation policies, thus falling behind industry. To help minimize this gap between commercial information technology (IT) testing agility and the DoD's embrace and execution of new IT acquisition and testing methodologies, the Joint Interoperability Test Command (JITC) is in the midst of major agile testing activities and software efforts. These efforts include development of the Tactical Digital Link (TDL) Automated Test Case Generator (ATCGen) TaaS capability; execution of agile testing efforts of the Afghanistan Mission Network (AMN) Coalition Interoperability Assurance and Validation (CIAV) Working Group; and agile development of test data management, instrumentation, and analysis software tools. This article addresses NDAA Section 804 policy recommendations and then follows with descriptions, successes, and the way ahead for JITC's successful development activities of TDL ATCGen, AMN CIAV, and agile testing and software tools. Further explored in this article are the challenges in ensuring that test, evaluation, and certification (TE&C) processes of science-based test design (SBTD), design of experiments (DoE), and Capabilities Testing Methodology (CTM)/mission thread currently being integrated by JITC are considered part of the agile T&E methodologies.

Key words: Afghanistan Mission Network (AMN); Agile; Capabilities Testing Methodology (CTM); cloud computing; Coalition Interoperability Assurance and Validation (CIAV); data analysis; data management; Defense Information Systems Agency (DISA); Defense Information Systems Network T&E Network (DTEN); design of experiments (DoE); Forge.mil; joint capabilities areas (JCAs); Joint Interoperability Test Command (JITC); just-in-time testing; Major Range and Test Facility Base (MRTFB); mission thread; requirements generation; scrum; systems acquisition; Tactical Digital Link (TDL); test, evaluation, and certification (TE&C); test instrumentation; testing as a service (TaaS).

The phrase "test and evaluation at the speed of need" was first coined in the March/April 2010 article of the same name in *Defense AT&L* magazine by Steven J. Hutchison, Ph.D. (2010b). The "T&E at the speed of need" concept has developed significant traction as Department of Defense (DoD) research, development, test, and evaluation (RDT&E) budget challenges have continued to increase. Government Accounting Office reports indicate that the DoD RDT&E budget has increased proportionally almost 50 percent more than the DoD acquisition and procurement budgets have during the last decade. Given the looming DoD fiscal and budget reduction potentials, there has never been a better time for the DoD RDT&E communities with parallel leadership efforts from the Office of the Secretary of Defense (OSD) operational T&E and developmental T&E staffs to engage and collaborate with the DoD acquisition communities, industry, and academia to execute agile test, evaluation, and certification (TE&C) processes. The recommendations of the National Defense Authorization Act (NDAA) Section 804 Information Acquisition Reform TE&C Working Group include key aspects of agile T&E approaches, (Office of the Secretary of Defense [OSD] 2010) though the momentum of 804 has recently slowed. Discussions continue about which 804 TE&C recommendations will become part of the rewritten DoD 5000 series documents.

Agile testing activities and software developments are occurring with select Defense Information Systems Agency (DISA) Joint Interoperability Test Command (JITC) testing activities, but the integration of agile TE&C concepts and methodologies with system users, system developers, and system acquisition communities has been challenging. This has also been the case for JITC's efforts with the implementation of design of experiment (DoE), science-based test design (SBTD), and Capabilities Testing Methodologies (CTM)/ mission thread TE&C methodologies.

Given that the DoD RDT&E budget has accounted for nearly 20 percent of the total DoD budget over the past two decades and that the T&E technical and engineering workforce currently constitutes approximately 25 percent of all DoD government and contractor scientists and engineers, the fiscal significance of the collaboration of agile TE&C efforts of the DoD with industry and academia is obvious. This collaboration is vital to delivering tested information technology (IT) system capabilities "at the speed of need" to the users and warfighters in the field.

This article examines how DoE, SBTD, and CTM/ mission thread TE&C concepts may, without thorough communication and understanding, seem to the user and acquisition communities to contradict agile TE&C processes. Integration and application of these concepts early in the DoD acquisition life cycle can help mitigate some of this contradiction. An examination using "agility in action" testing examples of JITC's Tactical Digital Link (TDL) Automated Test Case Generator (ATCGen) and Afghanistan Mission Network (AMN) Coalition Interoperability Assurance and Validation (CIAV), and an agile software tool development example, will illustrate the potential for executing test programs with successful agile approaches in this article.

In the December 2011 *ITEA Journal* article titled "Test as We Fight," it is pointed out that

> *"there are tremendous efficiencies to be gained in testing information technologies by exploiting the power of virtualization. As IT capability development shifts to more agile approaches and shorter cycles, testing will shift to a near continuous, 'on-demand' service."* (Hutchison, 393)

JITC's TDL ATCGen and AMN CIAV efforts are both good examples of testing shifting to "on-demand"-like services. This same article suggests that

> *"test-driven development is a means to translate user stories into test cases before development begins; the idea being that when developers understand how the capability will be used, and therefore tested, development improves, and the resulting product has fewer defects."* (Hutchison, pages 393 394)

ATCGen and CIAV approaches and methodologies both translate user stories into testing requirements or test cases much earlier than traditional TE&C approaches, and these successes are an important aspect of this article.

A brief examination of the "as is" TE&C process, the proposed NDAA Section 804 acquisition process, and the differences between them

The "as is" TE&C process can be viewed in *Figure 1*. The time-consuming aspects of this "as is" TE&C process involve multiple test organizations. Each organization not only has various test documents that have to be reviewed, coordinated, and signed by numerous oversight stakeholders all having chains of command, but many organizations have multiple decision makers including program managers, program executive offices, component acquisition executives (CAEs), and milestone decision authorities (MDAs),

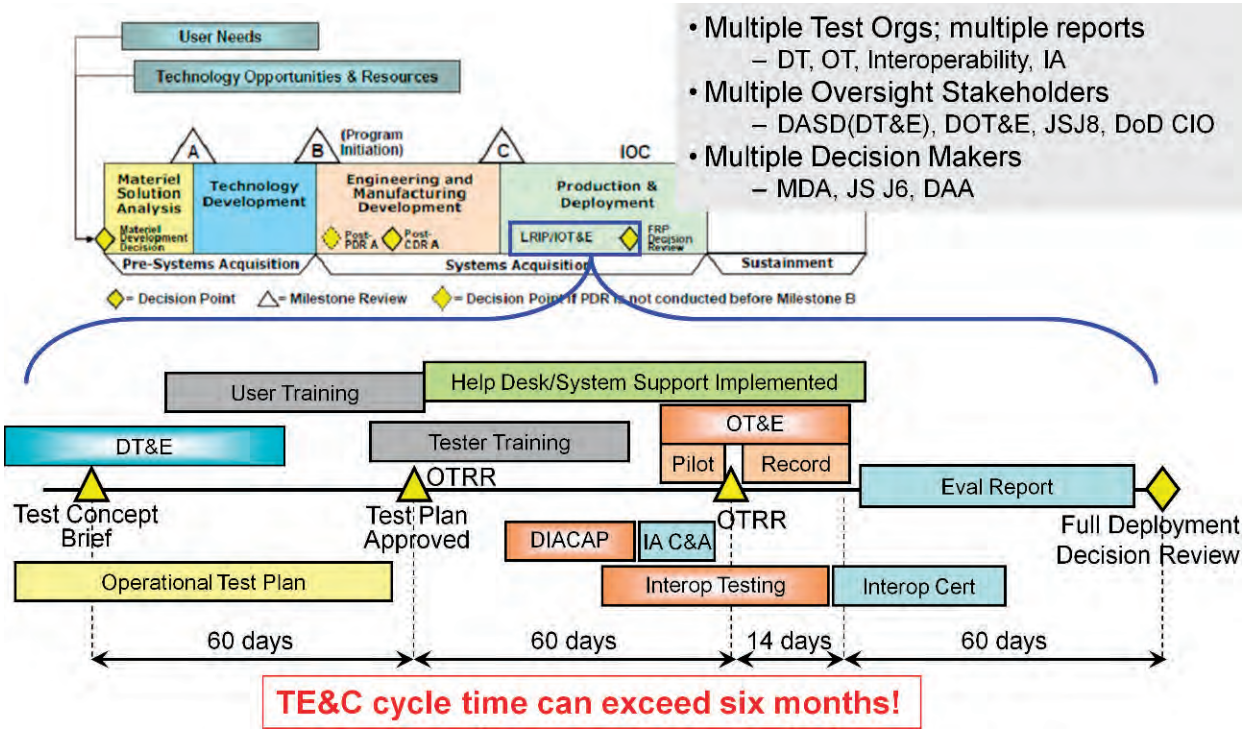

Figure 1. Snapshot of the "as is" TE&C process.[1]

among others that also have unique chains of command that are involved with staffing and coordinating fielding decisions. This is particularly challenging for joint information technology and national security system (IT/NSS) TE&C programs. Establishing testing as a service (TaaS) with other test methodologies, capitalizing on the Defense Information Systems Network T&E Network (DTEN), can help improve not only DISA's but the DoD's abilities to field enhanced services, software, and thus IT/NSS.

Because of rapid technology changes, one of the most significant challenges of IT acquisition reform for TE&C is to reduce the number of disparate test organizations, oversight stakeholders, and acquisition community decision makers, including program executive offices, CAEs, and MDAs. From the Defense Science Board's March 2009 report on policies and procedures for the acquisition of IT:

> *"The deliberate process through which weapon systems and information technology are acquired by DOD cannot keep pace with the speed at which new capabilities are being introduced in today's information age and the speed with which potential adversaries can procure, adapt, and employ those same capabilities against the United States."* (1)

Converging T&E network services in the DTEN, and making this available to all DoD Major Range and Test Facility Base elements and all DoD services and agencies, is paramount.

The DoD response in an NDAA Section 804 report to Congress (a November 2010 document titled "A New Approach for Delivering Information Technology Capabilities in the Department of Defense") suggested the following fixes to the current IT acquisition processes (OSD 2010): short-duration projects with incremental capabilities; "time-boxed" incremental capabilities to match commercial IT development cycles; inclusion of users in the fielding decisions; prioritized requirements with dialogue between developers and warfighters; continuous T&E integrated with certification and accreditation; a restructuring of traditional program phases, milestones, and review; and adoption of commercial IT processes, such as test-driven developments.

Toward this end, DISA's JITC has demonstrated TE&C methodology changes in TDL ATCGen and AMN CIAV testing approaches. Developing data management software through formal scrum processes in the development of the JITC Data Management Tool (JDMT) and the JITC Data Management Center (JDMC) also illustrates agile activities.

Following a commercial approach of agile software development using scrum processes, with an ultimate objective of evolving towards "integrated testing" by merging developmental, interoperability, information-assurance (security), and operational testing, JITC has

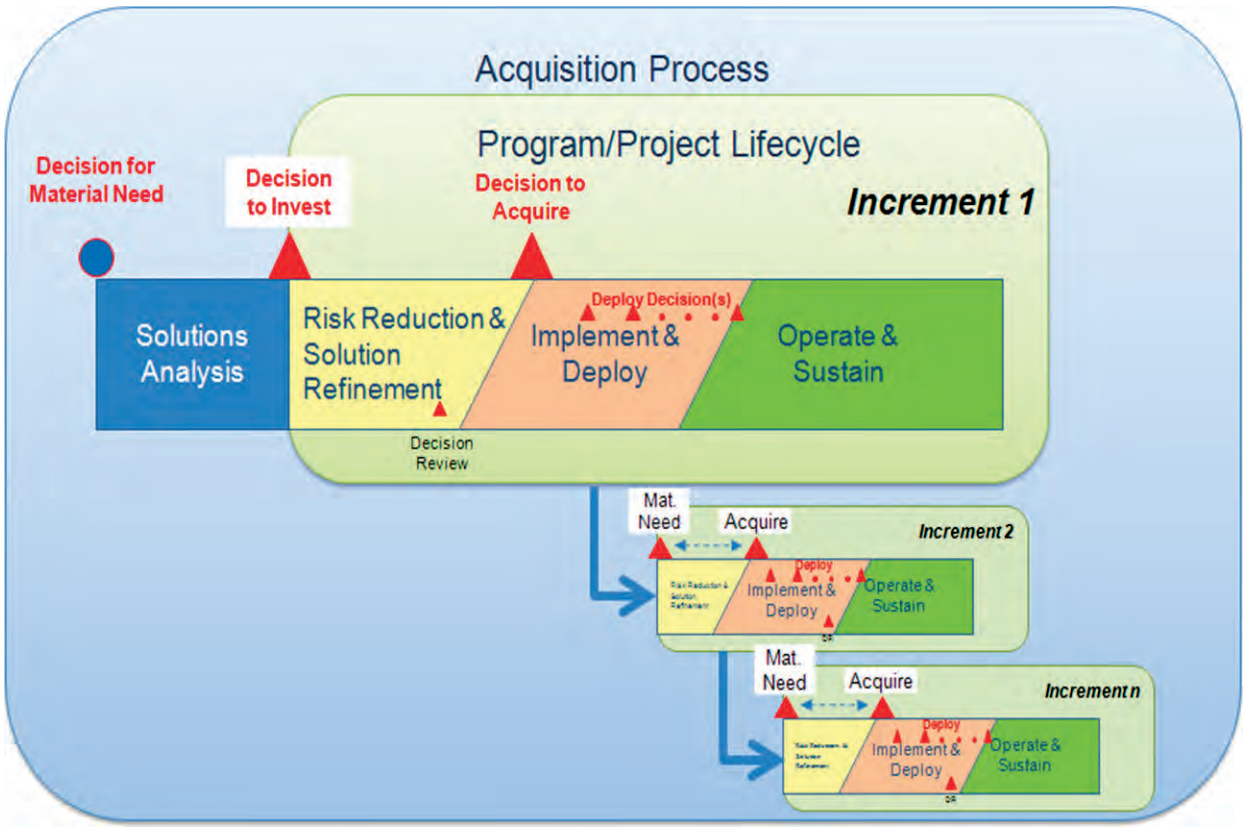

Figure 2. Proposed acquisition process.[2]

made significant progress with TDL ATCGen and AMN CIAV TE&C programs. Prioritized user stories (system requirements) have been developed and transitioned to test cases and then time boxed into "sprints" of capability development, with a primary objective of getting fielded systems into theater in shorter time cycles.

Fielding systems into theater more quickly is illustrated in the proposed modified acquisition process in *Figure 2*. Key tenets of the proposed acquisition process for IT in NDAA's Section 804 recommendations include: rapid fielding decisions of ever-increasing system capabilities via rapid cycles of identifying solutions; executing risk reductions; refining solutions; implementing and deploying systems; and operating and sustaining through increments of system capability (OSD 2010).

What is different between the "as is" IT acquisition process in *Figure 1* and the proposed NDAA Section 804 model in *Figure 2*? The key differences can be viewed in *Figure 3*: Requirements are prioritized and development cycles are shorter in duration. There is continuous testing, migrating towards an integrated testing concept and rapid capability enhancements. Finally, system capability changes are responsive to user requirements that continuously are reprioritized through user stories and test cases.

Ultimately, the objective of the Section 804 model is to migrate towards a "to be" TE&C process, graphically illustrated in *Figure 4*. Key to this "to be" TE&C process is the migration to integrated testing with a merging of developmental, information-assurance (security), interoperability, and operational testing. All of the testing should involve integrated planning, execution and test evaluation, assessment, and reporting. Host infrastructure must be considered and a persistent preproduction environment should be developed and utilized as a TaaS asset. The test methodology must transform to the usage of cloud computing services and Forge.mil environments. Integrated planning satisfying all stakeholders, risk-based integrated execution, and independent evaluation of integrated findings are all critical aspects of a "to be" TE&C Process.

DoE and SBTD as part of NDAA Section 804 transformation

In the midst of NDAA Section 804 debates the DoD tries to demonstrate faster and more agile means of fielding IT/NSSs for the warfighters. Some DoD T&E

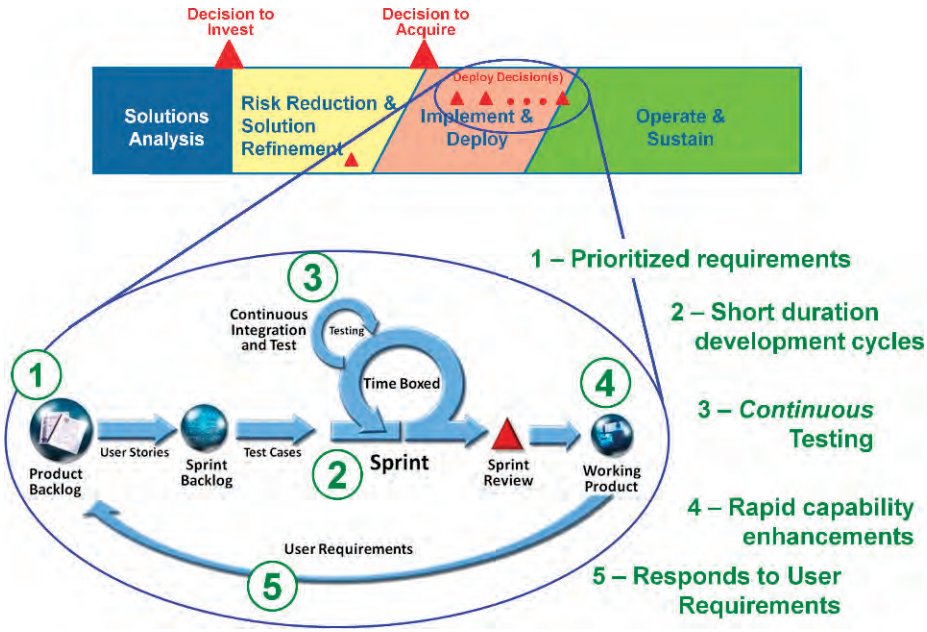

Figure 3. What's different?[2]

organizations are focused on integrating statistical rigor, DoE, and SBTD and CTM/mission thread TE&C concepts into testing methodologies, strategies, and concepts, with some mandates and strong endorsements from the OSD for DoE/SBTD.

Without a thorough understanding and acceptance of DoE, TaaS, SBTD, DTEN, and CTM/mission thread TE&C by all acquisition life cycle stakeholders that are involved with TE&C planning, execution, and reporting, the "agility" potential of DoE, TaaS, SBTD, DTEN, and CTM/mission thread TE&C cannot be fully realized. DoD system acquisition life cycle organizations need to not only embrace these concepts, but help engage and implement them in the "Solutions Analysis" phase of *Figure 4*.

DoE/SBTD approaches include the following elements: controlled test factors (controlled variables), system inputs, uncontrolled variables (noise), measures of system performance, and understanding of how varying controlled test factors can affect system

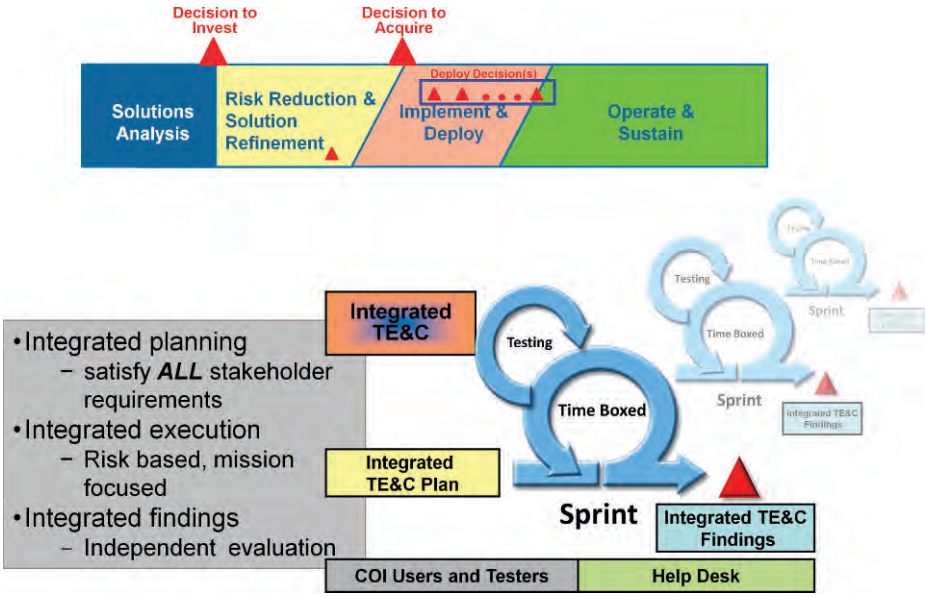

Figure 4. Snapshot of the "to be" TE&C process.[2]

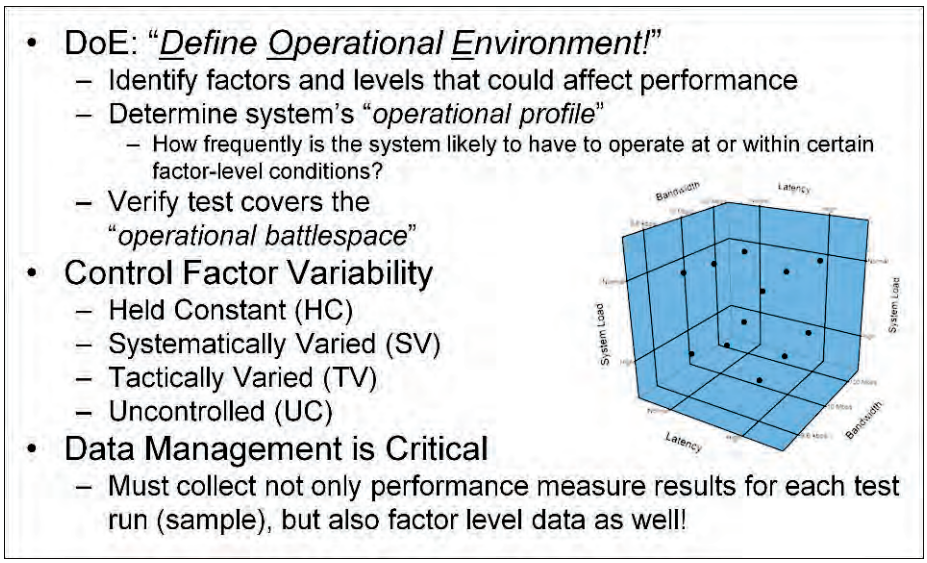

Figure 5. DoE in a nutshell.[3]

performance. *Figure 5* provides a simple graphical illustration of DoE in a nutshell, addressing controlled, uncontrolled, and response variables.

If the DoE and SBTD approaches are understood and agreed on by acquisition and TE&C stakeholders early in the phases of integrated planning, then DoE/SBTD advantages have a greater chance of being integrated into the TE&C methodology. Consideration of DoE/SBTD techniques should be given at the earliest developmental testing efforts and integrated testing. This could lead to better-defined operational testing scenarios for integrated testing and save time and testing resources as well. If analysing controlled test factors can help eliminated test cases, the operational testing envelope could potentially be reduced *(Figure 6)*. Critical to this scenario is the early use of automated test instrumentation data, log-file data, and even modeling and simulation data, so sample sizes are sufficient to accomplish statistical confidence intervals. To date, there have been instances in DoD TE&C programs in which DoE/SBTD were afterthoughts to the test concept and were forced into only operational testing. This is contrary to the potential advantages of DoE/SBTD being used early

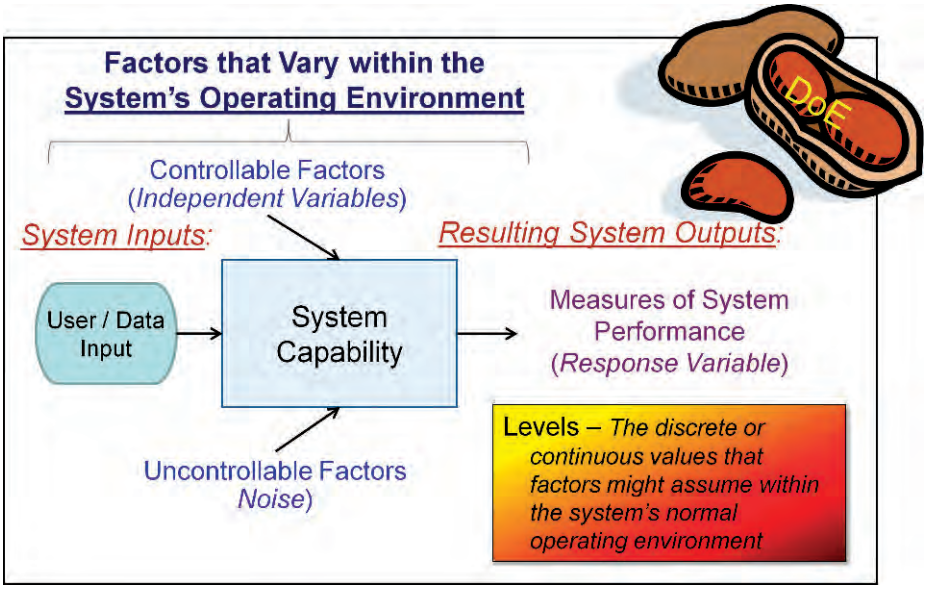

Figure 6. DoE considerations.[3]

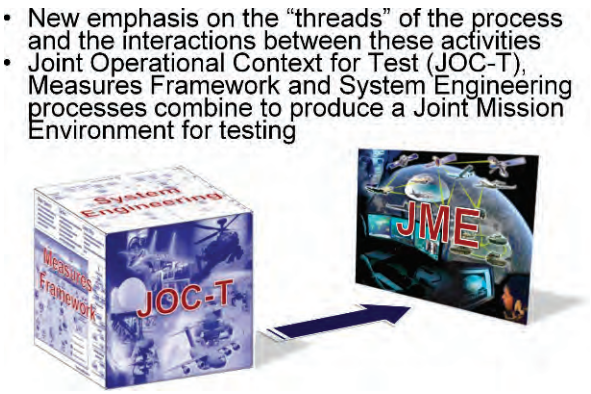

Figure 7. CTM (2010) "pillars." [4]

in support of T&E at the speed of need.

Perhaps the T&E organization in the DoD that has best defined and supported the return on investment for DoE testing is the U.S. Air Force (USAF) 46th Test Wing (TW). The 46th TW's Operations Analysis effort has been successfully implementing and executing DoE and SBTD methodologies in developmental testing programs with accolades from OSD for many years. Like JITC and various other DoD T&E organizations, including the Service Operational Test Agencies, the 46th TW has wrestled with DoE/SBTD techniques for IT/NSS. Because of this, the 46th TW, the Naval Postgraduate School, and JITC collaborated to develop a 5-day "DoE for Joint Interoperability IT System Testing" course. The Naval Postgraduate School taught this course four times at various locations from December 2011 through February 2012, with students from many different OSD, DoD T&E, and DISA organizations. The collaboration of these various DoD personnel with academia, sharing the objective of integrating DoE/SBTD techniques into applicable TE&C programs, supports the OSD Director of Operational T&E (DOT&E) and the OSD Director of Developmental T&E (DDT&E) objectives of integrating statistical rigor into T&E programs. This collaboration also supports the migration towards NDAA Section 804 and DISA/JITC's progression toward more agile TE&C processes and procedures.

CTM and mission thread TE&C as part of NDAA Section 804 transformation

CTM and mission thread TE&C concepts that are not understood by all acquisition life cycle organizations are sometimes assumed to increase costs and extend testing schedules. Better understandings of these concepts can indeed help with T&E at the speed of need. In 2009 and 2010, CTM transitioned into a mission thread TE&C analytical framework. If understood and implemented correctly by all DoD IT system

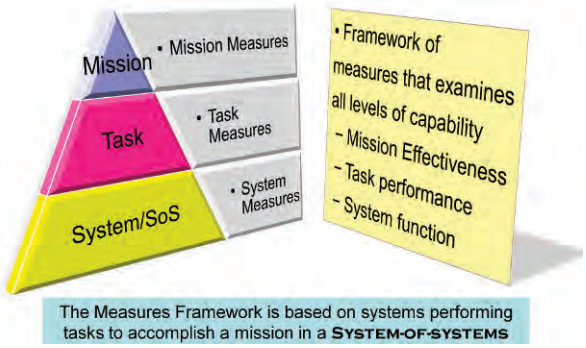

Figure 8. CTM measures framework. [4]

acquisition life cycle stakeholders, CTM and mission thread TE&C concepts can help with the key tenets of the NDAA Section 804 IT reform. In fact, implemented correctly, CTM and mission thread TE&C concepts can also have some synergy with DoE test methodologies and SBTD TE&C methodologies.

Figure 7 illustrates that in 2010, the CTM "pillars" reflected a new emphasis on the mission threads of the process and interactions between various activities which can have defined relationships to user stories and requirements. Defining and understanding these relationships can be complex. The joint operation context for test helps establish a measures framework involving mission, task, and system measures that tie back into the nine tier-1 DoD joint capability areas. The measures framework serves as a forcing mechanism to have measures at different levels to understand causality of what happens at the system level and how it impacts mission and task outcomes. From a systems-engineering standpoint, such a measures framework helps integrate a validated operational environment and helps verify that systems are integrated optimally. This measures framework also helps identify opportunities to target DoE and SBTD test factors that can be evaluated early in developmental testing to potentially reduce the operational testing envelope.

A CTM measures framework is the cornerstone of understanding how a system of systems actually performs in supporting a mission. A mission can be considered as a desired end state and the ability to answer the "so what?" Key to CTM and the mission thread TE&C approach is that task measures address activities across a task force and the functionality of the systems as they apply to a warfighter carrying out a mission, as seen in *Figure 8*.

The potential of using CTM and mission thread TE&C approaches with DoE and SBTD techniques can be increased by developing a mission thread analytic framework (MTAF). An MTAF integrates all the various entities together by mapping to mission

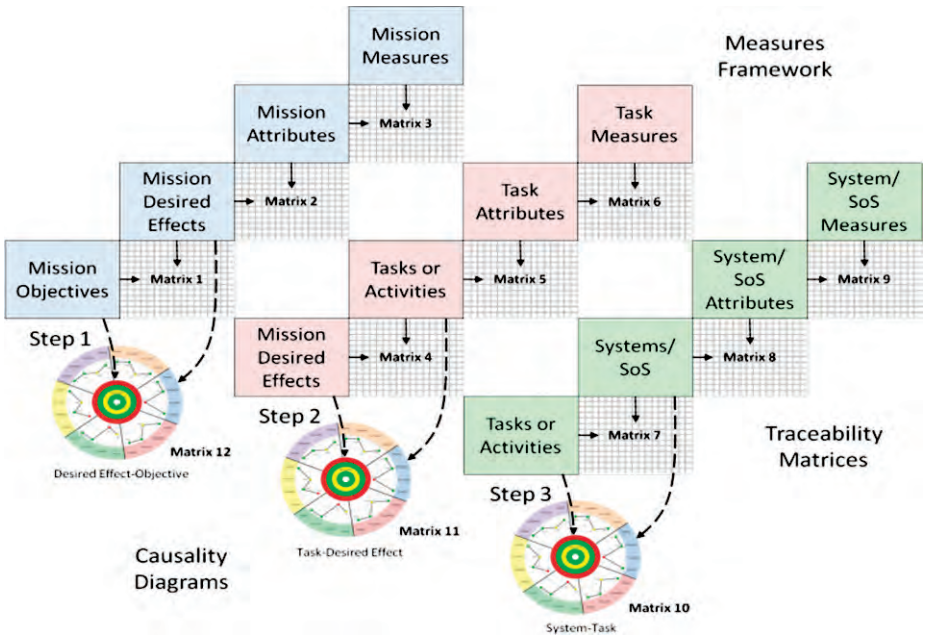

Figure 9. Mission Thread Analytic Framework (MTAF).[4]

outcomes and integrating all types of measures into analyses. As seen in *Figure 9*, matrices allow the mapping of each element or provide "bread crumbs" so one can trace the relationships. *Figure 9* graphically portrays the relationships in the path from system to task, task to desired effects, and desired effects to objectives, as they are viewed from the outer ring to the impact in the center.

Complex DoE, SBTD, and CTM/mission thread TE&C methodologies and techniques can be instrumental in the successful implementation of IT acquisition reform as the DoD transitions to integrated testing and TaaS methodologies and environments. The integration and execution of CTM/mission thread approaches and MTAF are vital to interoperability testing at the speed of need.

JITC examples of testing activities and software development towards T&E at the speed of need

Example 1: TDL Link 16 ATCGen testing

Current TDL Link 16 TE&C activities are expensive. Program offices and developers must schedule live and interactive major testing of a new system 6 to 15 months in advance. The testing requires other participants to precisely exchange Link 16 messages which may affect program results. Some critical areas of testing such as track correlation and decorrelation require complex geometric and time-sensitive calculations coupled with simulated sensor and Link 16 data. Joint TDL testing of a new system is commonly accomplished after completion of Service-level testing, usually long after development work is completed and when it is the most expensive to change.

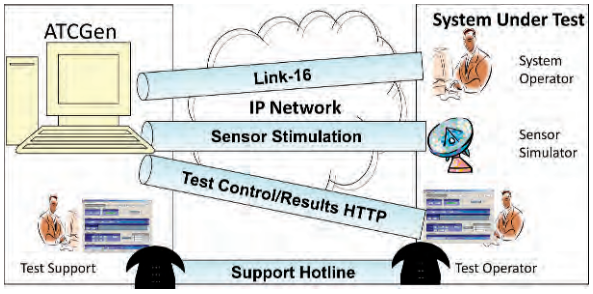

Figure 10. Automatic Test Case Generator (ATCGen) operational view.[5]

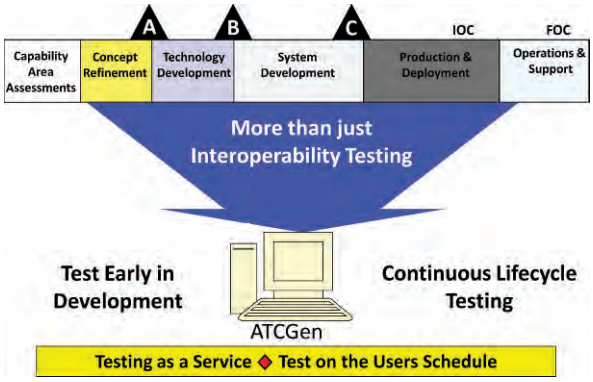

Figure 11. ATCGen supports the acquisition life cycle.[5]

Legacy systems that have been operating on the front lines for years have significant live testing cost to maintain their interoperability.

JITC must also maintain a costly test infrastructure and expert staff that too often spends effort retesting simple message exchanges instead of focusing on new and more complex data exchanges, such as net-enabled weapons. JITC's agile solution is a just-in-time TaaS system called ATCGen. ATCGen is an online Web service developed by JITC to test key Link 16 (MIL-STD-6016) portions of the standard. In *Figure 10*, ATCGen resides on an internet-protocol-based network on a secure intranet. After coordinating initial accounts with JITC action officers, the remote tactical system developers and testers log in to ATCGen using a standard web browser, select desired test cases, and begin testing. ATCGen simulates the system under test with Link 16 using the SIMPLE-J standard, and in some test cases with sensor simulation data via Test and Training Enabling Architecture or distributed interactive simulation standards. A typical test case takes about a minute to run. Pass/fail results along with exact mil-standard references are immediately presented to the remote tester and stored for the JITC action officer's records. ATCGen is tested and validated by independent divisions within JITC.

ATCGen reduces the program cost of testing TDL Link 16 and provides many advantages to program-of-record acquisition life cycle and to the JITC *(Figure 11)*. ATCGen is an online service that is available essentially full-time. After coordinating with JITC action officers, a program can test its system early in the development cycle and identify problems while they are less costly to fix. A system can be tested over and over again until it passes all test requirements. Message exchanges are compared to an independently validated reference system, reducing the risk of false problems as compared to testing with other systems under test. Complex geometric and time-sensitive behaviors such as correlation are more accurately tested. Programs don't have to wait months to test. JITC can use ATCGen to test common capabilities while focusing staff on testing new or complex data exchanges.

Using nonautomated or traditional testing processes, it typically takes about 90 days for analysis and publication of results. Using ATCGen, analysis is performed as the test case is executed and results are provided immediately at the conclusion of each test case. Systems testing with ATCGen will identify fixes earlier in the development cycle, test during their own schedules, and test with highly accurate and repeatable test cases, all in less time. Agile testing with ATCGen has the potential for substantial financial savings and supports TaaS.

JITC has been using a non-web-based version of ATCGen to support certification testing of U.S. and North Atlantic Treaty Organization (NATO) systems since 2009. ATCGen is in the final stages of its conversion to a Web-based testing service. JITC plans to expand the number of test cases from about 100 to a goal of around 500 test cases by 2014. In the past, ATCGen has supported minor parts of the DoD interoperability certification process, but it is JITC's objective to use ATCGen as a fully capable automated certification tool for U.S. and coalition systems as soon as is practical and to add an "active mode" testing capability to the existing "reactive mode" capability.

With any system, there are inherent advantages and disadvantages. The advantages of using ATCGen are supporting just-in-time testing, allowing testing earlier in the acquisition cycle, supporting full life cycle testing, reducing waiting, providing faster delivery to the warfighter, and reducing programmatic costs. On the other hand, there are disadvantages and limitations. ATCGen does not currently test the full standard, but rather the most common or critical areas. Currently, ATCGen only supports one user at a time. JITC is planning to accommodate multiple users in the future.

Example 2: Agile testing for AMN

AMN was chartered by NATO in March of 2010 with several goals, including:

1. To operate a seamlessly interoperable warfighting network in Afghanistan;
2. to actively baseline and track troop-contributing nation architectures for IT and for command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR);
3. to provide configuration management (CM) of the networks and software applications; and
4. to "assure and validate" IT and C4ISR applications for interoperability.

In support of these goals, the CIAV Working Group was chartered to address the interoperability-assessment responsibility. *Figure 12* depicts the AMN governance structures within NATO and in-theater. AMN has enjoyed substantial success. As operations in Afghanistan inevitably draw down, this federated mission network concept will continue with a "to be determined" new name. As of the time of writing this article, "Future Mission Network" is the program identifier of choice.

The CIAV Working Group has a large and growing mission to assure and validate that current coalition mission threads are being executed in-theater. Because

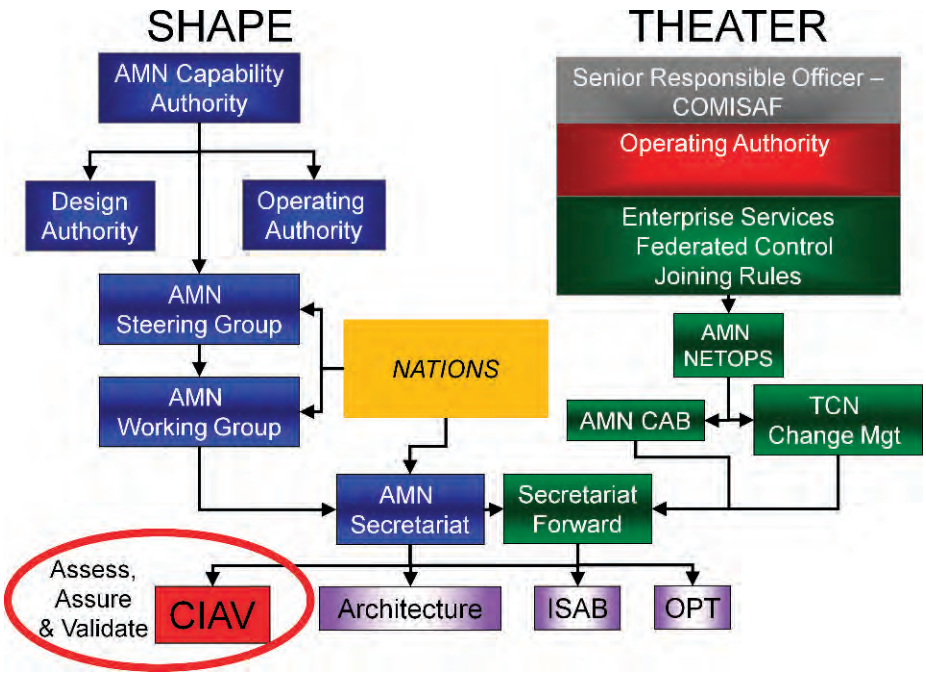

Figure 12. AMN governance concept.[6]

of international acquisition boundaries that limit test criteria within a nation, tests are actually "assessments," but the test community uses the term "test" interchangeably. Slow, cumbersome serial test processes that impede assessment and delay the delivery of capable systems directly affect warfighters' mission effectiveness. The CIAV leadership recognized the challenge and chartered a rapidly paced test cycle that nominally conducts one or two major assessments and three to six CM tests per 90-day test cycle; see *Figure 13* for a typical 90-day cycle. Tests are conducted on the Coalition T&E Environment, which is a cryptographically isolated enclave using the Combined Federated Battle Labs Network as transport.

Agile test processes

With only 90 days to complete test planning, test execution, and test results reporting for one or two major tests and several CM tests, the CIAV test teams do not have time to support traditional test processes.

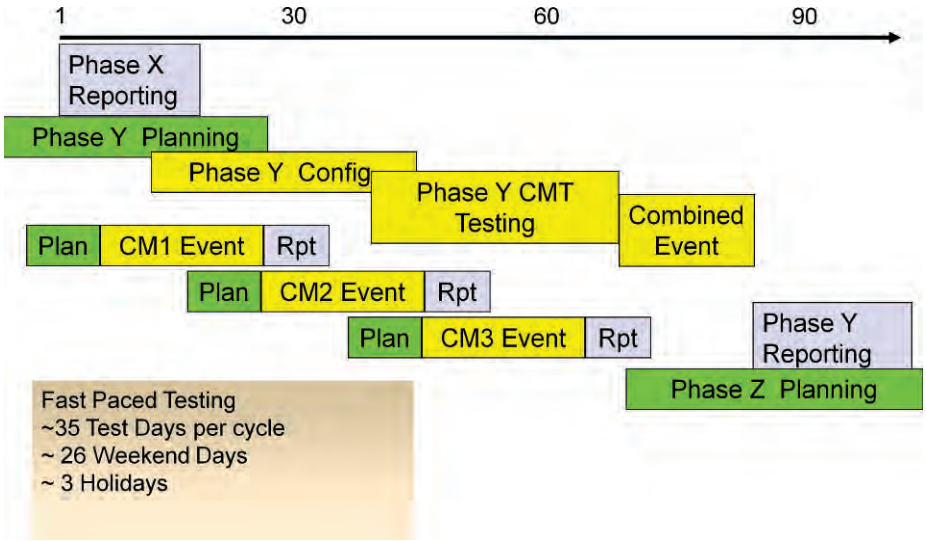

Figure 13. Generic 90-day AMN CIAV cycle.[5]

CIAV's agility comes from a combination of three methods: persistent repeatable processes, efficient planning and reporting, and quick analyses.

Agility through persistent, repeatable processes is supported by key factors that include a testing staff that is familiar with the processes and procedures; a persistent test environment that is always available; dedicated and easily accessible instrumentation to monitor networks, and data flows, dedicated to systems readily available for test; and a catalog of validated, repeatable configuration-managed use cases and test procedures.

Efficient planning and reporting improves agility. Experimenting with test processes within CIAV, the test team discovered that the typical large DoD test plans are not required. Most large test plans are too expensive and time consuming to produce, and too often unnecessary for an experienced test team familiar with the test process. The test team experimented with various levels of scrum test planning, from the low end of Excel spreadsheet and e-mail test plans to the typical 60-page test plan. Over time, the test team has settled on a combination of the following to support test planning: detailed DoD Architecture Framework or NATO Architecture Framework products such as architecture diagrams, operational activity diagrams, and event trace diagrams; DoD or NATO Architecture Framework products supporting the development of mission- and system-level measures, instrumentation, and data requirements lists; use cases and time-ordered event lists; and a 10-to-25-page execution plan that covers the details that the test community needs to conduct a test, such as test goals and criteria, schedules, participants, architectures, scenarios, contact information, ports, protocols, and addressing.

Test reporting has followed a similar experimental path to finding the optimal reporting process. The test team has tried everything from a short report to the full-scale approximately 200-page test report and is settling on a combination of test reports encompassing a CIAV Event Final Report that covers findings, which includes capabilities and limitations and associated operational impacts. This report is 12 to 15 pages total and is completed 3 weeks after the last test event. Data samples to support findings and allow systems developers and maintainers to find and fix their software "features" are included in the final report. A warfighter briefing to leadership, both in the continental United States and in-theater, is given within 6 weeks after the last test event

Throughout the 90-day test cycle there are multiple CM events and at least one mission thread event. These all require reports within 3 weeks from the end of testing. To accomplish this, data must be collected and analyzed, findings and observations must be adjudicated within a group of Coalition analysts, and a report must be developed. By requiring each test event to be discretely analyzed, the test team is able to shorten the time line for final reporting.

At the time of this writing, the CIAV Working Group is completing its fifth test cycle. Early test cycle analyses were mainly derived from real-time manual observations. The fifth test cycle is highly automated, with the ability to collect data from 18 systems in real time. Data are correlated, analyzed, and distributed to the CIAV report teams in more traditional reports and spreadsheets using data portals and secure e-mail.

This is still too slow, and due to the high workload and fast pace, the level of analysis is still not to the level of detail the test team desires. The team's goal by March 2012 is to more fully automate collection and reduction and to provide analysis to the reporting teams via a web interface. Within 12 hours of test completion, analysts will be able to select the desired test dates, select data sets, and receive raw and correlated data and high-level CTM/mission thread measures analyses.

As CIAV testing progresses, the level of automation and agility will increase with the goal of minimizing test personnel and allowing the test community to test with minimal manual analyses by maximizing automated analyses.

The CIAV assessment methods have many advantages and a few limitations. The advantages include a high capacity to test; a high success rate for finding and fixing problems; a low cost to maintain and staff a persistent test bed; a high return on investment; and the capacity to test using core mission-thread-based assessments to determine the ability of architecture to enable warfighters to successfully execute the mission, instead of detailed system-acceptance tests to determine if a system meets all procurement requirements. The limitations and challenges include testing across multiple typically nine time zones (which makes it difficult to test for a full 8-hour day); difficulty keeping an international community synchronized in a fast-paced test environment; and the need for more standardization within the test environment, although this is improving with time.

JITC example of an agile software tool development

JDMC serves as the primary data management center for accumulating, tracking, reducing, analyzing, and reporting test data for a growing number of JITC testing programs (it has supported approximately 20 different test programs). *Figure 14* is an operational view for JDMC.

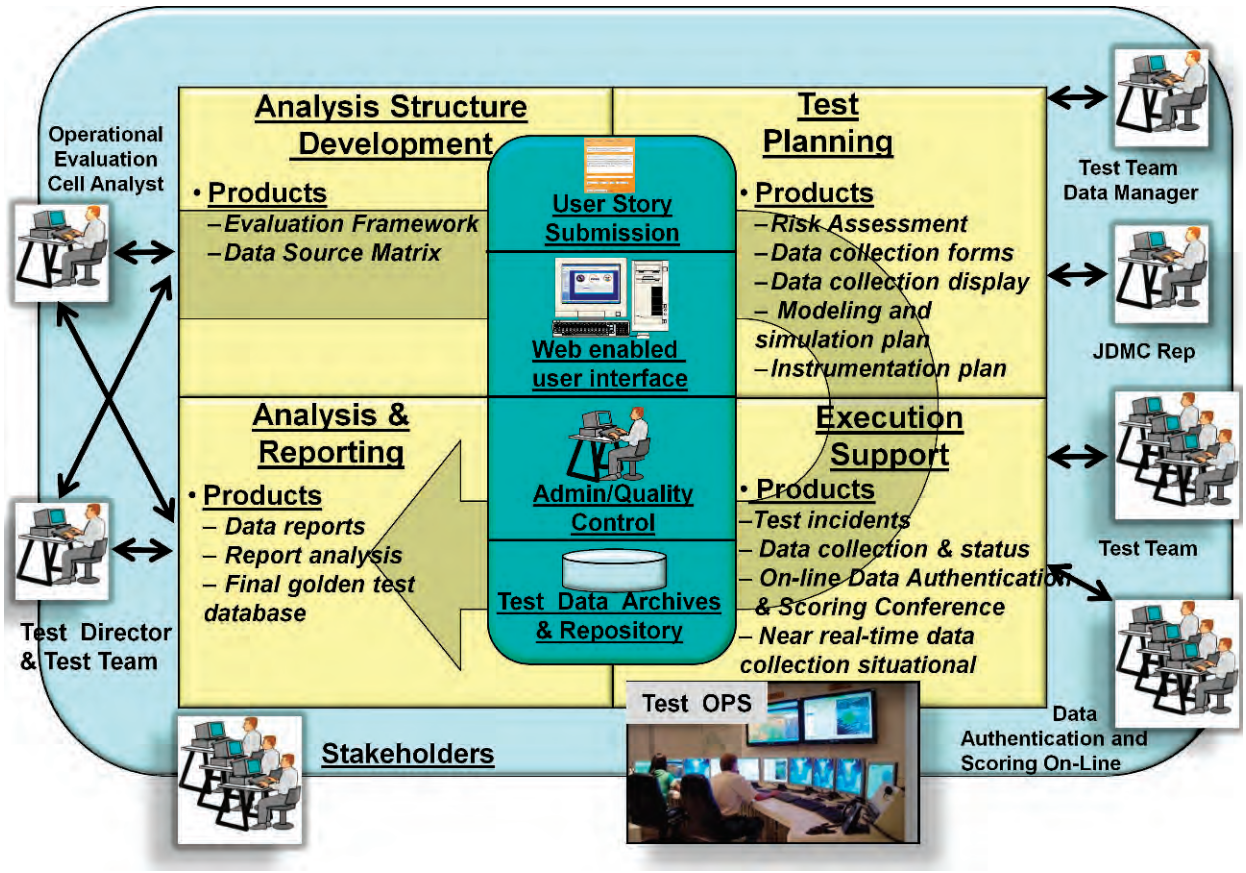

Figure 14. JITC Data Management Center (JDMC) facilities operational view.[7]

➢ **A JITC developed Microsoft Access based software tool**
- Aids in the development of Operational Test and Evaluation (OT&E) evaluation structures
- Supports the Capability Test Methodology (CTM) approach

Evaluation Element		Focus
➢ Critical Operational Issues	(COIs)	Mission-focused
❖ Measures of Effectiveness ❖ Measures of Suitability	(MOEs) (MOSs)	Operationally-oriented
⇨ Measures of Performance	(MOPs)	Task-based
⇨ Measures of System Attributes	(MOSAs)	Technical

➢ **Key Benefits**
- Encourages structure & rigor in developing evaluation structures
- Provide means to transfer relevant elements of a system's evaluation structure into the Joint Data Management Tool (JDMT)

Figure 15. JITC Capability Analysis Structure Tool (JCAST).[7]

JDMT provides the ability to manage, track, authenticate, analyze, and report/export test data and associated information. JITC will be integrating the JITC Capability Analysis Structure Tool (JCAST) into JDMT and migrating to SQL Server in the 2012 fiscal year. JCAST is a tool that provides the ability to develop test analysis structures (requirements, measures, data elements, etc.). It provides tools to develop and enter measures, associate them with requirements and Universal Joint Task Lists, and report/export them. JCAST's core structure evaluation framework starts with the DoD tier-1 joint capability areas. *Figure 15* shows the features and key benefits associated with JCAST.

JDMC's mission provides the primary data management capabilities and services preferred by the testing community in support of JITC test missions that have begun initial migration to an integrated test environment. JDMC assists test programs with all aspects of the testing life cycle, including test planning, execution, reporting, and analysis.

JDMC helps testers adapt to a newer automated process designed for capabilities and solutions, whereas former systems and data management used manual and redundant processes. Once tools and processes are in place, the SQL Server migration completed, and instrumentation and JCAST tools integrated, JDMC will be able to support more JITC testing programs. This should reduce costs and many of the redundant efforts typically necessary under the traditional data collection methods. Data will be available to appropriate stakeholders to meet their individual needs once it is authenticated and entered into the system. This near-real-time data availability will expedite processes and reduce unnecessary redundancies and costs while fielding capabilities and solutions for our warfighters more quickly.

Though the JDMC uses a suite of commercial and government off-the-shelf software, the major portion of the in-house-developed data management software tool for JDMC has been developed using the scrum framework, an agile software development methodology. JDMT is JITC's first software tool developed using scrum; plans are in place to use scrum for all future JDMC development efforts in addressing and delivering timely user-identified and prioritized needed capabilities.

The JDMC software development team is composed of government and contractor personnel known also as the JDMC Scrum Team, with a full-time product owner, scrum masters, and scrum team members who are developers and dedicated testers. The product owner retains a product backlog of JDMT requirements expressed in user stories. Based on priorities and considerations of return on investment, the product owner offers up a number of user stories to be worked by the scrum development team during the Sprint Planning meeting, the initial start of a Sprint cycle.

For JDMT, the Sprint is the length of the development window set at every 2 weeks. The Scrum Team determines what user stories offered up to product owner can be worked off within the 2-week Sprint. The adopted user stories are then tracked in the Sprint backlog, where the scrum development team breaks them down into executable tasks. At this point the scrum development team collaborates with the scrum team testers to develop test cases to determine when a user story meets the acceptance criteria or is considered "done." Collaboration with the user and the testers continues throughout the Sprint cycle to ensure that what is delivered at the end of the Sprint is what the user wanted and that the "done" criteria are met using input from the developed test cases and user acceptance testing. The testers play a key role in agile development methodologies, especially when executing short Sprint cycles. Not only do the new capabilities need to be tested, but the entire baseline also needs to be tested to ensure that the release of the new or enhanced capabilities did not impact the original baseline, thereby resulting in minimizing defects with the new release. This can only be accomplished through automated testing methodologies.

At the end of the Sprint cycle, the JDMT Scrum Team holds a Sprint Review meeting, demonstrates the working software produced during the Sprint, and determines whether the user stories met the "done" criteria. When considered "done," the software is considered releasable based on the product release strategy. To complete the Scrum Sprint cycle, the JDMT Scrum Team holds a Sprint Retrospective meeting to determine what went well and what can be improved upon, in an effort to continuously review and improve the team's scrum process with the intent of applying these lessons learned to the next Sprint cycle.

Throughout the Sprint cycle the team holds daily meetings. Due to the distributed nature of the Scrum Team, they have elected to use a Defense Connect Online instant-message conference room as their medium to conduct the scrum daily stand-up meetings, where each team member along with the scrum master states what was accomplished in the last 24 hours, what will be accomplished in the next 24 hours, and whether there are any impediments in the way. As a team they also update their task status, collaborating on tasks to be accomplished as a team as they continue to burn down their tasks during the Sprint. To capture how quickly and how well tasks are being accomplished over the Sprint, the team maintains a burn-down chart

indicating daily completion progress on the user-story decomposed tasks that were selected for this Sprint. Once a Sprint is completed, the process starts again and is repeated for the next Sprint. The scrum framework has proven thus far to provide a much more stable software development environment, with much improved visibility to the user as to what capabilities will be delivered at the end of every Sprint.

The next generation of JDMC is on the horizon, with development having begun in January 2012. By leveraging all the lessons learned, JDMT version 2 is anticipated to be a model for test-driven development where user needs are quickly met while minimizing defects. This effort continues to serve as a key test bed on how JITC, as a testing organization, will be able to support acquisition test programs adopting agile development methodologies to provide capabilities to the warfighter.

Conclusion

Given DoD RDT&E fiscal realities and the speed of rapidly changing IT technologies, T&E at the speed of need must be accomplished. Simultaneously with OSD's NDAA Section 804 IT acquisition reform efforts and potential impacts of new versions of the DoD 5000 series documents, DoD T&E organizations must execute agile processes and procedures in various testing activities and programs and in software developments using techniques, processes, and procedures that have some proven track record in industry or in pockets of excellence sprinkled throughout DoD. The use of TaaS test methodologies and DTEN for DoD services, agencies, and Major Range and Test Facility Base elements is vital to more rapid fielding of IT/NSS to the warfighters. Converging T&E network services and federating these services across DoD must be accomplished.

Though not thoroughly understood by all stakeholders in the life cycle acquisition process, agile TE&C, SBTD, DoE, and CTM/mission thread TE&C need to be studied for potential usage in DoD testing activities and software developments as the DoD transforms IT acquisition and evolves to a true integrated T&E environment. NDAA Section 804 IT acquisition reform recommendations have been demonstrated in varying degrees involving JITC's efforts with the TDL ATCGen and the AMN CIAV testing activities and JDMC/JDMT agile development case studies in this article. A significant challenge for DISA, JITC, and numerous other DoD T&E organizations that test IT systems is to incorporate some of the agile and CTM/mission thread methodologies from JITC's TDL ATCGen and AMN CIAV testing activities in conjunction with practical applications of DoE/SBTD techniques into DoD systems of record across the spectrum of the system acquisition life cycle in an integrated test scenario, using DTEN, TaaS, and cloud computing and Forge.mil environments.

Attracting, hiring, and retaining an optimal combination of TE&C engineers, operations research analysts, scientists, and IT specialists who understand and can implement IT acquisition reform policies, agile processes and procedures, TaaS, cloud computing, DoE, SBTD, CTM, and MTAF are high priorities for JITC. In concert with practical implementation of agile TE&C, SBTD, DoE, and CTM/mission thread TE&C into test strategies and concepts, it is vital that JITC and all major DoD T&E organizations collaborate with each other and seek training from academic institutions that are expert with new technologies, new processes, and new techniques.

Towards this end, in parallel with JITC's examples of "agility in action" TE&C activities and software developments, JITC has engaged in technical exchanges and training programs with the International T&E Association, the Armed Forces Communications and Electronics Association, the University of Memphis, Georgia Technical Research Institute, the Naval Postgraduate School, the Air Force Institute of Technology, Arizona State University, the University of Arizona, the Defense Acquisition University, and Cochise Community College, among other academic institutions. Implementation of technologies via academic outreach and collaboration with industry and DoD T&E and acquisition partners are key JITC strategies for supporting our nation's warfighters with testing at the speed of need. ❑

Randon (Randy) R. Herrin is a retired U.S. Air Force officer currently serving as the JITC senior technical director and chief scientist at Fort Huachuca, Arizona. Herrin did some helicopter flying, but spent most of his Air Force career with RDT&E, and with systems acquisition program management office organizations involved with C4ISR systems. Herrin has an undergraduate degree in mathematics and three advanced degrees, including being a distinguished graduate from the Joint C4I Systems Technology master's-degree curriculum at the Naval Postgraduate School. He has been an ACAT I program manager for different C4ISR programs and has a DAWIA Level III certification in systems engineering, program management, and test and evaluation. Herrin is widely published in a variety of professional journals and has served in various local chapter and national positions for ITEA and the Armed Forces Communications and Electronics Association. Most recently, he served as the ITEA Publications-of-the-Year Chairman from 2004 to 2010; he became the ITEA National Education Committee Chairman in 2011. E-mail: randon.herrin@disa.mil

Neil Barrett is a senior engineer at JITC with 21 years of testing experience focused on developing and providing test instrumentation. He has designed several ruggedized computer systems, many electronic data capture boards including serial and Ethernet sniffers a Single Channel Ground and Airborne Radio System simulator, a radio-controlled remote firing device for countermeasure testing, and hundreds of tools and machines. Barrett also led software development of significant C4ISR software testing systems, including the Joint Operational C4ISR Analysis Tool, ATCGen, the Remote Truth Detector, and the Personal Identify Friend or Foe. He is currently leading the development of CIAV instrumentation. Since earning a bachelor of science degree in engineering from Arizona State University in 1982, he has diversified his engineering education with approximately 110 college credit hours in systems engineering, modeling and simulation, software programming, network engineering, and electronic design. For fun, he tests ropes by falling from smooth vertical rocky surfaces. E-mail: neil.barrett@disa.mil

Endnotes

[1]Graphic previously published in the *ITEA Journal*; see Hutchison 2010a.

[2]Graphic created by the IT Acquisition Reform Taskforce TE&C Workgroup from presentation to DoD chief information officer, June 2011.

[3]Graphic created by Mr. Terry Powell, JITC Operational T&E Division, March 2011.

[4]Graphic created by Mr. Max Lorenzo, DISA T&E Office, November 2011.

[5]Graphic created by Mr. Terry Powell, JITC Operational T&E Division, March 2011.

[6]Graphic created by the NATO AMN Secretariat's Office.

[7]Graphic created by Mr. Gerry Lopez, JITC Operational T&E Division, November 2011.

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Agile Compliance Testing With Commercial Vendors

Jana Gallatin
Defense Information Systems Agency (DISA) Joint Interoperability Test Command (JITC),
Fort Huachuca, Arizona

Leveraging information from agile software development, the Joint Interoperability Test Command (JITC) is applying scrum-related methodology to provide ongoing, component-based, perpetual validation of product compliance in accordance with Department of Defense (DoD) 5015.02-STD, Electronic Records Management Software Applications Design Criteria Standard *(Department of Defense 2007). Subscription-based funding enables collaborative and iterative testing that supports the vendors' development processes. Three levels of subscription service allow flexibility for planning fiscal-year engagements, which supports out-year planning for both the vendors and the testers. Add-on packs permit ad hoc support of additional testing as needed during the fiscal year. Known levels of test support enable agile testing by not contractually specifying the scope of the testing. Developers and testers work together to decide how best to schedule the development and testing.*

Agile testing is collaborative by nature and enhances testers' visibility into the developing software and means of testing transparency for the vendors. Test-driven development leverages agile development by supporting definition of vendors' specifications within the context of how the solution will be tested. Test-first development supports testing of existing vendor functional capabilities, which enables vendors to modify their specifications only where necessary to develop required functionality. Agile testing supports frequent opportunities for testing as components are built, delivered, integrated into the solution, and upgraded during the system life cycle.

Key words: Agile; records management; standards testing; perpetual compliance.

Prior to the Persian Gulf War (August 2, 1990 to February 28, 1991), most Department of Defense (DoD) managed federal records were stored in nonelectronic formats and managed by trained file clerks. During this war, electronically stored information and electronic communications provided the strong command and control foundation for the modern military that enabled advanced technologies such as integrated intelligence systems, global positioning systems, and effective theater-wide communications. Automation and electronically stored information led to the creation of tens of thousands of electronic federal records. The Joint Chiefs of Staff were responsible for "coordination of logistic and administrative support of the component forces of their unified command" (Joint Chiefs of Staff 1948). However, harmonized policy and processes for managing electronic federal records had not been developed and effectively promulgated. Military units were focused on winning the war and had little or no guidance in how to archive information as they transitioned out of theater, so federal records that had been created in the prosecution of the war were not routinely captured and some were lost or destroyed.

As the war continued, support activities back home were increasingly reliant on digital creation of federal records. During the Clinton administration, Vice President Gore championed the effort to re-engineer government by leveraging computers and paperless offices. File clerks, records managers, information managers, and the National Archives found themselves faced with hundreds of thousands of federal records in formats for which no planning existed.

In 1993 and 1994, the Assistant Secretary of Defense Command, Control, Communications, and Intelligence undertook a project to reengineer the Records Management Business process to bring management of electronically stored information and Federal Records under control. The Federal Records Act of 1950 (44 U.S.C. Chapter 31) (U.S. Code 2011b), as amended, establishes the framework for

Federal Record Lifecycle

Figure 1. Capabilities required for supporting the life cycle of a federal record. ''Capture and identify'' includes functionality to expose the record to management and identify the record with metadata. ''Store and protect'' includes functionality to protect the record from change and control user/group access. ''Discover and use'' includes functionality to query and retrieve the record. ''Schedule and manage'' includes functionality to manage a file plan and track records through the life cycle. ''Accession or destroy'' capability includes functionality to export records for transfer to the National Archives or complete destruction of the record.

records-management programs in federal agencies. *Figure 1* shows the major capabilities required to manage federal records. (For more detailed information about federal records management, please visit Archives.gov and search for "records management.")

In 1995, the Defense Information Systems Agency's Joint Interoperability Test Command (JITC) was charged with supporting the Office of the Secretary of Defense in the technical development of what became DoD 5015.02-STD, *Electronic Records Management Software Applications Design Criteria Standard* (Department of Defense [DoD] 2007) and associated compliance testing. DoD 5015.02-STD describes the software capabilities necessary to support electronic management of DoD's federal records.

As requirements for creating automated functionality emerged, testers were challenged with identifying ways to evaluate the capabilities. Records management is a foundational information-management activity, and by federal law it must be adequately addressed by all federal agencies. Yet each agency has unique mission needs and requirements for managing mission information, so one-off traditional end-to-end operational testing does not support acquisition. Developmental testing alone verifies functionality at the component level but does not address the required capability to be integrated into a variety of enterprise environments. Since 1997, JITC testers have collaborated with vendors to evaluate solutions using a standardized scenario and test cases in a high-stakes end-to-end test. This testing resulted in a single version and configuration of the software that was evaluated as compliant, with a compliance period of 2 to 3 years before retesting was required.

Existing testing methodology was insufficient to provide acquisitions efforts with compliant products and to provide vendors with the ability to seek compliance for variations on the versions and configurations without undergoing the whole test process.

DoD agencies using software to manage federal records must use software that complies with DoD 5015.02-STD (DoD 2007), as required by DoD Directive 5015.2, "Department of Defense Records Management Program" (DoD 2000). Commercial vendors such as EMC, Oracle, Feith, Hyland, Iron Mountain, IBM, Hewlett-Packard, OpenText, Autonomy, and GimmalSoft and open-source service providers such as Alfresco have either modified existing document- and content-management systems or created dedicated records-management solutions. These solutions undergo compliance testing.

The simultaneous development of the standard and test scenario and test cases provides the vendors with the opportunity to implement test-driven development ("Test-driven development") and extreme programming ("Extreme programming"), which support their agile development efforts for creating and integrating the new capabilities into their enterprise and cloud-based offerings.

DoD 5015.02-STD is constantly under revision as required by DoD policy, and it is necessary for stakeholders to keep up with new changes in technology and requirements. Today's technologies provide the capability to produce records anywhere, anytime, and to store them everywhere.

Recent changes in the Federal Rules of Civil Procedure have impacted public and private companies, as well as government agencies like the DoD, as they realize the need to implement records management to address new electronic discovery requirements. Those requirements are not limited to official records, but apply to all electronically stored information.

DoD issuances are officially reviewed and revised on a 5- or 6-year cycle. Each cycle includes a review of lessons learned and best practices identified in the

interim since the last revision. Advances in technology allow for new capabilities and upgrade of existing capability areas. For example, instead of waiting to capture a record upon publication, the "capture and identify records" capability (see *Figure 1*) can be enhanced to capture and annotate records before birth, by identifying the types of information to be generated by business-process modeling and associated information-technology-enhanced collaborative work flows. As a document matures through its development life cycle, contextual metadata are associated with it, so that when the document is published as an "official record" it has a full provenance. This information is critical for establishing both trustworthiness and discoverability of authoritative information resources.

Figure 2 illustrates simultaneous development for the DoD 5015.02-STD publication cycle. As capability areas are identified and revised, researchers develop updated user stories that identify the user role, goal, and benefit. An example of a user story would be "As a records researcher, I would like to further query result sets, so that it is easier to gather specific records for analysis." The user stories with the new and updated capabilities provide groundwork for revising and updating the end-to-end capstone test scenario, as well as test cases for evaluating vendor component functionality. User stories and test cases support definition of clear, unambiguous, and testable functional requirements. The testers, collaboratively with vendors, validate the test cases and scenario iteratively as components are developed and capabilities delivered. Once validated, the test cases and scenario form the basis for determining compliance with the current version of the standard.

JITC applies scrum-related methodology as part of agile software development for perpetual validation of product compliance with DoD 5015.02-STD (DoD 2007).

Key aspects of the compliance testing methodology

Service-based subscriptions

Subscriptions enable a collaborative relationship between JITC's testers and the vendors' technical staff. Levels of service include three tiers of annual support with optional add-on testing service packs. Service subscriptions also allow vendors and JITC to better plan and manage annual budgets and staffing and reduce contracting-paperwork overhead. This translates to better tester responsiveness and availability. It also allows development of an ongoing, collaborative relationship that provides testers valuable insight into emerging technology.

Component-based testing

Vendors allocate requirements to components and further refine them to component specifications. As the components emerge, vendors can "tap a tester" to look at proposed designs and interfaces to get early feedback about whether something will pass the test or not. Once the components are coded, vendor test technical-support personnel install them into the test environment for testers to evaluate and provide feedback on. As components are revised or integrated into the overall solution space, testers perform targeted

Figure 2. Illustration of the activities to update DoD 5015.02-STD (DoD 2007) and associated test program.

regression testing to ensure that the end-to-end records-management mission is smoothly evolving.

Collaborative testing

Testing is designed to plug into the vendors' existing development schedules. Software development is not a beginning-to-end sequence that maps with any specific mission thread or work flow. Components have dependencies that may require sequential development or allow parallel development.

Iterative testing

As shown in *Figure 3*, JITC testers collaborate with the vendors to identify the items from the product backlog to be addressed in each sprint and draft the development and test schedule ("Scrum (development)"). Testers execute tests as the components become available and provide immediate feedback. Vendors are encouraged to provide at least one component per month for a test sprint. Testers identify which portions of the scenario (if any) will be exercised and which test cases or steps are to be exposed. During the test sprint, daily stand-ups are held via e-mail, chat, or teleconference. Testers draft end-of-day status reports to feed back to the vendor's team to plan for the next day's stand-up. Testers continue through the planned sprint unless test anomalies stop progress. At the end of the sprint, testers detail the issues that require attention before that component can be tested again.

Once all the components are exposed to testing, an end-to-end capstone test verifies that all functionality is present and properly integrated into the records-management life-cycle processes. Upon successful completion of the capstone test, the product is listed as compliant on the JITC product register.

As the vendors integrate new user-requested capabilities and repair software anomalies, they collaborate with JITC testers to perform targeted and regression testing to verify continued compliance. JITC testers will also offer vendors the opportunity to collaboratively validate emerging functional requirements and test cases, with functionality compliance credit given for positive outcomes. This evolutionary feedback into the standard and test-program development allows vendors to incrementally move towards compliance with the developing new standard.

Key benefits

Transparency

JITC testers have visibility into the vendor's development environment as early as the vendor requests evaluation of an idea or component. This understanding allows testers to better predict what tools and capabilities they will need to test emerging technology. Vendors have visibility into the requirements and capabilities that will be included in the next version of the standard and test program. This allows them to better allocate and schedule updates, enhancements, and new functionality into their products.

Collaborative component-based scheduling

Developing a software component is analogous to shooting a scene for a movie. As the scenes are shot, they are edited into place just as components are integrated into the solution. It is only after the last scene is shot that final editing/integration begins. Even then, a director or scrum master may send the cast back into the studio. JITC testers support this out-of-sequence behavior and will collaboratively identify software harnesses and stubs that will provide sufficient visibility into the component's behavior.

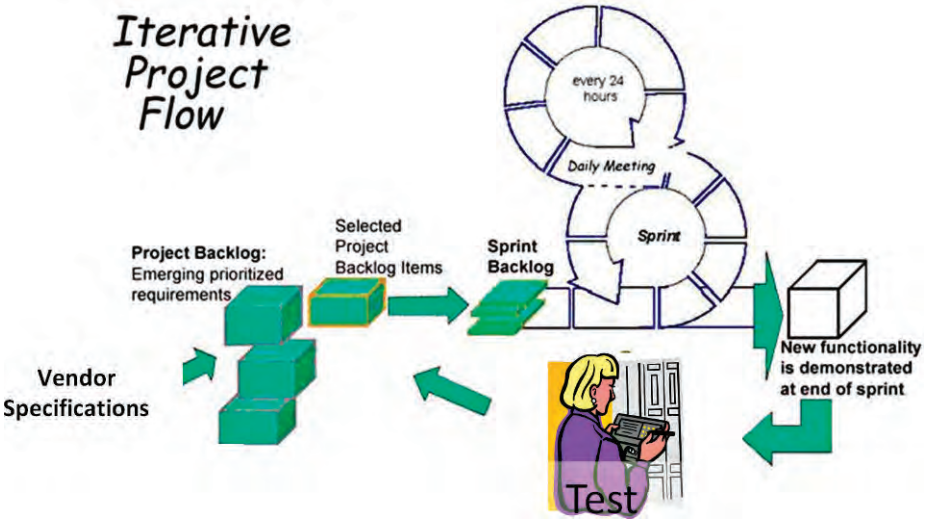

Figure 3. Scrum iteration.

Frequent test exposure

As components are moved into the product baseline, they are exposed for testing opportunities. JITC testers work with vendor teams to identify where and when items should be subjected to retest. Testers will also perform some amount of "free testing," unplanned interaction with the software to review how it responds. Most component testing is based on the Web or a virtual private network, which allows frequent and easy access to the software. JITC testers will perform hands-on testing after demonstration or walk-through of the functionality. In some cases, JITC testers may evaluate planned functionality presented through a developmental design review.

Iterative integration and regression opportunities

Vendors have the opportunity to iteratively deliver upgraded capabilities without requeuing for compliance testing. JITC testers have access to check functionality that has been reported anomalous or has been difficult to configure during testing, and to provide guidance about the intent as well as the letter of the standard, encouraging vendors to make minor changes that gradually improve software functionality.

Operational-test-like capstone

JITC's scenario includes the dependencies and process flow shown in *Figure 4*. The scenario also includes roles for testers to provide end-to-end evaluation of a vendor's records-management solution. Once 90 percent of the requirements are exposed in component testing, the vendors and JITC tester confirm the schedule for the capstone test. JITC testers assume the roles associated with the records-management responsibilities and execute work flows and processes to evaluate how the software will support the organizational records-management requirements.

DoD 5015.02-STD requires that capabilities be accessible via Web technology. Testers conduct most of the component testing remotely, which proves Web accessibility. Web access can be slow, so to ensure that the capstone test can be completed in 1 week, vendors and JITC testers determine whether the capstone test will be on-site or based on the Web or a virtual private network.

Touch validation and appropriate regression testing as upgrades and patches are applied

Once the vendor deploys the initial solution, JITC testers continue to be available to advise and evaluate patches, upgrades, and additional capability.

Add-on integration evaluations supported with a short lead time

Many vendors choose to add on optional capability such as managing classified records or supporting Freedom of Information Act and Privacy Act requests. Mid-tier subscription and add-on testing service packs allow shorter lead time to begin evaluations, even providing tester input and guidance on the intent of specific requirements.

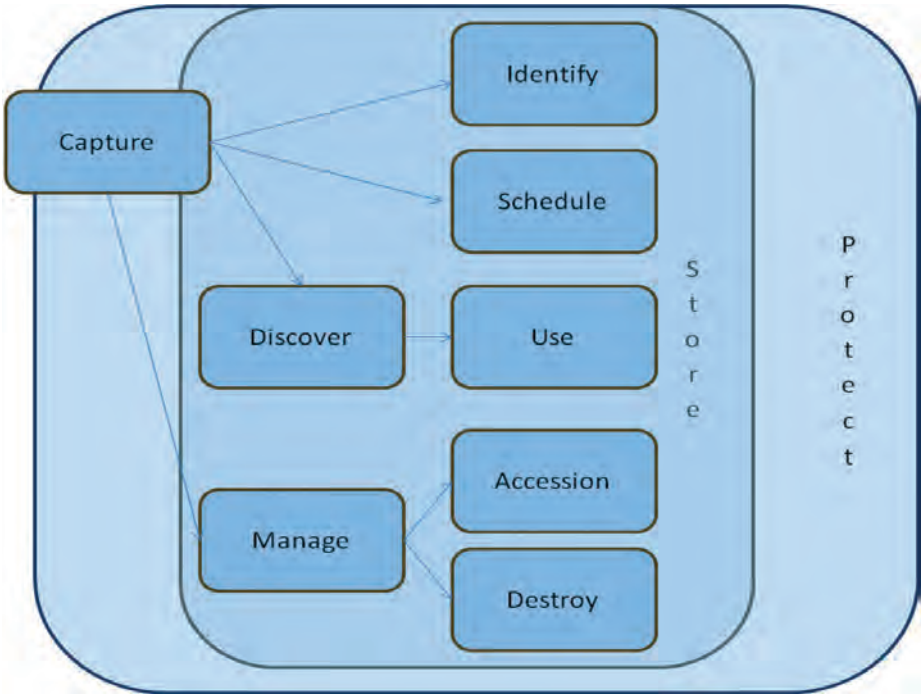

Figure 4. Records-management dependencies and process flow.

Ability of dedicated testers to domain and solution subject-matter experts

JITC records-management testers are domain experts in federal records management. Many vendors do not have access to records managers or federal records managers, and developers appreciate clarification of overloaded terms such as "record," "version," and "life cycle." Dedicating a team of two testers to each vendor allows the testers to become conversant in the developer's vernacular, which makes them more effective testers and "interpreters."

Collaborative discussions with vendors about emerging requirements

Vendors must keep on top of technology to maintain market share. They have to be innovative and creative in providing solutions to their customers. JITC testers can leverage this to identifying emerging functionality that may impact DoD records management. Currently, XML is technology that supports interoperability, long-term archiving, and continued exploitation, but as the information-technology community learns more about how to effectively represent data, new standards are born and integrated into the set of electronically stored information that must be managed. To be able to continue to use a long-term record, it should be transformed or translated into the new representation(s) at regular refresh cycles to ensure that the data representation will continue to be supported by technology. Federal records stored as MultiMate or Lotus 1-2-3 files and in other formats that are no longer supported by editing programs do exist, but they do not meet the intent of the Federal Records Act, because of their limited usability.

Vendors provide feedback on the feasibility of emerging functional requirements and advise on wording that makes requirements easier to understand and implement.

Nonexpiring certification

While the commercial world is moving to provision capability within days or hours, DoD acquisition durations are measured in years. Acquisition baselines specify versions that have expired under traditional compliance and certification methodologies. Subscription-based perpetual compliance allows JITC testers to provide testing services to vendors for all currently supported versions of their solutions. This ensures that acquisitions do not have to be concerned with an expired version and can be assured that the version of the software they selected for enterprise baseline will still be configurable to comply with the functional requirements of DoD 5015.02-STD.

Conclusion

One-off testing leads to one-off funding. This model restricts the ability for an acquisition activity to benefit from the knowledge and experience accumulated by testers and evaluators. The past model for "big bang" or waterfall testing is not cost- or time effective, as funds and schedule must be allocated to bring testers up to speed with the program when the testers are brought on board at a fairly late stage in the acquisition. Additionally, any insight brought with the testers may well be fed back into the acquisition process in revised requirements. This leads to expensive rework.

Agile testing enables test-driven and test-first development by providing a clearer understanding of how the required functionality will be tested. Collaborative by nature, agile testing allows testers visibility into the vendors' development cycles and a transparent testing process for the vendors. Agile testing also supports the frequent provisioning of updates, enhancements, and changes that commercial records-management solutions are bringing to the market.

Multiple-level test-service subscriptions provide vendors and testers the ability to budget and plan necessary staff levels at the beginning of a fiscal year, while add-on hours allow flexibility to address unexpected difficulties or test additional functionality or additional versions and configurations.

Component-level evaluations give testers and vendors the ability to test functionality as it is developed, providing a shorter turnaround when anomalies are found. These lower-level evaluations also provide for multiple exposures to testing as components are integrated into the overall solution.

The iterative nature of the evaluation allows vendors to deploy functionality as it is developed, without worrying that a patch or update will "break" a compliant solution. This also supports more rapid acquisition of new functionality, without having to wait for an expensive operational test.

Subscription-funded, agile, component-based testing provides testers, developers, and users an ongoing collaboration structure in which they work together to ensure perpetual compliance of the software supporting the DoD and federal records-management infrastructure. This results in compliant functionality becoming available to acquisition activities more reliably, more rapidly, and more cost-effectively. ❑

JANA GALLATIN is currently the DoD 5015.02 standard compliance test officer. Her team performs all technical research, update and drafting of DoD 5015.02-STD in support of OSD/NII(CIO). Jana is a primary technical expert on DoD 5015.02-STD electronic records manage-

ment and integration with enterprise information systems within DoD. She has worked in records management for 14 years. As part of her duties, she collaborates with OSD on the technical aspects of policy regarding new and emerging technologies, resulting in updated directives and policy letters about the ramifications of email and social networking on records management. She works with the Joint Staff to advise COCOMS in how to identify requirements for, evaluate solutions, and integrate the selections for records management of COCOM and war records. Jana collaborates with vendors to help them prepare for certification testing and conduct the test and is responsible for development, update, and execution of all DoD 5015.02-STD compliance testing for vendors and government agencies. She also presents records management issues at industry and government conferences such as RACO, AIIM (Info360), NARAGA, NARA, and COCOM RM Conferences. Jana holds a bachelor of science degree earned in 1993 and a master of science degree earned in 1999, both in computer information systems. She has worked for DISA for 22 years as a contractor and employee and is a certified federal records manager. E-mail:jana.gallatin@disa.mil

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Lessons Learned From a Rapid Acquisition Integration and Test Program

Charles P. Wentz
Test and Evaluation Engineer, Rootstown, Ohio

A Joint Urgent Operational Need (JUON) program is a high-priority defense program. When an urgent operational need is identified by a combatant commander, the program understandably becomes the hired contractor's highest-priority program, involves collaboration between different contractors, and receives much attention in Washington, D.C., including a high level of involvement from multiple government organizations. Working toward the common goal of delivering an exceptional, urgently needed product to the warfighter as rapidly as possible (at the speed of need), the program team examined different schedule-minimizing approaches and increased the overall efficiency of the integration and test program. The effort culminated in support of the warfighter prior to the contractual deadline and offered insights, challenges, and lessons learned from the collaborations. Recommendations for other JUON programs are offered that stem from the lessons learned.

Key words: Collaboration; defense programs; lessons learned; rapid acquisition; urgent operational need.

The Defense Acquisition University defines a Joint Urgent Operational Need (JUON) as follows:

> *"A Joint Urgent Operational Need (JUON) is an urgent operational need identified by a combatant commander involved in an ongoing named operation. A JUON's main purpose is to identify and subsequently gain Joint Staff validation and resourcing of a solution, usually within days or weeks, to meet a specific high-priority combatant commander need. The scope of a combatant commander JUON will be limited to addressing urgent operational needs that: (1) fall outside of the established Service processes; and (2) most importantly, if not addressed immediately, will seriously endanger personnel or pose a major threat to ongoing operations. They should not involve the development of a new technology or capability; however, the acceleration of an advanced concept technology demonstration or minor modification of an existing system to adapt to a new or similar mission is within the scope of the JUON validation and resourcing process."*[1]

Implied therein is a rapid response, which (officially) "must be based on proven technology and robust manufacturing processes"[2] and aimed at delivering a capability as quickly as 2 months and no longer than 24 months after the need is identified.

So a program is designated as a JUON in cases that demand product delivery to the warfighter as rapidly as possible, specifically fewer than 24 months in duration. The full program schedule (design, production, and test) is aggressive yet possible theoretically it assumes a perfect world and all going according to plan. Input from both contractor and subcontractor(s) is incorporated in the plan. (On the program under discussion, the extent to which input from subcontractors was weighed is unknown to the author.)

Any project or program is measured in terms of its cost, schedule, and performance specifically in terms of its *cost performance* (Was the program completed within budget?), *schedule performance* (Did the program meet milestones or other deadlines?), and *product* or *technical performance* (Did the program meet the specification requirements?). Impressed upon all contractor and subcontractor employees working this program was the mind-set of "schedule first." This expression did not ignore cost or product performance; satisfactory product performance was assumed, leaving cost performance at contractor risk. Product performance must be met.

The details of program planning and execution required creativity in planning. The overused mantra "Think smarter!" applied smarter about how to get

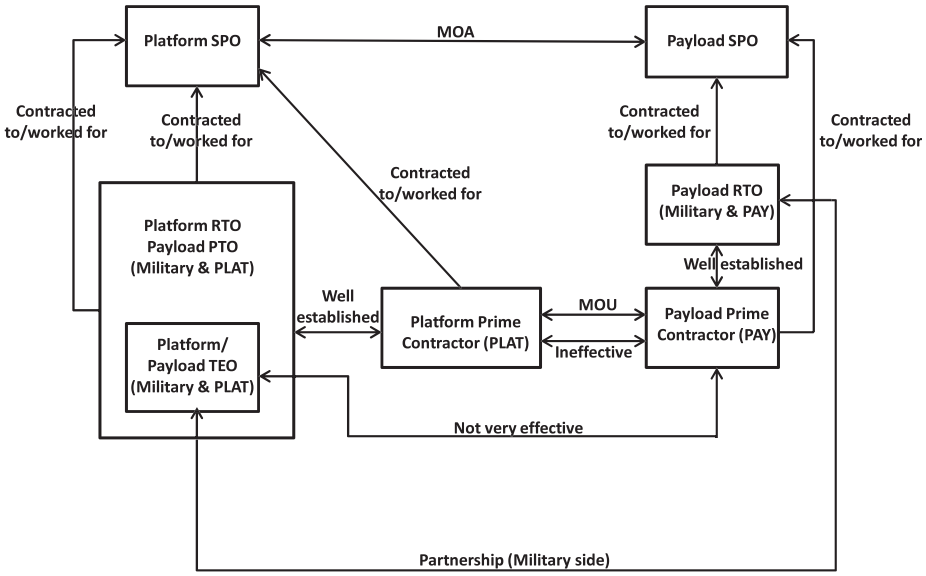

Figure 1. Organizational relationships.

tasks accomplished more efficiently while complying with processes and procedures that have time-consuming potential. Perhaps some technical risk, such as a design approach or production sequence, is assumed that is not assumed under normal development schedules. Schedule risk to some extent is certain. (As always, safety risk is never acceptable.) The motto "schedule first" implied some cost risk. Budgets are finite, and if a product's development is slowed due to flaws discovered in early testing or product performance that cannot be verified within schedule or at least in a satisfactory time frame, the customer will find a different product solution. In that case, critical time will be lost unless an alternative solution is under simultaneous development.

Program position in the Defense acquisition structure

JUONs comprise a special set of Defense Department programs, yet like any other program, each JUON is given a priority. The subject program will not be identified herein, nor will the organizations that worked it. It must suffice to state that the program was contained in an Office of the Secretary of Defense Test and Evaluation Special Interest Oversight List. Its objective was to modify and integrate a proven payload with a proven platform and deliver the final product to the warfighter as rapidly as possible. There were other urgent-need programs at the military test site during its period of performance, and the subject program had second-highest priority. Fortunately, there was no conflict with the program that had higher priority during its planned test days and times. All efforts were made to remove conflict with other programs on site. Nevertheless, the subject program had a very high profile to military Test leadership, who was briefed almost daily during execution. It received much attention in Washington.

The platform prime contractor (PLAT) was teamed with the payload prime contractor (PAY), each of which worked for a different military special program office (SPO). (There were additional relationships between one of the SPOs and other military organizations; these have no impact on the present discussion and are not discussed herein.)

Organizational impacts and challenges of a JUON program

Due to the rapid build and test schedule, a JUON requires a new way of doing business as well as a new way of thinking. This implies organizational impacts and may require an organizational culture change the latter seldom comes easily, even if only for a program's duration. Routine tasks taken for granted need not be immune to change in some way.

Program structure

Of significance to this discussion (as well as to program execution) are the working relationships among the organizations. Referring to the organizational relationships in *Figure 1*, each box represents an organization; each line with one arrowhead depicts the historical relationship in an organizational pair; and each line with two arrowheads depicts the business relationship or the quality of the working relationship between the organizations.

- The Platform SPO and the Payload SPO operated under a memorandum of agreement (MOA).

- Referencing the right side of *Figure 1*, the Payload Responsible Test Organization (RTO) worked for the Payload SPO and consisted of both military and contractor (PAY) personnel; thus a well-established working relationship existed among the three organizations.
- Referencing the left side of the figure, the Platform RTO also served as the Payload Participating Test Organization (PTO) and ultimately worked for the Platform SPO. This RTO was also a team of military and contractor (PLAT) personnel, and within it resided the Platform/Payload (integrated implied) Test Executing Organization (TEO). The working relationship among these organizations was also excellent and well established.
- The PLAT and the PAY operated under a memorandum of understanding (MOU). Except for a few individual cases, the relationships that the PAY had with any of the platform organizations were not positive; some details follow.

The TEO was the team responsible for testing the integrated product. While the Payload RTO was equally involved in test activities, its testing activity was limited to the payload.

The number of organizations and the complex interrelationships combined for the potential for relationship problems from the start. Solid contractual (and working) relationships were already in place among some of the participating organizations because these separate relationships had existed for several years. Ignoring this complexity and the dual lines of funding flow, what is significant about this particular program structure is the fact that it is contrary to the usual way of doing business between platform and payload manufacturers (at least in this engineer's experience, wherein the PAY would be subcontracted to the PLAT). New to the dynamics was the Payload SPO-PAY team working with all (or nearly all) the others. This arrangement became problematic for all and for a variety of reasons, many of which are identified and described herein.

Streamlining efforts

Necessarily much discussion between the PLAT and the PAY was devoted to ways to reduce a "normal" development (integration and test) schedule to a rapid-development schedule. The following methods received primary focus:

- **Acceleration of processes.** One new method of doing business on this program was *rapidly* performing in accordance with applicable corporate processes and procedures. Processes and procedures are established for standardization of execution, thus allowing thoroughness and efficiency of operations. At least an implied purpose is maximum possible speed of execution, depending upon program and other circumstances. Typically the tailoring of processes is encouraged when applicable. The schedule pressures of a JUON program require acceleration or tailoring of processes wherever possible. These pressures in turn need thoughtful planning as to how operating efficiencies might be improved on a case-by-case (procedure-by-procedure) basis, possibly out of one's comfort zone.

  Indeed, this was accomplished on the subject program on two fronts. First, the TEO had a robust scheduling software tool to lay out a program's timeline using detailed metrics and incorporating historical data (i.e., potential weather disruptions, task durations, and task dependencies/prerequisites) from previous platform programs to realistically predict this program's completion date. This software is based on the theory of constraints. Second, at a schedule-planning meeting for payload integration and test, the PLAT and the PAY managers, planners, and engineers discussed details of the integration, in-process tests, integration tests, acceptance tests, and "development" tests necessary based on the first-time integration of this particular payload and platform. With thoughtful insight, the PLAT's lead manufacturing engineer found ways to eliminate some procedures that were either unnecessary or redundant in this particular case, thereby trimming many days off the integration schedule.
- **Compression of schedule.** In addition to accelerating processes, other ways to trim schedule were examined. Consideration was given to conducting all tests at one location, in an effort to minimize the test time. The suggested location was the PLAT's manufacturing facility. The PAY made this request of the TEO; predictably, the approval for this did not happen. The PLAT had advised the PAY that approval for one specific test at any location other than the military test site would not be forthcoming. Safety concerns won over potential schedule savings that were unlikely regardless, but all questions are worth asking.

  Schedule was compressed when possible with extended shifts and an additional shift. For payload integration and testing activities at the PLAT integration site, the day and evening work shifts were extended. During testing at the military test site, a third shift of personnel was assembled for the duration by staggering work shifts and using new hires for certain tasks.

Interactions, impacts, and challenges

A variety of challenges faced the contractors; they are consolidated and categorized in terms of team approach, communication and coordination, management and leadership, and schedule pressures. One should note that the sum of these identified items was exacerbating.

- *Team approach.* A "team" approach was mandated and readily accepted by the contractors; the slogan "One Team" was frequently verbalized. The "One Team" approach had to be learned. Any time different organizations must suddenly work together, there are certain to be growing pains. However, factors such as backgrounds, experiences, corporate cultures, and individual attitudes and personalities can combine to make the situation more or less "painful." The program had a "mixed bag" of customers, and by all appearances, more than one organization was trying to act as the lead most if not all of the time. The different roles of the PLAT and the PAY were clear "on paper" but not truly accepted by the latter. In practice, this team philosophy worked when convenient to the PAY.
- *Communication and coordination.* Crucial elements of streamlining any effort are communication and coordination. Their criticality cannot be overemphasized *at any level* in an organization. From the beginning of a program, workers should be reminded by management of the importance of, and sensitivity to, effective and timely communication through the most effective channels. The most effective channels are those that take advantage of existing relationships, follow a proper chain, and promote expeditious action. This obvious but often overlooked tenet should be emphasized at a kickoff meeting for any program, especially when a critical schedule could be adversely impacted by ineffective or incomplete (missing a key player) communication.
    - Using existing relationships. The PLAT and the Platform RTO have worked together very effectively for years; communication chains were well established. In the PLAT-PAY relationship, the PLAT was not only providing a platform and integrating a payload, but testing "full service" as well; this readily available service was ignored by the PAY. This full service included working and communicating directly within the TEO so as to facilitate efficient testing. The PAY was so aggressive at communicating directly with the military side of the TEO, and to different individuals in that organization, that the PLAT was asked by the military side of the Platform RTO to do what it could to control the proper communication chain. (The thought of a cart, a horse, and which is the leader comes to mind.)
    - Following a proper communication chain. There is a reason for protocol: It can facilitate action while incorporating knowledge not known to all in the chain. This idea ties into the use of existing relationships. If the communication chain is an existing one, all the better; adding to the chain is easy (e.g., adding names to an e-mail distribution). The PAY circumvented protocols routinely, which had the predictable consequence of dropped communications. For example, one episode particularly irritating to the Platform RTO was a request by the PAY directly to the Platform RTO for use of military assets. The request simply went to the wrong individual and was dropped. The advice to communicate through the PLAT was passed to but ignored by the PAY a situation that, over time, tended to erode the healthy working relationship that existed within the TEO. (A cart, a horse…)
    - Promoting expeditious action. The greater the attention given to the communication (i.e., the number of people in the communication), the greater the chance the action will be taken by the appropriate personnel and at the appropriate time, barring valid circumstances.

It can be easy to forget to communicate to all parties concerned i.e., informing some but not all individuals who need to know the information or actions to be taken. The more eyes or ears that are exposed to the message, however, the more likely the right ones will receive the message. On the day that the payload was to be delivered to the PLAT system integration lab (Platform SIL), the responsible PAY engineer failed to notify a counterpart at the PLAT prior to the former's departure for the short trip; the desired notification was to alert personnel receiving and installing the payload to be ready in place. There was no communication and, consequently, no personnel in place. (The delivery was 8 hours later than originally estimated, so receiving personnel were sent home at end of shift, whereas the PAY expected Platform SIL personnel to be ready in place whenever the payload arrived.) One shift of schedule was lost. This event was even repeated

for delivery of some equipment. The luxury of such labor budgets does not exist. At the military test site, personnel scheduling was especially critical, as some work-shift requirements applied.

- *Management and leadership.* How active should management be? Obviously managers must monitor progress, but should they take a passive view from the outside looking in, being supportive and available to remove obstacles to rapid progress as is necessary? Or should they take a more proactive approach and risk becoming obstacles? Naturally, individual management styles play a role, possibly negating any mandated, preplanned high-level directive as to how management should allow engineers and support personnel to execute the program.
- *Schedule pressures.* Many challenges were simply the result of schedule pressures. The previous illustration of the payload delivery is a case in point. Humans have faults, and it is understandable, at least to a degree, that a dropped communication such as that could happen (once).
  - Indeed, the fast pace of the program was a factor for communication problems. However, circumvention of communication protocol and proper chains of command undoubtedly had additional origins, Machiavellian corporate culture being one possibility. These are reasons not excuses.
  - The primary focus tended toward schedule at all costs. While a JUON schedule is almost as important as safety, it may be that this focus was the cause of a design oversight in the payload that literally resulted in smoke from the payload during integration testing in the Platform SIL. (Corporate culture may also have had a role in this instance; the entire on-site payload team feared for the design engineer's job.)
  - The aggressive pace of a JUON is taxing on personnel. Fatigue and a rush to accomplish tasks take a toll. Additionally, all organizations especially at military test sites have personnel rest requirements, strict compliance with which by all test participants is mandatory. Any violation is a serious matter with possible severe consequences beyond the violating individual(s).

Backgrounds and experiences

On any collaborative program JUON or not it is imperative to consider the backgrounds and experiences of teammate organizations. The differences in the test experiences of the PLAT and the PAY were evident and became unnecessarily problematic. As stated previously, the PLAT had a well-established, effective working relationship with the TEO. The tests were conducted at a very busy military test site where testing schedules were arranged several weeks in advance. The PAY had neither a prior relationship with the TEO nor any experience at the military test site, having conducted its previous testing elsewhere and on a very different platform. At this other site, the PAY's private test program could be conducted almost at will; only short notice of a planned test to the site's controlling authority was necessary. There were additional differences in the test experiences of the two contractors.

Different testing backgrounds and environments were most evident once integration testing began (in the Platform SIL, at the manufacturing/integration facility, and at the military test site). When the PAY personnel arrived at the military test site to participate in testing, they thought the subject program was top priority and that virtually everyone at the site was at their disposal, working *for* them, despite numerous warnings to the contrary. It was "their" payload and "their" program. Learning the contrary was a culture shock to them, but their collective attitude remained unchanged, making effective communication and coordination an even greater challenge.

Program execution: Challenges, impacts, and lessons learned

Program execution had its challenges to overcome, impacts on operations, and lessons to be learned. For sufficient perspective of the effort, it is appropriate to summarize the major activities during the integration and testing phase. The payload underwent an in-process verification test in the Payload SIL, followed by system integration tests in the Platform SIL and after integration in the platform. The platform underwent in-process verification tests, acceptance tests, integration tests, and system tests.

Lessons learned

Almost every program has a lesson to be learned for betterment of execution on subsequent programs. Despite the program's ultimate success, several lessons emerged:

- Expect surprises. Testing *anything* either *on* a military vehicle or *to be integrated* with a military vehicle requires documentation for which the PAY was surprisingly unprepared.
- Communication and the coordination of communications are extremely important, including following proper communication chains. It is better to communicate the same message twice than to do so once to the wrong individual.

- Organizations and individuals often have to rethink standard ways of doing things to become more efficient.
- The high-level profile of a JUON invites involvement from multiple organizations. Aside from the *necessity* for the involvement of multiple organizations on this JUON program, the desire for personal visibility or association with the program incentivizes one to "hang around" when one's presence is no longer required. Consequently, there is also a tendency for an organization or individual(s) to overstep boundaries of responsibility. On the subject program there were definitely too many cooks in the kitchen.
- The PAY could have and should have used the PLAT more than it did, and the fact that it failed to do so was a cause of some problems and inefficiencies for the PLAT and for the TEO overall. (In contrast, the Payload RTO yielded all testing to the TEO, as was appropriate.)
- Lack of understanding of TEO processes by the PAY equated to ignoring those processes. In this regard, the different backgrounds and environments and probably conflicting corporate cultures played a role.

Recommendations for other JUON programs

Certain individuals were interviewed from every organization depicted in *Figure 1*. There was less than 100% concurrence on some of the recommendations that follow. However, based on those interviews and the insights gained from experience on the subject program and the individuals' perspectives, the following specific recommendations for the conduct of other JUON programs are presented:

- Conduct a kickoff meeting at the highest level of (or above) the participating organizations. At this meeting, there needs to be discussion and understanding of what each organization's roles and responsibilities are (and of what they are not), in no uncertain terms.

Additionally, throughout the program's execution:

- As applicable, coordinate on processes or procedures that may differ and on any appropriate streamlining.
- Share expertise. This is as essential as communicating.
- Coordinate and collaborate on joint deliverable materials.
- Hold recurring coordination meetings among the test organizations (and other engineering disciplines) at the engineer level.
- Regardless of the complexity of the program's organizational structure, remind all parties that they share the common goal of delivering an exceptional product to the warfighter the ultimate customer as rapidly as possible. This is of paramount importance.
- Allow each teammate to do the job expected of that teammate. The underlying reason for the team is that each individual person or organization has a purpose for being on the team. (This should be common sense.)
- Continuously examine different schedule-minimizing approaches.
- Emphasize effective communication through the proper chain(s) of command and respect for established protocol. Communicate, even if merely by telephoning. Overcommunication is better than undercommunication, especially on a JUON; otherwise, delays in progress can be expected. The lead individual in each organization should emphasize this and lead by example.
- Ensure that all engineering disciplines are involved during all phases of the program; ensure that each discipline is adequately funded and that the process for approval of additional funding, if required, will be fast.
- Provide strong leadership at the customer level by a seasoned professional. For a military organization, the recommended minimum rank is major.
- Ensure consistent coordination between government/customer and contractor representatives, as new or unfamiliar organizations may be involved in the JUON process.
- Carefully consider staffing profiles; a high level of effort is typically needed for a short period of time.
- Keep only one Integrated Master Schedule, and update it continuously to ensure that all stakeholders and involved personnel are aware of and tracking with the dynamic schedule. Having more than one "working" schedule was cause of much confusion. The TEO had a schedule, the PLAT had a schedule, the PAY had a schedule, and the Payload SPO had a schedule and each was different from the others.
- Stand firm on adherence to standard processes and documentation in the face of a rapid schedule. For example, documenting troubleshooting steps allows the engineer to know what approach or procedure works and what doesn't. Processes and procedures exist for a reason. The test organization is the first line of defense against poor quality! Testing is the first opportunity to wring out any design problems; the sooner this occurs, the better for maintaining schedule.

Result and conclusion

In the end, the subject program achieved its goal, effectively supporting the warfighter and doing so prior to the contractual requirement. Additionally, to date four awards (known to the author) have been granted to the integration and test teams and individuals as a direct result of the success of the program. Collectively, two awards were granted by industry associations and two by employers. ❑

CHARLES P. WENTZ is a lead test engineer with a major systems integrator. His 29-year engineering career has encompassed broad systems and test engineering experience in platform-level development work in the defense industry. Additionally, Charlie taught full-time at the university level for 9 years. Charlie possesses master's degrees in aerospace engineering, systems engineering, and business administration. He has published more than 50 papers and has made numerous presentations at a variety of conferences and as a keynote speaker. He is an airline transport pilot who flies airplanes, helicopters, and gliders.

Endnotes

[1]"Joint Urgent Operational Need (JUON)." Defense Acquisition University, https://acc.dau.mil/CommunityBrowser.aspx?id 204169 (accessed November 7, 2011).

[2]"Report of the Defense Science Board Task Force on the Fulfillment of Urgent Operational Needs," Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, Washington, D.C., July 2009, pp. ix, 26.

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Collaboration Between Testers and Program Management: It's Not Always Bad

Alan K. Jenkins, D.M.
Naval Air Systems Command (NAVAIR), Patuxent River, Maryland

While the typical test and evaluation experience in working with a program office may be an adversarial one, it does not have to be the norm within the profession. The CH-46E test team, aka the Mighty Battle Phrog Test Team, was formed after a 10-year hiatus of dedicated test capability at AIRTEVRONTWOONE (the developmental test and evaluation squadron for U.S. Navy and Marine Corps helicopters) and in conjunction with the program office PMA226 at the Naval Air Systems Command (NAVAIRSYSCOM). The restart of a dedicated test capability was in response to several aircraft losses in the War on Terror. Rather than become a required hurdle, the team quickly proved itself as a program office asset with respect to delivering new equipment and capability to the battlefield. A somewhat unorthodox arrangement of leadership, resources, and capability allowed the test team, test squadron, and program office to have a collaborative arrangement. The test team did not always deliver glowing reports on the various projects, yet it was able to perform as a valued resource and continued to deliver needed data to get the right equipment to the user. The Mighty Battle Phrog Test Team demonstrated one way to achieve collaboration between the test and evaluation and the program office professionals.

Key words: Collaboration; dedicated flight test capability; environmental instability; organization culture; teamwork; test control; tester/program office relationship.

Given the pressures placed on the program office, it is not unexpected that an adversarial relationship could develop (Dostaler 2009; Thorn 2003). Test and evaluation may be no different from any of the other disciplines within the program office structure with respect to that type of relationship. What further exacerbates the relationship between the testers and the program office is the unstable nature of testing, where certain outcomes are not guaranteed. Emergent events may require a change to the test and evaluation structure or the starting of a specific test capability. The reestablishment of a dedicated test and evaluation capability was required after a series of recent losses with the CH-46E Sea Knight, or Phrog. The test team needed to meet a number of immediate challenges. For example, quickly starting a test capability after over a decade lapse, and overcoming the ubiquitous adversarial culture between testers and the program office. This article focuses on the underlying considerations in the tester/program office relationship and how this relationship developed from addressing a specific task into a highly collaborative effort.

The pervading culture of an organization drives the leadership styles (Casse and Claudel 2011). When the program manager must continually trade the pressures of performance, schedule, and funding, the desire to increase control is a normal outgrowth. Greater attention and control allows the organization to better adjust the tradeoffs among cost, performance, and schedule resources as the environment changes (Weick 2001).

However, a dynamic environment is not conducive to increased control. What is a difficult and perhaps significant cause of contention is the belief that higher levels of control are possible and are desirable within the test and evaluation discipline, where unstable environments are routine. This should not lead one to infer that test and evaluation is an uncontrolled or uncontrollable discipline; rather, if greater controls over test and evaluation are desired, then increased collaboration is needed.

In fact, the testers and program office must encourage collaboration to increase awareness of the environment

or situational awareness of the project. The increased collaboration and awareness allow each member to adjust their objectives and priorities as the environment changes (Staber and Sydow 2002), and none of the members of the organization are immune from environmental instability (Valle 1999), so when the program manager adjusts cost, schedule, or performance, each discipline within the program office is affected. If the organization's culture is one of collaboration and inclusion, then the members, regardless of discipline, are in a better position to anticipate the opportunities the adjustments will create as well as the challenges that must be addressed.

One way managers can increase control is by using program management performance measures or metrics. However, this effort may prove to be problematic in establishing or fostering an effective relationship. Part of the difficulty in establishing a collaborative relationship is that the metrics imposed upon the program offices do not translate well into something perceived as constructive or useful either by the program office or by the personnel supporting it (Thorn 2003). The program office personnel, who have to collect, analyze, and report on that data, must either find time to perform the perceived unneeded tasks or deprioritize other issues more germane to completing the primary work of the program office. The conflict over completing the project versus completing the latest data call creates barriers to teamwork.

Included among the challenges to establishing a collaborative environment are the personnel working in a program office who are rarely in the direct chain of command of the program manager and must continue to prove their worth to avoid being tagged as not required (Thorn 2003). These two personnel-centered issues may be directly related.

The competency aligned or matrix organizations pull personnel from disciplines needed for a project or program. When the program manager decides the project no longer needs the discipline, those personnel are released back to their homeroom. If there are performance problems, the program manager must work through the employee's supervisor and may or may not be able to be effective in correcting the problems and must rely on the supervisor also outside of the program manager's chain of command to find a replacement should the employee leave or need to be removed from that project. When the program manager has to, in effect, subcontract out various functions needed for project completion, the subcontractors are only employed as long as there is a perceived value; they must then continually self-promote to ensure continued employment.

Increased standardization of processes also has an adverse effect on performance. While this may be contrary to popular thought, a checklist mentality develops in that the person performing the task just checks the boxes rather than first considering whether the box is needed or is in the right order. Accountability is reduced as the person goes on autopilot (Hall and Johnson 2009). The problem is not the process but how the process is implemented. Routine functions, or executions in a stable atmosphere, do well with standardized processes. In an unstable environment, such as test and evaluation, typical processes fail. The letter of the process is hard to follow, although the intent is not. If the relationship between the competency and program management is a combative one, then one side may rely on the letter of a process to shield poor results. However, if the relationship is supportive, exploration to the acceptable limits of the letter of the process is possible.

The culture of an organization affects its projects (Andersen, Dysvik, and Vaagaasar 2009), so if the culture is one of teamwork and positive expectations, then building a collaborative environment will be an easier task than when having to overcome a less than positive culture. Once established, the culture in an organization is difficult to change (Turnbeaugh 2010). However, a program crisis may be a vehicle to establish a new start.

Such a crisis occurred in the winter of 2007 with the Purple Foxes of HMM-364. In February 2007, Morphine 12, a CH-46E Sea Knight (aka Phrog), was shot down over Iraq and the entire crew of seven was lost. The loss also represented the seventh aircraft lost or downed by hostile fire that year. Extreme measures were required to modify and test protection upgrades to the Phrog. Additionally, the production and fielding schedule of the replacement V-22 aircraft was behind, requiring an extension to the Phrog's in-service time and delaying retirement by several years. Decisions made regarding upgrades and fixes for the Phrog, which had made sense when the aircraft was to be retired in 2010, now became problematic. Airframe fixes, improvements to reduce maintenance actions, and replacement of obsolete avionics were needed yet were years behind schedule in a standard acquisition timeline. To keep the Phrog viable, the program office, PMA226 at the Naval Air Systems Command, started several new programs to increase payload, increase survivability, and keep the Phrog as a viable platform until retirement. The majority of the efforts required test and evaluation, and the scope of many of the subsequent projects required a dedicated test capability.

The developmental test and evaluation squadron for U.S. Navy and Marine Corps helicopters is AIRTEVRONETWOONE or HX-21, based at Patuxent River, Maryland. A dedicated test capability

for the Phrog was retired in 1996 under what could be considered mutual agreement between the air wing and the program office. Waning flight test project requirements, increasing costs, and somewhat contentious relations between the testers and program office created a scenario where the test capability was terminated.

Active duty or reserve squadrons would handle the minor efforts needed in future years. Test pilot billets for the H-46 were reallocated to other aircraft types and models, the technical publications were removed from the library, the maintenance expertise was absorbed into other platforms, and the engineering personnel moved on to other projects. The longer the dedicated test capability remained untapped, the less likely reestablishment of a dedicated flight test capability could easily or quickly occur.

The loss of Morphine 12 set in motion events that necessitated reinstituting a dedicated flight test capability. Reserve and active duty squadrons did not have the aircraft or personnel to support full-time flight testing. Test pilots and flight test engineers were needed for many of the efforts, and those personnel were located in Patuxent River, Maryland, some 350 miles from the program office in Cherry Point, North Carolina. A dozen years and several generations of squadron commanding officers and program managers had passed since the Phrog left HX-21. Time had filtered out much of the previous history (Bolman and Deal 2003), so that the program office and squadron would start with a relatively neutral expectation, in other words, a clean slate.

The new start provided the opportunity to use fresh expectations with respect to the relationship between the program office and the testers, namely, working together to achieve specific goals. The restart of the dedicated test capability needed a near-term task completion to activate the team. "Competencies cater only for a potential for action, not the action itself" (Freiling and Fichtner 2010). Thus, building, shoring up, and activation were needed to capitalize on the resources. In other words, the competences need to be activated in order to achieve. To extend this thought, the activation can also feed back to the program office (Walsh and Glynn 2008), which would tend to reinforce the expectations. If the program office expects a certain performance level from the testers, and the testers deliver that performance level, then the feedback becomes self-reinforcing. Note that this feedback loop can be a positive or negative. When first started, the momentum is small. The more activity in the loop, the greater the momentum, which is one reason a well-established culture is hard to change.

Beginning the momentum in a positive direction then becomes very important to the result of establishing a positive culture. The testers and the program office had the benefit of a clear and common threat along with a strong direction with respect to how to defeat that threat. Proximity to the end users also helped keep the team focused. A nebulous goal may be a good marketing tool, but having closeness to the people relying on the team to keep them alive allows for easy differentiation between what is truly needed and what is not. Additionally, the expectations that the working relationship would not only be positive but would enable the team to achieve its goals helped to start the momentum in a positive direction.

Forming the test team would be just as challenging as the needed outcomes. The work was emergent, meaning that advance planning was not possible. The work was limited to 2 or 3 years, thus those who chose to leave their current position had no option of continuing on with the new program for any extended length of time. No current test pilots were identified to support the Phrog flight tests, and the test pilots that could be reassigned to support the effort were not going to be released from their current projects. Finally, the squadron would need to find maintainers for the test aircraft. By the last month of fiscal year 2007, two-thirds of the engineering side of the flight test team had been identified. In the following months, the test pilot was identified, forming the final core member of the engineering side along with the seven members of the maintenance side. In March of 2008, the engineering team began its first flight test phase, officially accepting the aircraft in April, and thus establishing the Mighty Battle Phrog Test Team with one test pilot, two engineers, and seven maintainers.

A pressing and real-time need helped to keep the team's efforts in perspective. For example, only direct test-related metrics were used. The program office worked as partners rather than employers of the test team. A core team with well-experienced personnel was constant throughout testing and the tailoring of processes to meet the intent if not necessarily the letter of that process. For example, the test squadron gave the test team priority in test plan and test reporting so that the critical timelines could be met. Perhaps one of the more significant aspects was starting with the expectation of success.

Expectations on results from the testers were high. The need was critical, and unnecessary delays added risk to the U.S. Marines in the field. The start was not without problems. Acceptance of the aircraft required more time, given issues with the aircraft transfer, and the Phrog was one of hundreds of projects on the base. Rather than establishing a contentious atmosphere, the

testers and the program office found ways to work together. For example, the program office was outstanding with logistical support and helped to raise the priority of the Phrog to be able to compete for resources, and the testers established experimental billets to bridge the program office/tester gap, built maximum flexibility into their plans, and tailored the test execution requirements to meet the needs of the program.

The initial project involved developmental and operational flight testing on a new missle countermeasure system. Flight testing was performed from March though July 2008. The evaluation was less than complimentary, but by this time the team had formed a good partnership with the program office. Normal pressure on a vendor is to provide the answers the customer desires (Church and Waclawski 1998). The pressure on the testers was not to find the answer that the program office wanted but to find the answer that was right for the Marines in the field. The direction never varied throughout the multiple test projects.

There was no fear of a wrong result, thus allowing the testers to continue to increase their efforts in finding innovative ways to meet the coming challenges. Fear tends to stifle innovation and creativity (Katz 2004), and the team had to be innovative with the continuing stream of emergent efforts. When specific disciplines were needed, members were added as needed. Operational test pilots were tapped to supplement developmental test flights. Conversely, developmental test pilots supplemented operational testing. The team capitalized on a serendipitous program cancellation that had freed an active duty developmental test pilot. The team continued to stay small and agile.

At its peak in 2009, when the team completed developmental testing on three different missile countermeasure systems, the team consisted of two pilots, three engineers, and seven maintainers. Each of the developmental test periods was successful. Even though a considerable investment of time and effort was made to flight test the three systems, only one was fielded. Again, throughout each of the tests, the pressure was to find the right answer, not the answer that would best suit the program office.

In addition to the missile countermeasure systems tested, the team also performed developmental testing on avionics improvements including a new blade track method, integrated monitoring health system, electronic kneeboard/moving map display, integrated landing system, and a new heads-up display. These types of tests benefitted the CH-46E fleet directly. The projects were a mix of emergent and more traditional acquisition efforts, and several of the Phrog's efforts benefitted other aircraft types.

Shipboard testing of an embedded global positioning system and inertial navigation system was an emergent effort upon which the team was able to capitalize even though the ship was on the opposite coast. The importance of being able to collect that data in the near term was a benefit to the Phrog community as well as the CH-53E fleet. Direct support to the H-53's new missile warning system was provided as the Phrog's configuration was very similar to the H-53. Consequently, a large percentage of the software testing could be conducted on the Phrog. Having the flexibility to test on the H-53 and the H-46 prevented major slips in the fielding of the system on the H-53 when the specially configured H-53s were down for maintenance-related issues. The Phrog was even able to perform an operational test phase for the H-53, which is a testament to the working relationship between the testers and the program office.

The benefits of a healthy working relationship extended beyond just the Phrog and H-53 communities. The team was able to support operational testing of a shipboard chemical biological detector system, support training for future test pilots by providing tandem rotor time, and evaluate changes to engineering change proposals to provide additional risk reduction even when flight testing was not specifically required. In addition, the team ensured form/fit/function replacement products met mission requirements prior to fielding, thus avoiding hazard reports from the user and improving simulator performance.

A healthy relationship also allowed the program office and the test team to tackle challenges that stretch even the best of teams. For example, to demonstrate a data interoperability desire, the test team working with multiple agencies and contractors was able to demonstrate frequency neutral data interoperability in flight, so that over radio frequency or satellite communication link, the aircrew was able to transmit and receive real-time information. The aircraft transferred actionable emergent threat information to the information grid and received changes to operation plans, while assault assets neutralized the threat. Other aircraft performed post-action assessment, and the entire process was completed in the order of minutes rather than hours.

Normal pressures within a program office can create a climate of contention among its members and with those supporting the program office efforts even when the projects proceed smoothly. Emergent requirements can also stress that relationship. However, building a solid foundation on a good footing enables a more productive outcome than one where the support teams go on autopilot to sate the program office appetite for data. Rather, the teams can anticipate the needs of the program office and adjust operations and processes to meet those needs.

Collaboration, commitment, and cohesion are attributes that define teamwork. A distinct focus, such as solving the loss of aircraft, may allow a team to start with those attributes. Continuing support and strengthening of those attributes by members of the team and with its customers provides the motivation to advance beyond a simple piece-work type of arrangement. It is possible, as the Mighty Battle Phrog Team has demonstrated, that a test and evaluation team may become a valued resource to the program office. The alternative type of relationship, one where contention drives the efforts, is not one under which either side can flourish. While this less than optimal type of relationship may be the normal one in the acquisition environment, it comes at a cost of lost productivity and opportunity. When a better type of relationship is chosen and maintained, significant accomplishments can be made. ❑

Alan K. Jenkins, D.M., is the Lead Flight Test Engineer for the CH-46E at HX-21 and the Assistant Program Manager for Test and Evaluation at PMA226 at NAVAIR in Patuxent River, Maryland, and has been flight testing U.S. Navy and Marine Corps helicopters for over 25 years. He earned his bachelor's degree in electrical engineering from Auburn University, his master's of science degree in applied science from the Naval Postgraduate School, and his doctor of management in organizational leadership from the University of Phoenix. He has received the Burdette Award for Flight Test and Integrity, Naval Test Wing Atlantic Flight Test Engineer of the Year, and Rotary Wing Aircraft Test Directorate Flight Test Engineer of the Year among other awards. E-mail: alan.jenkins@navy.mil

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Live-Virtual-Constructive Capabilities for Air Force Testing and Training

John M. Colombi, Ph.D.
Air Force Institute of Technology,
Wright Patterson Air Force Base, Ohio
Capt. Christopher Cobb and Damian Gallegos
705th Combat Training Squadron,
Kirtland Air Force Base, New Mexico

Over the recent years, the Department of Defense has shifted toward a more rapid and responsive acquisition strategy to address current threats that face our nation. Global threats have made it imperative to test and train for a greater variety of adversaries and mission threats. With continual enhancements being made in the Live-Virtual-Constructive (LVC) community, there has been an expanded role for incorporating these capabilities into testing and training. As LVC comes to the forefront, there are disconnects across the test and training communities as individual organizations incorporate various LVC environments, technologies, architectures, and standards. Such disconnects include non-interoperability and non-standardization across the Services. The heavy investment in old simulations and the cost of conversion will result in disconnects for many years, but the path forward with modern solutions holds a promising future. This article evaluates the current state of LVC capabilities within the test and training communities.

Key words: Acquisition; constructive simulation; Joint test environment; Joint training environment; live test; testing; training, virtual simulation.

The nature of modern warfare, along with the limited resource availability, necessitates major changes to the way the Department of Defense (DoD) tests and trains to meet current and future warfighting needs. A majority of DoD systems being developed today are to be deployed in Joint Mission Environments (JMEs). Testing of a system by a single service is inadequate to demonstrate that the system meets the warfighters' training needs. DoD policy is moving from a traditional single-system approach to a new Joint capability-based approach, demonstrating that a weapon system integrates seamlessly into a system-of-systems within a JME.

Live, virtual, and constructive (LVC) technologies enable the DoD to meet their current demands of the testing and training communities *(Figure 1). Live* refers to real people operating real systems, such as an F-16 pilot flying an F-16 aircraft. *Virtual* involves real people operating simulated systems, such as a pilot operating an F-16 Unit Training Device. *Constructive* refers to an environment that involves machine-to-machine interactions with various amounts of human-in-the-loop control, mainly consisting of environment generators. A test or training event utilizing all three of these components is considered a Joint LVC (JLVC) event when participants are from across Commands and Services. The LVC environment gives the DoD the ability to integrate various tools that provide a more robust, realistic, and efficient testing and training capability. As virtual and constructive simulators become more technologically advanced, both communities have supplemented live test and training events with virtual and constructive capabilities.

In a previous *ITEA Journal* (2009), DeForest wrote, "Live range space, availability, and technical capabilities are being outpaced by warfighter systems technology. We cannot exploit the capabilities of the fifth generation F-22 or F-35 fighters, and we cannot produce adversary support sufficient to test and train fifth generation fighters" without the use of an LVC environment (DeForest 2009). Live test and training is resource intensive and cost prohibitive; LVC is the method to augment live test and training to prepare the

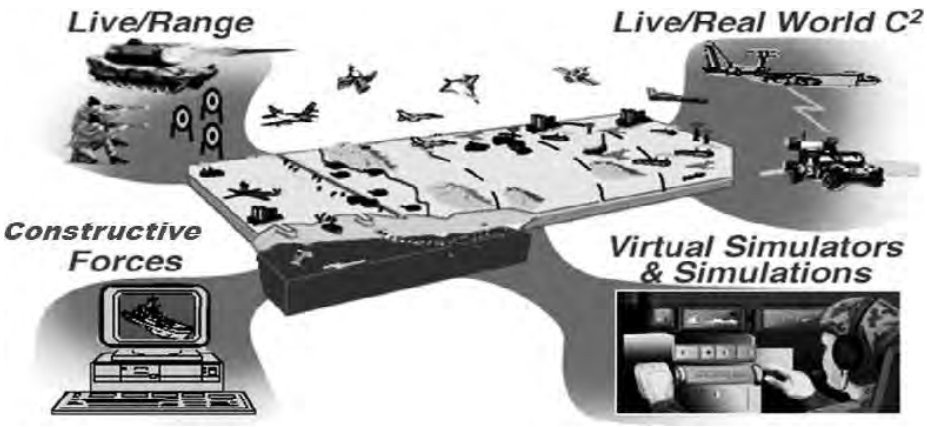

Figure 1. Live-virtual-constructive synthetic environment.

warfighter for combat. LVC enhances the environment needed to test and train the capabilities and functionality of the warfighters.

Deputy Secretary of Defense, the Honorable Gordon England, established DoD Directive 1322.18 in January 2009. The DoD policy on military training states, "The training and test & evaluation communities shall share infrastructure, resources, ranges deployed in Joint Mission Environments (JMEs). Testing of a system by a single service is inadequate to demonstrate that the system meets the warfighters training needs" (DOD 2009).

This article examines the current challenges and recommendations for LVC capabilities for DoD system test and training in a network-centric, system-of-systems environment.

Policy and guidance

From program initiation of a desired capability, through Test & Evaluation (T&E), and culminating in operational training, the use of LVC in Modeling and Simulation (M&S) is guided by directives and instructions stemming from DoD, as well as from the Chairman of the Joint Chiefs of Staff (CJCS). Each of the policies is levied to a specific community of interest: acquisition, T&E, and training. Thus, adoption and enforcement of these policies have occurred in a disjointed manner amongst the separate communities. The effectiveness of our military inventory relies on the acquisition system, upgrades to the weapons inventory, T&E, certifications, and ultimately the training of our armed forces. Synchronized governance is essential to binding T&E and training requirements into a common M&S maturity strategy. Major Vila, from the Joint Interoperability Test Command (JITC), highlighted the similarities and differences amongst each of the three communities (Vila 2009). The following sections summarize some of the overarching policy and guidance influencing the communities of interest and the common themes that emerge among them.

Acquisition LVC guidance

The three major policies for the acquisition community include the Defense Acquisition System, DoD Directive 5000.01 (DoD 2008); Operating Instruction of the Defense Acquisition System, DoD Instruction 5000.02 (DoD 2008) with updates in the Weapon Systems Acquisition Reform Act of 2009; the CJCS Instruction of the Joint Capabilities Integration Development System (JCIDS) Process, CJCSI 3170.01G and the manual for its operation (CJCS 2011). Themes start to develop among the three policies:

- reliance on M&S throughout a system's lifecycle,
- reliance on the LVC to achieve training efficiencies and facilitate T&E activities,
- training systems mirroring interoperability requirements of operational systems, and
- interoperability of M&S in the LVC training and test environment.

Although each of the documents introduces the theme of LVC, no specific direction of its usage can be enforced. The most fundamental acquisition policy and guidance available to the acquisition community begins to paint an incomplete picture of how to synchronize M&S and LVC along the acquisition timeline. Specified instruction and guidance is lacking and is open to interpretation by the community, which allows each Service to develop their individual governance to meet JCID's requirements.

Test LVC guidance

The four major guidance and polices for the T&E community include the Director of Operational Test and Evaluation (DOT&E), DoD Directive 5141.02 (DOT&E 2009); Test and Evaluation Master Plan

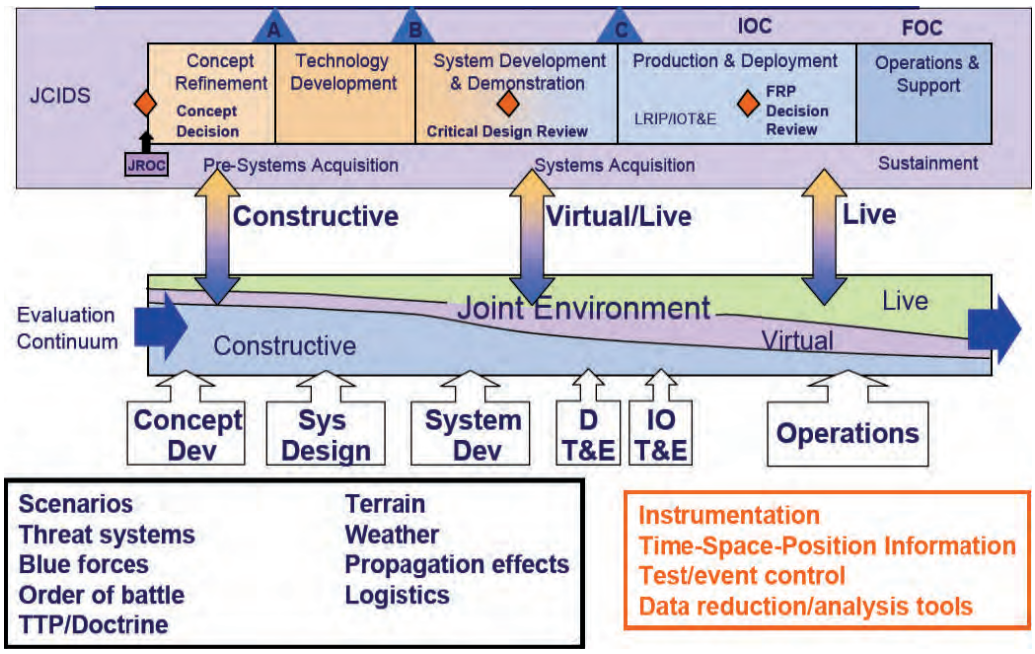

Figure 2. Joint mission environment across the acquisition lifecycle.

(TEMP) Guidelines (DoD 2008), Joint Test & Evaluation (JT&E) Handbook (DOT&E 2008), and the CJCS Instruction on Interoperability and Supportability of Information Technology and National Security Systems, CJCSI 6212.01E (CJCS 2008).

T&E activities differ among military departments. Each Service "grows" their testing centers, range complexes, policy, and guidance. Most of the Service-specific T&E governance is developed to meet requirements imposed by Acquisition guidance. However, some common themes emerge, which cut across the four polices:

- Interoperability is a major concern of the T&E community, as more systems join the net-centric environment.
- Emerging, net-centric capabilities must be mirrored by training systems, which raises similar interoperability challenges.
- Verification, validation, and accreditation (VV&A) is essential to the adoption of LVC capabilities in realistic T&E environments.

As with the acquisition policy above, LVC is touched upon but referenced solely within the specific T&E community. Usage of LVC in T&E lacks any specific correlation to training (DiPetto 2008). However, the JT&E Program handbook does reference training in the context of relying on operational training exercises to conduct JT&E activities. This statement is the first applicability and validity of relying on M&S and training systems in T&E.

Training LVC guidance

Training is the most specific, Service-driven activity. The guidance set forth by the training community is the most detailed as it relates to working across the Acquisition and T&E communities.

DoD Directive 1322.18 (DoD 2009) defines requirements for training of military personnel and outlines the responsibilities of each of its organizations (England 2009). Although the main focus is on military training, the directive necessitates the collaboration with the Acquisition and T&E communities.

Acquisition restructure

In order to utilize LVC capabilities/assets to train in a Joint environment, changes to how DoD currently acquires and tests systems need to be addressed first. As shown in *Figure 2*, the acquisition, testing, and training communities can utilize the LVC environment.

The effectiveness of our military relies on the acquisition system, upgrades to the weapons systems inventory, T&E, certifications, and ultimately the training of our armed forces. Synchronized governance is essential to actions that bind T&E and training requirements into a common M&S strategy. DoD acquisition instructions are slowly being updated to include changes that declare the need to test Joint capabilities in the JME. The Joint Capabilities Integration and Development System (JCIDS) implements an approach to identifying current and future capability gaps in DoD's ability to carry out Joint

warfare. This activity begins the process of using LVC throughout the acquisition life cycle. Even if acquisition policy is fully in place, actual LVC testing depends on requirements and resourcing. Programs of record need to include requirements for Joint testing and resources for both testing and the LVC environment.

Common Joint LVC environment

DoD policy and directives dictate the need for a common Joint collaborative environment within the test and training communities. This effort will take considerable time and effort among many organizations within the DoD but, in the end, will enhance JLVC capabilities and greatly reduce the resources needed to sustain each community as a separate entity. The establishment of a singular test and training acquisition and development process is essential for the success of this effort. However, many obstacles, which need to be addressed individually, contribute to the current limitations and shortfalls of the JLVC efforts. "The ultimate goal would be a truly plug-and-play environment where different simulation can simply be dropped into an LVC environment and work seamlessly, this vision is still some way off" (Buxbaum 2009). The following assessment and review describes what needs to be accomplished in resolving JLVC interoperability issues.

Network infrastructure

Networks are essential in order to enable JLVC testing and training to occur. These network connections allow for large amounts of data to pass between sites in real time across vast distances; however, there are limitations to the current DoD network infrastructure, which limit this capability.

Over the last decade, DoD has established a variety of robust, high-capacity, low-latency networks including the Defense Research and Engineering Network (DREN), Joint Test and Evaluation Network (JTEN), Air Reserve Component Network (ARCNet), Navy Continuous Training Environment (NCTE), Joint Information Operation Range (JIOR), Missile Defense Agency Classified Network (MDACNet), Battle Lab Collaborative Simulation Environment (BLCSE), and Distributed Mission Operations Network (DMON), shown in *Figure 3* (Gallegos 2010).

Each network is maintained by separate government agencies and is connected to various sites and systems, which other networks typically have no direct connection to. For example, the DMON is connected mainly to U.S. Air Force bases and facilities, while the NCTE is connected to U.S. Navy ports and stations. Currently, there is no persistent connection between the two networks nor is there a single hub in which to schedule such network connection activities. There is

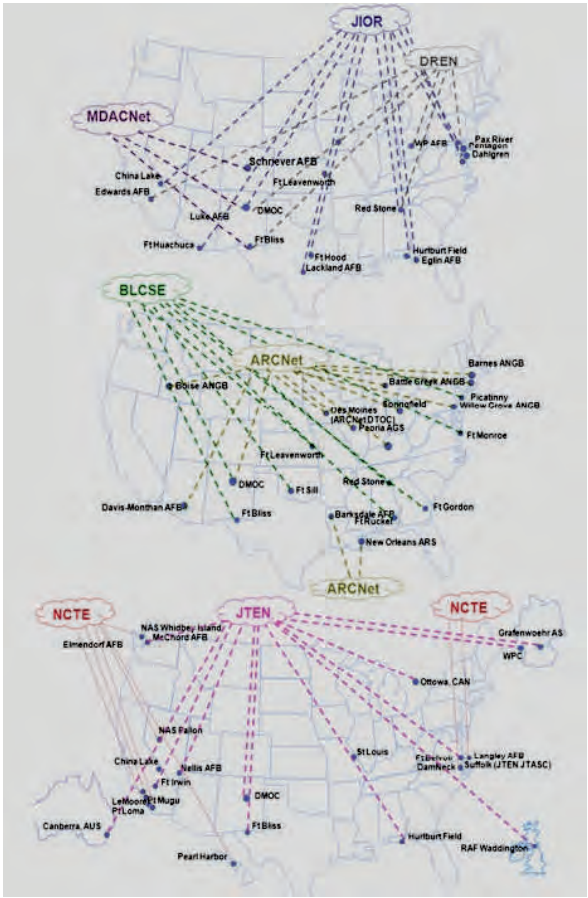

Figure 3. Department of Defense live-virtual-constructive networks.

limited access between separate networks as well as limited cross-domain standards and costly redundant T-1 network connections.

To create a persistent connection from one site to the next, from one Service to the next, is extremely resource demanding. For instance, in order for a U.S. Air National Guard F-16 simulator to connect to a Naval EP-3E simulator site, it must pass data through four different autonomous networks (ARCnet, DMON, JTEN, NCTE) (Sorroche 2005). Each network hub has its own personnel managing the network who ensure appropriate connections and setups are made and monitor data traffic. With multiple network nodes, technical network issues can easily arise such as latency, lost data packets, lost connections, and data translation issues. Other non-technical issues include scheduling, configuration management, limited personnel and resources, and cost (Hudgins 2010).

Recent efforts by the Office of the Secretary of Defense (OSD) have created the Joint Mission Environment Test Capability (JMETC). JMETC is the DoD approach for linking distributed facilities that

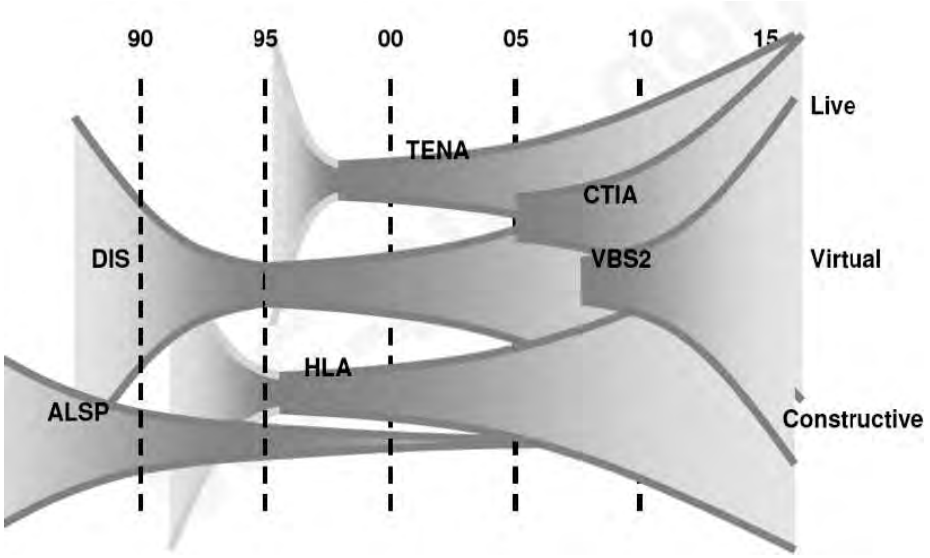

Figure 4. Simulation architectures and live-virtual-constructive coverage, including Virtual Battle Space 2 (VBS2), Common Training Instrumentation Architecture (CTIA), Distributed Interactive Simulation (DIS), High-Level Architecture (HLA), Test and Training Enabling Architecture (TENA), and Aggregate Level Simulation Protocol (ALSP).

will provide the needed compatibility between test and training communities and become an easily reconfigurable infrastructure (Riggs et al. 2011; Hudgins 2010). This environment addresses such issues as network persistence, collaboration tools, configuration, centralized security management, and many others.

Collaboration tools

In the LVC construct, collaborative tools would include tools that deal with information sharing such as chat and file sharing. Although several file sharing tools like Microsoft Chat and InfoWorkspace (IWS) are commonly used throughout DoD, the Defense Connect Online (DCO) capabilities are starting to become the standard file-sharing approach throughout DoD. Defense Knowledge Online (DKO), a Joint Web-based collaboration environment, includes DCO, which is a Government Off-The-Shelf (GOTS) product (Joint Knowledge Online 2010). Although DCO has been around for a few years, use within the DoD has been limited, but employment of the tool set is growing.

Chat and file sharing may seem like trivial issues within the LVC environment; however, using such collaborative tools as DCO helps to simulate and promote an integrated, distributed community. It is important to consider and promote such enterprise software solutions across the DoD.

Simulation architecture

Aside from networks to distribute and connect sites and systems, the simulation language used by each system is also important. There are three main simulation architectures used in the distributed simulation world: Distributed Interactive Simulation (DIS), High-Level Architecture (HLA), and Test and Training Enabling Architecture (TENA); when combined, they represent 90 percent of the distributed M&S community (Gustavsson 2009). Each simulation language has a varying amount of LVC capability. *Figure 4* shows the progression over the last 2 decades of how each protocol language has evolved and is projected to evolve within LVC.

Originally HLA was created to replace DIS. However, this did not occur as some programs embraced HLA, while others continued to use DIS. Each protocol continued to be used, and standards development continued for both protocols in a disjointed manner. Today, systems using one simulation architecture have difficulties interoperating with systems using another, without a gateway or bridge between them. Gateways/bridges are used to move data from one network to another, change the data format from one network standard to the next, translate one simulation language to another, regulate bandwidth, filter data, and ensure standards are maintained for the network they are attached to.

Gateways/bridges are making network connections more seamless; however, each language has limitations that make it impossible to translate certain information from one language to another. This issue is becoming increasingly prevalent in creating higher fidelity systems with enhanced capabilities such as advance electronic attack for a fighter aircraft and Improvised Explosive Devices (IEDs).

The Institute of Electrical and Electronics Engineers (IEEE) controls the standards for HLA and DIS. Participation across the Services in such development groups is essential to ensure greater interoperability, fidelity, and capabilities for JLVC. Currently, the DIS standard has 30 members reviewing and voting for the standard. This number is fairly small considering the overall DoD community that employs the DIS standard. It is essential that such standards are properly monitored and that representation is given to promote the interest of the DoD and the JLVC community as a whole.

In trying to move towards a more standardized process, the HLA community wrote and approved the Federation Development and Execution Process (FEDEP). The FEDEP "is a standardized and recommended process for developing interoperable HLA based federations." (Lowe 2010). Despite the establishment of a process for a standardized approach, this "recommended" process has not been stringently followed or enforced thus far. The FEDEP was published in 2003; and in 2007, the Simulation Interoperability Standards Organization (SISO) decided that the FEDEP should be revised and expanded to include all distributed modeling languages (SISO 2010). The FEDEP was renamed the Distributed Simulation Engineering and Execution Process (DSEEP). Although still considered a "recommended" process, the DSEEP is a universal standard that the M&S community can use to reach a more unified and interoperable environment (Lowe 2010).

Over the last several years, the promise of TENA and its continued opportunity for interoperability has been documented and demonstrated (Gibson 2010; Hudgins 2010; Testa et al. 2006). TENA was created to address test and training requirements that HLA does not handle and its capabilities are focused on live training events; while HLA capabilities favor the virtual realm. Some have argued that these languages need to converge toward a single standard, enveloping all the capabilities from both languages into one (Morse 2010).

Data filters

In any given JLVC event or exercise, a multitude of data is passed from one simulator to the next. In a given operational theater construct, there can be many different participants in the battlefield environment, with thousands of entities being generated and passed between simulations. As in a live exercise, various assets are not required to receive data that are of no operational concern to them. Some systems, legacy and non-legacy alike, can only handle a specific traffic load because of antiquated operating systems, limited memory, and older software versions. Receiving all the data within a JLVC exercise would overwhelm systems and cause instability and failure. Filters are set up between such systems to remove unneeded data traffic and to regulate bandwidth. Many systems have their own filters; some use external filters, while others rely on their network portals to act as filter mechanisms for each system. Each of these filters works differently, can be either a Commercial Off-The-Shelf (COTS) or GOTS product, and follows no specific standard. Filters play a large factor in the success or failure of a large-scale exercise.

There are many variants of filtering tools available in the JLVC environment. Each tool set has its own strengths and weaknesses, and specific tools are preferred by certain organizations. Although most filters can supply the abilities necessary to employ a successful event, configuration management and human error play a large part in filter failure. For example, the filter operator can enter the wrong routing address, so the simulator receives no data; or the operator may accidentally allow data through that should have been filtered out, causing the simulator to be overloaded with extraneous data. Also, some filters are much more advanced than others; the Distributed Mission Operations Center (DMOC) has very intricate filtering software, which is a GOTS product. Although it is only compatible with DIS, this filtering tool is being employed in many organizations throughout the DoD.

Common models

The ability to translate data between one simulation language and another is very important to ensure a consistent and seamless environment as is the passing of data from one system to another using the same language. DIS, HLA, and TENA are well established and have users that can easily implement the protocols needed to accomplish their tasks. However, the data passed within each language through various protocols are not standardized. One example is the passing of emission, or radar, parametric data (e.g., frequency, pulse rate interval, bandwidth) between two different simulators. One aspect of this issue is the need to understand where each simulator derived its radar parametric data. The National Air and Space Intelligence Center (NASIC) and the Missile and Space Intelligence Center (MSIC) are considered the subject-matter experts for realistic parametric data for Electronic Warfare (EW); however, there are also other sources as general as IHS Jane's, an open-source intelligence provider. Defense contractors often create proprietary representations, mining data from a variety of sources. Even simulators created by the same company do not necessarily ensure commonality and interoperability of models.

In addition to the lack of correlated data for a given model, a 3-D model is also a concern within the testing and training communities, specifically for Close Air Support (CAS) and urban warfare type events. High-fidelity modeling is necessary to test and train in the type of warfare environment seen in Iraq and Afghanistan today.

Terrain databases also play a very important role in the JLVC environment. All simulators were not created equal, and many legacy systems are limited by their processing capability, memory, and speed. Depending on the terrain data source and the Digital Terrain Elevation Data (DTED) used, ground objects created in one simulator may look like they are under the ground or floating in another system. Correlation between databases is a significant issue and concern in JLVC events. Some legacy simulators even use bald-earth terrain databases, with no elevation data taken into consideration. In a testing event or training exercise, this would lead to issues such as entities traveling through mountains and hills, target tracking radars being able to "see" aircraft through mountains, and entities being created above and/or below the terrain.

In order to overcome these issues and create a single-source repository of information that is accessible to all DoD users, Joint Forces Command (JFCOM) has begun developing the Joint Training Data Services (JTDS) software. Currently, the main focus of the JTDS software is on common data models, terrain/geospatial database, weather, and force structure data. Involvement in this activity includes the National Geospatial-Intelligence Agency (NGA) and the Defense Information Systems Agency (DISA) to garner this information. The JTDS software is GOTS, available for download and currently on its third spiral release. The information being gathering is certified data and easily accessible for DoD agencies. The next critical step is to mandate that the software must be used for DoD events and exercises. DoD agencies are hesitant to employ new databases and models, which can be time consuming and costly to retrofit. It is imperative to have a single-source location for terrain and parametric data. However, if only a few organizations use this software, it will not resolve the overall data noncorrelation issue.

Environment Generators (EGs)

EGs are used to create constructive entities for virtual and live systems to test and train against. Typically, EGs are created for a specific program or simulator, meaning that the EG is specialized for its use. For instance, NAVAIR's Next Generation Threat System (NGTS) EG, specializes in air-platform training, while Teledyne Browne's Extended Air Defense Simulation (EADSIM) EG specializes in theater missile defense. In their current states, neither simulator could replace the other without the loss of capabilities. The purpose of EGs is to provide the best and most realistic testing or training environment to the warfighter. However, there are other EGs that do air-platform training much like NGTS. Boeing's Big Tac, Air Force Research Laboratories' eXpert Common Immersive Theater Environment (XCITE), Plexsys' Advanced Simulator Combat Operations Trainer (ASCOT), and Presagis' Scenario Toolkit and Generator Environment (STAGE) all have the standard baseline of air-platform EGs. Although they are all developed for different types of air platforms, by different contractors, they all have similar air-platform testing and training capabilities. Yet, instead of promoting a single EG for a given domain, the Services continue to build new EGs when a new system or capability comes online. Developing and supporting a multitude of EGs is very costly to the government because of the mass duplication of effort. The Services need to promote reusability of EGs and move more towards a consolidation versus expansion of the EGs it employs.

To address the redundancy and management of multiple EGs for various U.S. Army systems, the Army established the One Semi-Automated Force (OneSAF) program. The purpose of OneSAF is to build a single EG, replacing many existing SAFs to save the Army money and promote interoperability. The other Services can learn from the pathfinding of the OneSAF program.

Multi-level security

Multi-level security is important to both the test and training communities within DoD and to our coalition partners. Different sites and simulators operate at various security levels, each with different information-sharing limitations. An example of this is the F-22 simulator; it does not participate in distributed exercises because of the secure nature of the real-world system. Playing in a distributed environment would demonstrate its operational capabilities, along with broadcasting its parametric data via the data packets passed to the other simulators that can be viewed on a recording device. The importance of keeping that information secure is known; however, it limits the testing and training capabilities of the system for the operator. Some exciting recent efforts have been demonstrated on JMETC, which implemented a National Security Agency (NSA)-approved cross-domain solution for multi-level security.

Multi-level security is also very prevalent in coalition exercises. Sharing information about each site and system within the DoD, although requiring both a

Memorandum Of Agreement (MOA) and an Authorization To Operate (ATO) to connect, takes only a signature from both site commanders for approval. In order to connect and share information with non-U.S. participants, a lot more paperwork, time, and effort are involved. There are specific limitations and restrictions of what information can be shared, and depending on the nation, the restrictions will vary. Events with non-U.S. participants can be a long and arduous process.

Conclusion

The LVC environment is very large and complex, with many different facets that must be taken into consideration in establishing a distributed environment for the testing and training communities. There is no easily identifiable single element within the LVC environment that is the critical fail point nor is there a single solution that can resolve all LVC issues facing the DoD today. It is important to understand that while work has begun, there is considerably more to do to create a fully interoperable LVC environment. Presently, there is still much redundancy of effort with many small technical and financial issues. A follow-on article will document recommendations for LVC interoperability, along with results from polling the LVC community.

From program initiation of a desired capability, through test and evaluation, and culminating at the operational training capability, the use of LVC in M&S is guided by directives and instructions issued by the DoD. Adoption of these policies has occurred in a disjointed manner among the LVC communities of interest. The effectiveness of the military inventory relies on the acquisition process, test and evaluation, certifications, and ultimately the training of our Armed Forces. ❑

Dr. John Colombi is an assistant professor of systems engineering at the Air Force Institute of Technology (AFIT). Before joining AFIT as a civilian, Dr. Colombi served 21 years in the U.S. Air Force leading various C4ISR systems integration and systems engineering activities, developed information systems security at the National Security Agency (NSA), and researched communications networking at the Air Force Research Laboratory. E-mail:john.colombi@afit.edu

Captain Chris Cobb, USAF, is participating in the Air Force Education with Industry Program for Space Lift Operations. He spent the last few years at the 705th Combat Training Squadron at Kirtland Air Force Base as chief of integration and standards for modeling and simulation, and 1 year as training flight commander in charge of distributed mission operations for the squadron. Captain Cobb holds a bachelor of science degree in electrical engineering from the Colorado School of Mines and a master's degree in systems engineering from the Air Force Institute of Technology. E-mail: cobbcj@gmail.com

Damian Gallegos has worked for the last several years as a systems engineer at the Distributed Mission Operations Center (DMOC) at Kirtland Air Force Base, New Mexico, working in standards development. He is team leader for large-scale distributed virtual exercises. He holds a bachelor of science degree in electrical engineering from the University of New Mexico and a master's degree in systems engineering from the Air Force Institute of Technology. E-mail: damian.gallegos.ctr@kirtland.af.mil

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Benefits and Challenges of Multidisciplinary Project Teams: ''Lessons Learned'' for Researchers and Practitioners

Haydee M. Cuevas, Ph.D. and Cheryl A. Bolstad, Ph.D.
SA Technologies, Inc., Marietta, Georgia
Robert Oberbreckling
Perceptive Research, Inc., Boulder, Colorado
Noelle LaVoie, Ph.D.
Parallel Consulting, LLC, Petaluma, California
Diane Kuhl Mitchell and James Fielder
U.S. Army Research Laboratory, Aberdeen Proving Grounds, Maryland
Peter W. Foltz, Ph.D.
Pearson Knowledge Technologies, Inc., Boulder, Colorado

Adopting a multidisciplinary research approach would enable test and evaluation professionals to more effectively investigate the complex human performance problems faced in today's technologically advanced operational domains. To illustrate the utility of this approach, we present "lessons learned" based on our experiences as a multi-agency, multidisciplinary team collaborating on an Army research project involving a dynamic military command and control simulation. Our goal with these lessons learned is to provide guidance to researchers and practitioners alike concerning the benefits and challenges of such collaboration. Our project team's diverse members, drawn from both industry and government organizations, offer their multiple perspectives on these issues. The final sections then summarize the challenges and benefits of multidisciplinary research.

Key words: Collaboration; command and control; experiments; human performance; multidisciplinary research; simulation.

Multidisciplinary research involves a coordinated effort that brings together several disciplines to provide complementary contributions in the service of a common goal (Fiore and Salas 2007). Multidisciplinary project teams offer multiple perspectives and a broad range of expertise for generating unique and creative solutions to solve real-world problems. We propose that test and evaluation professionals would benefit from adopting a multidisciplinary research approach to investigate the complex human performance problems faced in today's technologically advanced operational domains. We illustrate this approach by presenting "lessons learned" based on our experiences as a multi-agency, multidisciplinary team collaborating on a U.S. Army research project involving a dynamic military command and control simulation. We begin with a brief overview of the experiment and then discuss each lesson learned in turn. The discussion reflects the multiple perspectives of our project team's diverse members, drawn from both industry and government organizations. Commentary is also provided from the project manager's perspective. We conclude with a summary of the challenges and benefits of multidisciplinary research.

Experiment overview

As part of a U.S. Army sponsored project, an experiment was conducted at the Aberdeen Test Center (ATC) in Aberdeen Proving Ground, Maryland. Six Soldier, Operator, Maintainer, Tester, and Evaluator (SOMTE) soldiers were assigned to one of two

three-person crews (vehicle commander, driver, and gunner) of a Mounted Combat System (MCS) vehicle. Crews completed eight 75-minute simulated military missions, maneuvering their MCS vehicles through desert and urban environments while controlling unmanned ground and aerial systems. For complete details on the objectives, methods, and results for this experiment, see Bolstad et al. (2009) and Mitchell et al. (2009).

Experiment research objectives

For our project team's industry representatives (SA Technologies, Pearson Knowledge Technologies, Perceptive Research, and Parallel Consulting), the primary research objective was to collect data in future command and control scenarios to develop the Automated Communications Analysis of Situation Awareness (ACASA) system, which unobtrusively assesses situation awareness based on analysis of team communications. The goal was to link measures of situation awareness to correlated measures derived from communications among team members. To facilitate discussion, these project team members are referred to as the "ACASA researchers."

For our project team's government representatives (Army Research Laboratory Human Research and Engineering Directorate [ARL-HRED]), the primary goal was to verify existing ARL-HRED task analysis and workload predictions associated with an Improved Performance Research Integration Tool (IMPRINT) analysis of the MCS. To facilitate discussion, these project team members are referred to as the "ARL-HRED analysts." The ATC representative on our project team served as the experiment coordinator, handled participant recruitment, and supervised the programming and running of the simulation and collection of the physiological and task performance data.

Data collection measures

To address these research objectives, our project team utilized different measures and techniques. ACASA researchers collected objective situation awareness data using the Situation Awareness Global Assessment Technique (SAGAT) (Endsley 1995) and recorded digital audio files of voice communications, both within and across teams, using BBN-Talk. ARL-HRED analysts used a modified version of the Instantaneous Self-Assessment of Workload (ISA) (Kirwan et al. 1997) questionnaire to assess participants' self-reported estimates of their perceived workload during the missions. The workload data were supplemented with experimenter observations. ATC researchers set up the electroencephalogram (EEG) recordings to collect physiological workload data. Task performance data were collected automatically by the simulation and recorded in log files.

Lessons learned

Here, we discuss several important lessons learned gleaned from our multidisciplinary collaboration in conducting this experiment. These lessons learned are aimed at providing guidance to researchers and practitioners alike concerning the benefits and challenges of such collaboration. Insights are presented from all perspectives of our project team regarding the process of planning and executing an experiment involving multiple stakeholders with distinct research objectives.

Meeting distinct research objectives

In multidisciplinary research, researchers must understand their own research objectives as well as how these are related to the other project team members' objectives. Our project team's research objectives for this experiment were similar in that we were all interested in assessing human performance during completion of complex cognitive tasks. However, our objectives differed in terms of the specific aspects of cognition and performance investigated by each team member (e.g., situation awareness, mental workload). Our project team members had multiple data modalities, with different requirements, from multiple independent researchers. Further, each planned analysis for each data modality required different "minimums" of data to be collected for a valid and reliable analysis. One researcher's experimental design would likely not provide enough data (or enough of the right kind of data) for the other researchers involved.

Ensuring that our project team's distinct research objectives were met required careful planning of the experiment, involving all stakeholders. We created a comprehensive test plan detailing how all the researchers' measures would be implemented in the experiment. This allowed us to visualize how our data collection would fit within the experiment and to coordinate our data collection activities, so we did not interfere with each other. The experiment was designed well enough ahead of time to allow our project team members to generally work within their own stovepipes when collecting data within their specialties. Our project team's investment in planning and designing the experiment paid considerable dividends during the execution of the experiment and subsequent data analysis.

Our multidisciplinary project team's different research objectives were aligned in terms of the need for a small-scale experiment involving a realistic task and manageable variability of events. Using realistic

scenarios with representative participants (soldiers) provided context validity to the results. Although we had limited control over scenario design and simulation configuration, enough flexibility was available to enable the project team to meet their research objectives. For example, to verify their workload analysis, ARL-HRED analysts needed to ensure that scenarios developed by ATC researchers represented missions analogous to missions in the IMPRINT MCS analysis. The similarity of missions was important to make it more likely that soldiers participating in this experiment would perform the same set of tasks as the soldiers in the ARL-HRED IMPRINT analysis. Collecting data from a similar set of tasks, in turn, would permit ARL-HRED analysts to compare workload data and performance measures collected during the experiment to the IMPRINT-predicted workload data for the same tasks.

Lesson learned #1. Upfront collaborative design of an experiment allows each researcher to effectively work independently within his/her area of expertise during the actual data collection of the experiment. Thus, in multidisciplinary research, team members should begin working together early during the experiment's planning and design stages and then work independently, where appropriate, during the execution stage (rather than the reverse!).

Resolving conflicting data collection requirements

Meeting our project team's distinct research objectives involved careful consideration of how to efficiently incorporate the different measures and apparatus into the overall experimental design. For example, collecting team communication data during a distributed team simulation requires instrumentation technology for each participant (e.g., headphones, multichannel digital recording software). It can be challenging to instrument each participant to reliably collect the required data while not being overly intrusive to the point of affecting participants' performance during the experiment, which would interfere with other project team members' research objectives.

Similarly, each group within our project team had specific requirements to optimize their organization's data collection techniques. While continuous measures (e.g., EEG recordings) were easy to coordinate during the experiment, collection of non-continuous measures (e.g., the SAGAT) had to be more carefully planned in advance. For example, the SAGAT used by ACASA researchers required pausing the simulation and interrupting task performance. These pauses, in turn, created challenges for ARL-HRED analysts who would have preferred to collect continuous workload data during the mission. This required a trade-off in the experimental design, prioritizing collecting situation awareness data over collecting continuous workload data.

Collecting team communication data was also a priority in this experiment. Accordingly, the simulation scenarios were specifically designed to elicit frequent voice communications among participants. However, this created another challenge for ARL-HRED analysts in that sending and responding to voice communications became the most frequent tasks performed by participants, both alone and in combination with other tasks. This frequency of communications may have biased results regarding which tasks contributed to the highest workload during the experiment. If ARL-HRED analysts had collected data in their own independent study, this bias may not have occurred.

Lesson learned #2. Conducting multidisciplinary research requires careful consideration of conflicting data collection requirements with the goal of minimizing interference across the different measures and judicious prioritization of research objectives when necessary.

Leveraging data collection efforts

Another important consideration for conducting multidisciplinary research involves leveraging the data collected by other project team members to meet one's own research objectives. Support for the utility of such synergistic collaborations was demonstrated in this experiment. For example, to create predictive statistical models of situation awareness, ACASA researchers had to integrate several sources of experimental data from multiple researchers, including transcriptions of the digital audio recordings, SAGAT scores, multichannel digital EEG logs, and additional data logged by the simulation. While these streams were collected by experts in different disciplines, it was possible to integrate these into a useful dataset for analysis because of our project team's early collaborative planning.

Furthermore, by comparing the physiological data collected by ATC researchers with the ISA self-report ratings collected by ARL-HRED analysts, we could establish an association between these two different types of workload measures. Similarly, by comparing this workload data with the situation awareness data collected by ACASA researchers, we could also possibly identify a relationship between different workload levels and performance. ARL-HRED analysts could also use the team communication data collected by ACASA researchers to calculate frequency and duration of messages for input into subsequent IMPRINT analyses of manned ground vehicles.

Lesson learned #3. One of the major benefits of multidisciplinary research is that team members have access to a broader range of data at no (or only minimal) additional cost.

Resolving technical issues

Technical issues are almost always encountered in empirical research, particularly in studies involving simulations. The larger the experiment, the greater is the potential for unanticipated technical problems to occur. Our project team was distributed, multiple technologies were involved to instrument and collect data, and those installing and configuring the technology were removed from those who would be analyzing the data. Indeed, our project team members did not all meet in person until everyone assembled together on the days scheduled to conduct the actual experiment. Additionally, our project team worked under resource and time constraints owing to project deadlines and other commitments, leaving limited time available to conduct practice runs of the experiment test plan to test the systems and measures. Not surprisingly, our project team encountered its share of technical issues during the execution stage.

One of the more significant technical problems involved synchronizing the simulation "clock" time with the different measures (e.g., SAGAT, digital audio recordings, EEG recordings, observations). Synchronization of data collection to the simulation clock times was critical for aligning and comparing results across the different measures administered during the experiment. Although our project team had agreed upon having a central reference clock, so that all researchers could synchronize their individual data collection efforts, how those clock times were recorded within the individual data streams differed. Unfortunately, this issue could not be completely avoided because of the different technologies used to run the simulation and collect each type of data. This resulted in some challenges in resolving different interpretations of the central clock when analyzing multiple data streams together. Nonetheless, through careful comparison across data files and follow-up discussions, our project team was able to sufficiently resolve this issue to facilitate data analysis. In particular, our project team benefited from the manual recording by ARL-HRED analysts of the simulation clock time whenever the simulation was started and stopped. Their detailed records facilitated scoring the SAGAT data using the simulation log files.

Lesson learned #4. Establish from the outset a standardized central reference time that can be used by all researchers for tagging and analyzing data.

Another concern for any research endeavor is to minimize the occurrence of missing or incomplete data. In some cases, this is unavoidable, such as with unexpected equipment malfunctions or simulation delays. However, other instances of missing data can be avoided with proper planning. For example, in addition to SAGAT, ACASA researchers had planned to collect additional situation awareness data by having a Subject Matter Expert (SME) present real-time queries to participants. Unfortunately, this SME had also been assigned to serve as the company commander during the experiment and was responsible for briefing the participants on their missions and operations orders as well as monitoring their activities. The workload associated with performing this important role prevented him from being able to administer the real-time queries and record participants' responses on a consistent basis. Because of a lack of sufficient data, analysis of the real-time queries could not be conducted.

Lesson learned #5. Review assignments to minimize conflicts; individuals assigned to critical roles in the experiment should not be tasked with also collecting data and vice versa. Whenever possible, designate a trained experimenter to regularly verify that data are being collected as scheduled and to inform researchers when any problems are detected.

Another incident that occurred during the experiment highlights the importance of coordinating with others outside of the project team. During one of the missions, a computer acting as a central data collection point was accidentally taken offline by a regularly scheduled maintenance operation. The personnel in charge of this operation were simply performing their regular duties to effectively maintain the organization's technologies. However, because they were unaware of the experiment and the criticality of keeping this computer online, this communication failure resulted in a potential vulnerability in our data collection efforts. While the results were not catastrophic overall, the event did require resetting the simulation run.

Lesson learned #6. Beyond the project team's research stakeholders, a multidisciplinary team can also benefit from including representation of operational stakeholders. This helps ensure explicit communication of data collection requirements and constraints with members of the broader organization who may either directly or indirectly affect the project team's data collection efforts.

On a more general level, our multidisciplinary project team members have different training, backgrounds, experiences, and traditions. Similarly, each discipline has communal conventions for how data are collected, what formats are preferred, and how data are

labeled, organized, and analyzed. A multidisciplinary project team must communicate these practices and preferences to others who may be analyzing their data. What may seem implicit, obvious, or expected data collection practices within one research discipline may not be so when another discipline is analyzing that same data. To illustrate, one of the technical challenges noted by ARL-HRED analysts was their lack of adequate understanding of the relationship between the physiological measures recorded by ATC researchers and a workload algorithm embedded in the software associated with these measures. ARL-HRED analysts observed the measures and algorithm fluctuating throughout the experiment. However, because they did not understand the relationship between the measures and workload, they could not annotate this observed relationship in their observation data of participants' performance.

Lesson learned #7. A more thorough understanding by all project team members of the different instrumentation, software, and techniques used in the experiment may mitigate the occurrence of technical problems during multidisciplinary research activities. It can also provide synergistic benefits to the team as a whole.

Resolving administrative issues

Multidisciplinary research also creates potential administrative issues. To minimize the occurrence of such problems, our project team held regular meetings to design the experiment, create a common test plan, and coordinate our various research activities. Creating a common test plan helped to foster a broader perspective on the experiment. Still, some administrative issues had to be addressed both before and during the experiment.

Our project team was distributed across the country in different time zones, requiring a greater level of coordination to schedule regular meetings among researchers. Additionally, much of the simulation software design and hardware/software instrumentation was handled by contracted resources onsite. This required training the contractors on the technology to be employed along with documenting and communicating requirements. Since ACASA researchers were unable to access the experiment site prior to the study, this arrangement worked out well.

A notable administrative constraint associated with the experiment resulted from differences in funding mechanisms. Ideally, when several organizations participate in a joint experiment, funding for all parties involved should be provided prior to planning. Unfortunately, ACASA researchers experienced delays at times in receiving contract funding. As a result, ARL-HRED analysts experienced delays in receiving the inputs they needed from the other organizations. Nonetheless, our project team was able to reduce costs overall by collaborating with other researchers on this multi-agency experiment. For example, ATC researchers had access to soldiers whose mission is to support ATC testing. Thus, working with ATC researchers shortened the process for obtaining soldiers to serve as participants, and one of these soldiers also helped develop the mission scenarios.

Another administrative issue resulted from differences in the publication approval processes of the participating organizations. Thus, each organization prepared and published its own separate reports and manuscripts, with reference, as appropriate to the other project team's publications. Still, all data collected during the experiment were shared among all project team members, and we have been coordinating across our different organizations to prepare joint publications that provide a more comprehensive report of the experiment's findings.

Lesson learned #8. Multidisciplinary research requires consideration of the administrative capabilities and constraints of all key stakeholders, including, but not limited to, geographical distribution, funding mechanisms, and organization-specific policies and resources. Careful planning and regular communications among project team members can help avoid or minimize the effects of many of these issues.

Managing multidisciplinary projects

Managing and providing oversight on a multidisciplinary research project involving multiple stakeholders with distinct research objectives presents unique challenges to the project manager. Arguably, the greatest of these is *prioritization*. The project manager has to weigh the benefits of each of the research aims with the specific test requirements imposed by the researcher. As part of the prioritization process, the project manager is the "middle-man" between the different disparate groups. Communicating the project's end goal with each of the researchers and de-conflicting their different requirements takes up much of the project manager's time during the planning process. However, the end result of this prioritization and de-confliction process is an overall experiment test plan with consent from all project team members.

These challenges notwithstanding, a multidisciplinary research approach offers distinct advantages compared with collecting data in a simpler study focused on a specific research question. Researchers conducting stovepipe research rarely venture outside of their own

lanes. However, when working with other researchers toward a common goal, they can critically think through their own processes and techniques and judge them against other research techniques. Multidisciplinary project team members also have access to data they usually would not collect. This additional data may spur them to adapt their techniques to include new sources of data in future research or refine their theories based on conclusions drawn from this previously unexplored data. At a broader level, with multiple researchers from several disciplines all working toward achieving the same goal, their combined output will examine the problem from every side and provide a robust answer not typically found in a stovepipe one-discipline approach. Thus, the added input from other disciplines furthers the conclusions derived from the research, and multiple groups are all able to converge and support a unified comprehensive solution to the problem.

Challenges in multidisciplinary research

The primary challenge in conducting multidisciplinary research is meeting the constraints of different stakeholders with different agendas. Although our project team actively worked together to develop a comprehensive experiment test plan that addressed each researcher's data collection requirements, in execution, trade-offs had to be made when attempting to coordinate overlapping implementation of multiple measures. Thus, a potential disadvantage of multidisciplinary research is that conflicting data collection requirements may hinder the project team's ability to meet all their members' different research objectives.

Mitigating this issue requires establishing a systematic process by which the project team can objectively agree to a primary goal while still permitting stakeholders to determine their specific research objectives and carefully prioritize their data collection requirements for meeting this goal. Multidisciplinary project teams would also benefit from assuming there are "hidden" requirements and subtle interdependencies that can only be discovered and addressed through early exchanges among team members. Thus, upfront collaboration on planning and experimental design is crucial for successful multidisciplinary research. With experience, multidisciplinary project teams can improve their ability to make the right decisions on necessary trade-offs, balancing research objectives with available resources.

Benefits of multidisciplinary research

In many cases, the advantages of multidisciplinary research generally outweigh its inherent challenges and costs. Still, the decision on whether or not this is the optimal approach primarily depends on the research question being investigated, with more complex research questions benefiting the most from participation of team members with a wider range of resources and different areas of expertise. Setting up and executing even a small-scale simulation experiment is cumbersome, time-consuming, and expensive. By dividing up this task, our project team was able to significantly reduce the amount of time needed to plan and execute the experiment. Pooling resources also resulted in significant cost savings as none of the organizations possessed the resources to conduct such a complex experiment on their own.

Multidisciplinary research also enables the project team to capitalize on a broader range of expertise, drawing from several disciplines. By working together, we were able to draw upon our members' unique yet complementary areas of expertise to address the numerous challenges we faced during planning and execution of the experiment and, thereby, achieve a greater return on our investment. Working independently, a single organization would have had to invest a significant amount of time and expense to develop and implement all the technologies and measures required.

Multidisciplinary research can also be beneficial from a theoretical perspective. Unexpected yet fascinating results and greater theoretical insights can emerge when researchers are empathetic to and knowledgeable of the interests and objectives of other stakeholders. Thus, rather than viewing requirements of other team members as potential constraints, it is worthwhile to leverage these different perspectives to achieve greater theoretically significant outcomes arising from the synergistic activities of multidisciplinary research. It will certainly not happen every time, but this is no reason not to leave the door open to something new, unique, and potentially important to the scientific community. Many great scientific theories and discoveries have come from precisely these kinds of robust interactions. An independent researcher conducting his or her own separate experiment would never have these valuable opportunities afforded by multidisciplinary research.

Conclusion

Science is about problems and possibilities; that is, solving problems and realizing possibilities (Fiore and Salas 2007). In today's technologically sophisticated organizations, human operators must contend with a wider range of problems and possibilities marked by ever increasing complexity. Solving these complex problems and realizing the possibilities of technological advances requires coordinated collaborative scientific endeavors that cut across multiple disciplines. Our goal with this paper was to illustrate how a multidisciplinary

research approach holds significant promise for yielding greater scientific advances in understanding and improving human performance than could be accomplished by a researcher working within a single discipline. We hope our lessons learned will encourage researchers and practitioners alike to consider a multidisciplinary approach for their future research endeavors, so they, too, can achieve a greater return on their investment. ❑

HAYDEE CUEVAS is a Research Associate III at SA Technologies, Inc. She has a doctor of philosophy degree in applied experimental and human factors psychology from the University of Central Florida and has over 12 years experience as a human factors researcher working on numerous Department of Defense and industry-funded projects investigating human performance in complex domains. E-mail: haydee.cuevas@satechnologies.com

CHERYL BOLSTAD is a Principal Research Associate at SA Technologies, Inc. She has a doctor of philosophy degree in psychology specializing in cognition and aging from North Carolina State University and has over 20 years experience as a human factors engineer investigating numerous research areas, including design, training, and assessment of situation awareness in individuals and teams. E-mail: cheryl@satechnologies.com

ROBERT OBERBRECKLING is a founder of Perceptive Research, Inc. He has a bachelor of science degree in computer science from the University of Puget Sound and a master's degree in business administration from the University of Denver. He has over 15 years of applied research and software industry experience, focused on applying software systems to problems in natural language processing, machine learning, data analysis, and predictive modeling. E-mail: rjo@perceptive-research.com

NOELLE LAVOIE is a co-founder of Parallel Consulting, LLC. She has a doctor of philosophy degree in cognitive psychology from the University of Colorado and has over 10 years experience working as an applied cognitive psychologist. She has developed innovative tools that use communication analysis technologies to support multinational collaboration and training applications for increasing tacit knowledge. E-mail: lavoie@parallel-consulting.com

DIANE KUHL MITCHELL is a Lead Analyst for the Army Research Laboratory Human Research and Engineering Directorate. She earned her master of science degree in Industrial/Organizational Psychology from the University of Baltimore. She analyzes the relationship between soldier mental workload and performance using a combination of experimental design, human performance modeling tools, and cognitive task analysis techniques. E-mail: diane.k.mitchell@us.army.mil

JAMES FIELDER is an Operations Research Analyst with the U.S. Army Aberdeen Test Center. He has a master's degree in psychology from Loyola College. He currently serves as a test director for the Tactical Warfighter Interface Branch and is also working on methodology for using EEG sensors to measure soldier workload during test events. E-mail: james.fielder@us.army.mil

PETER FOLTZ is a founder and Vice President for Research at Pearson Knowledge Technologies. He has a doctor of philosophy degree in cognitive psychology from the University of Colorado. He has over 20 years experience working in industry and academia, focused on discourse processes in cognition, computer-based natural language processing, educational technology and team cognition, and cognitive modeling. E-mail: pfoltz@pearsonkt.com

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Test Point Ordering Genetic Algorithm With Precedence Constraints

Daniel Carlson
412th Electronics Warfare Group, Joint Strike Fighter Integrated Test Force,
Edwards Air Force Base, California
P. Travis Millet
412th Test Engineering Group, Global Vigilance Combined Test Force,
Edwards Air Force Base, California

Flight testing is often performed using a build-up approach, where lower risk testing builds up to higher risk testing to ensure flight safety. Efficiently ordering test points can reduce the number of flight hours and, consequently, cost and schedule. This is especially true for testing that includes a large number of test points or test points that can be completed simultaneously. Ordering test points that use a build-up approach is analogous to solving the Traveling Salesman Problem with precedence constraints. This article applies a previously published method of solving the Traveling Salesman Problem with precedence constraints to find a near-optimal test point order that minimizes a user-defined fitness function. The algorithm proposed is a genetic algorithm that implements a topological sort to ensure that precedence constraints are met. A simple fitness function is proposed and applied to past RQ-4 Global Hawk test data to determine if the test point order used in testing was near-optimal.

Key words: Genetic algorithm; heuristics; precedence constraints; test point ordering; traveling salesman problem.

Flight testing is one of the most expensive and high risk aspects in the development of operational aircraft. Typically, an aircraft must go through several different types of testing as part of the flight test process. These include structural testing, flight control testing, flying qualities testing, performance testing, avionics testing, navigation testing, and sensor testing to name a few. Often, safety limitations require that certain testing be performed before other testing (for example, it might be required that high-speed taxi testing is completed before an aircraft is allowed to proceed to first flight); this is referred to as a precedence constraint in this article. On the other hand, multiple types of testing can often be performed simultaneously (for example, avionics, navigation, or sensor testing might be accomplished at the same time as cruise performance testing).

Efficiently ordering test points can reduce program costs, help avoid schedule delays, and decrease risk for a flight test program. Ordering test points is analogous to the classic Traveling Salesman Problem (TSP) in which a traveling salesman is tasked with visiting n number of cities throughout a region and wants to visit the cities in an order that minimizes the total distance traveled (Johnson and McGeoch 1997). The TSP is a nondeterministic polynomial time (NP)-hard combinatorial optimization problem with an exhaustive search of the order O(n!) (Goyal 2010). In other words, the time to find the optimal solution via exhaustive search (i.e., trying every possible solution) is proportional to n factorial, where n is the number of test points. This makes finding a solution to the TSP computationally expensive. Research has shown that humans are good at finding near-optimal solutions to the TSP when the number of cities is small (i.e., less than 20) (MacGregor and Chu 2011). However, once the number of cities increases or complex precedence constraints are applied, the solutions proposed by humans start to show less advantage over heuristic computer-generated solutions. Even with powerful modern computing, ordering test points (solving the TSP) can be very difficult, particularly if the number of test points is large (i.e., greater than 20).

Previous research on the traveling salesman problem

Solving the TSP has attracted much attention over the last several decades. This is largely because it is strikingly easy to formulate but very difficult to solve; additionally, the TSP has applications to many different fields of research. Subsequently, numerous techniques have been developed to find solutions to the TSP using different algorithms and techniques (Goyal 2010; Hahsler and Hornik 2007; Johnson and McGeoch 1997; Nilsson 2003). Exact solutions have been formulated using techniques such as linear programming (Dantzig, Fulkerson, and Johnson 1954), branch and bound (Little et al. 1963), and dynamic programming (Held and Karp 1962). Heuristic approaches have also been developed that find near-optimal solutions. Heuristic methods cannot be guaranteed to find *the* optimal solution, but the near-optimal solutions generated are typically within a few percentage points of the true optimal solution. These methods include but are not limited to nearest neighbor methods (Rosenkrantz, Stearns, and Lewis 1977), insertion methods (Prim 1957), k-Opt heuristics (Croes 1958), tabu search (Jackson et al. 2010), simulated annealing (Cerny 1985), and genetic algorithms (Gen and Cheng 1997; Potvin 1996).

Solving the TSP with Precedence Constraints (TSPPC), where certain cities must be visited before other cities or certain test points must be completed before other test points, is a more complex problem since certain solutions are no longer feasible. In addition, many of the previously mentioned methods break down or do not guarantee to find a solution that meets the constraints. Modifications can be made to some heuristic methods to satisfy the precedence constraints (Bockenhauer et al. 2010; Savelsbergh 1995), but there is limited published research available that focuses on using genetic algorithms for finding solutions to the TSPPC.

Genetic algorithms

Development of genetic algorithms began as early as 1975, when Holland published his algorithms in his book *Adaptation in Natural and Artificial Systems* (Holland 1975). Genetic algorithms used today, however, have evolved significantly from the initial concepts. Genetic algorithms take their name because of the many similarities they have to biological evolution theory. Specifically, genetic algorithms incorporate the ideas of passing parent traits onto offspring from one generation to another, genetic mutation, and survival of the fittest. Unlike other methods of solving the TSP, genetic algorithms do not guarantee an optimal solution; however, the strength of genetic algorithms is that they are often able to find near-optimal solutions in a fraction of the time required for methods that return the optimal solution.

One of the more common implementations of a genetic algorithm is as follows:

1. Randomly generate an initial population of N chromosomes.[1] This population, from which parents will be selected, is called the parent generation.
2. Evaluate the fitness[2] of each chromosome in the parent generation.
3. Select parents[3] from the parent generation based on their fitness, with priority given to those chromosomes with a better fitness.
4. Perform a crossover operation on two selected parent chromosomes to create two offspring chromosomes that retain some of the traits of the parents.
5. Mutate some of the offspring in order to introduce new attributes to the gene pool.
6. Continue parent selection, crossover, and mutation until N children are generated.
7. Determine the next parent generation by using elitism[4] or by replacing the parent generation with the N children generated.
8. Repeat steps 2 7 until the solution converges, some number of generations have been completed, or the fitness is good enough.

One of the primary complications in applying genetic algorithms to the TSP lies in the crossover operation used to create offspring chromosomes from parent chromosomes. A chromosome in a traditional TSP genetic algorithm contains a list of all cities to be visited in the order in which they should be visited. The difficulty with performing crossover on this form of chromosome lies in ensuring that crossover does not duplicate the same city or eliminate cities from the offspring chromosomes. Potvin describes several methods of chromosome representation and crossover methods that make genetic algorithms better suited to the TSP (Potvin 1996). These methods include but are not limited to ordinal representation, path-based representation, order-based crossover, and position-based crossover. Although these techniques make genetic algorithms compatible with the TSP, they do not resolve the problem of satisfying precedence constraints in the TSP.

Solving the TSPPC with a genetic algorithm

There are currently few publications that employ genetic algorithms for solving the TSPPC. Kotecha discusses the application of genetic algorithms to the

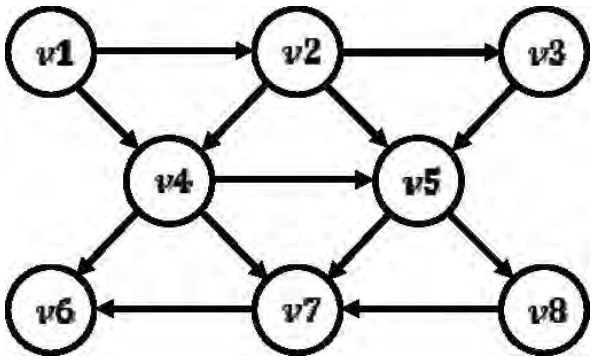

Figure 1. Directed graph with precedence constraints.

TSPPC in modest detail (Kotecha and Gambhava 2003). Moon et al. proposed the use of a topological sort to ensure that precedence constraints are met for every chromosome generated (Moon et al. 2002). Additionally, Moon et al. described a new method of crossover that is not covered in Potvin's survey of genetic algorithm implementations used to solve the TSP. Both the method used to ensure that precedence constraints are met and the new crossover algorithm proposed by Moon et al. were utilized in the implementation of the test point ordering algorithm presented in this article.

Test Point Ordering Genetic Algorithm (TOGA)

The next several sections of the article will show how the generic genetic algorithm process described in the "Genetic algorithms" section is applied to the test point ordering problem in an implementation the authors have called TOGA.

In step 1, the initial population of *N* chromosomes is randomly generated. To guarantee that the precedence constraints are met, a topological sort[5] in combination with a priority vector is used as published by Moon et al. (Moon et al. 2002). Test points to be completed can be represented as nodes in a directed graph with the direction of the arrows representing the precedence constraints, as shown in *Figure 1*. The directed graph in *Figure 1* can then be read as follows: node *v1* must be completed before nodes *v2* or *v4* can be completed; *v2* must be completed before nodes *v3*, *v4*, or *v5* can be completed; *v3* must be completed before *v5* can be completed; and so on. The directed graph is redrawn each time a test point has been completed by deleting the node representing the completed test point and all lines coming out of that node. Only nodes with no arrows pointing to them are valid options to be completed since nodes with arrows pointing to them still have precedence nodes that have not been completed.

A topological sort can determine all valid paths of a directed graph.[6] For problems containing few test points, all valid orderings could be determined via topological sort, and the optimal path could be determined by computing the fitness of all valid orderings.[7] However, the complexity of the problem increases combinatorially as the number of test points increases, making an exhaustive search infeasible for problems containing even a moderate number of test points (more than about 20). This is the motivation for solving the test point ordering problem with a genetic algorithm.

Moon proposed using a random priority assignment vector to uniquely define the path of visiting each node in the directed graph. For example, if the priority for the test points were assigned according to *Figure 2*, then the unique path for that priority would be *v1–v2–v3–v4–v5–v8–v7–v6*. This path is attained because *v1* is the only possible start node since all other nodes have precedence constraints. Once *v1* has been visited, *v2* is the only node that does not have precedence constraints. At this point, there are two nodes without precedence constraints: *v3* and *v4*. This is when the priority vector is used to determine which of the two nodes should be chosen. Node *v3* has a priority of 7, while *v4* has a priority of 2, so *v3* is chosen next since it takes priority over[8] node *v4*. The final five nodes are determined by the precedence constraints resulting in *v1–v2–v3–v4–v5–v8–v7–v6*. A more detailed explanation and pseudocode detailing the implementation of a topological sort is presented in the work by Moon et al (Moon et al. 2002).

In the method proposed by Moon, the priority vector (which uniquely defines a test point order when used in combination with the topological sort of the directed graph) is the chromosome on which the crossover operation is performed. To initialize the parent generation, *N* random priority vectors are generated, each corresponding to a unique path generated using the topological sort.

TOGA fitness function and parent selection

After the parent generation is generated, step 2 is to evaluate the fitness of each chromosome in the parent generation. The chromosomes in the original parent generation and the chromosomes in the subsequent

Vertex	v1	v2	v3	v4	v5	v6	v7	v8
Priority	5	1	7	2	8	6	3	4

Figure 2. Priority string for test point number.

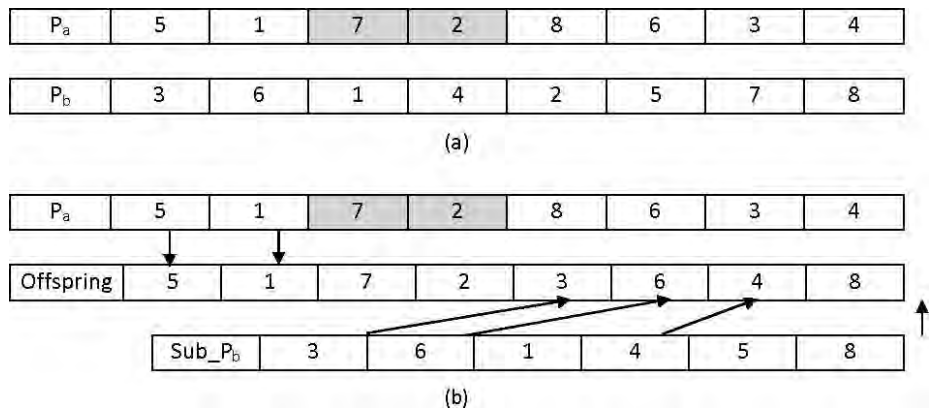

Figure 3. Example of moon crossover operator: (a) parent chromosomes P_a and P_b with a substring from P_a selected at random; (b) moon crossover results.

generations must be ranked by how well they fit some definition of "good." The fitness function provides this definition of good by calculating a numerical value for each chromosome. The parameters used in the fitness function to calculate the fitness must be customized by the user according to the specific application the genetic algorithm is applied to. For Global Hawk envelope expansion testing, altitude and airspeed were the principle parameters changing to characterize the flight envelope; therefore, the fitness function used for optimizing the Global Hawk envelope expansion flight testing was a function of both changes in altitude and changes in airspeed. The goal of ordering the Global Hawk envelope expansion test points was to minimize flight time.[9] Accordingly, the fitness function was the total time between test points for a specific chromosome (or test point order) as presented in equation 1.

$$\textit{fitness} = \sum_{i}^{n-1} \begin{cases} (\Delta h_{i,i+1} * RoC + \Delta V_{i,i+1} * t_{accel}), & \textit{if } \Delta h_{i,i+1} > 0 \\ (\Delta h_{i,i+1} * RoD + \Delta V_{i,i+1} * t_{accel}), & \textit{if } \Delta h_{i,i+1} < 0 \end{cases} \quad (1)$$

In this equation n is the number of test points to be ordered, $\Delta h_{i,i+1}$ is the change in altitude from test point i to the following test point, $\Delta V_{i,i+1}$ is the change in velocity from test point i to the following test point, RoC is the rate of climb of the aircraft, RoD is the rate of descent of the aircraft, and t_{accel} is the time required to change airspeed by 4 knots[10] and then stabilize at the new airspeed.

The genetic algorithm aims to minimize this fitness function as it progresses from generation to generation by giving priority to chromosomes with a more preferred fitness when selecting candidates for crossover.

The third step is parent selection. For the TOGA algorithm, tournament selection was the method of choice. In this method, two parents are chosen at random; then their fitness functions are compared, and the "fitter" of the two chromosomes is chosen to be parent A. This process is repeated to choose parent B. These two parents are then used for the crossover and mutation operations.

TOGA crossover and mutation

Step 4 in the genetic algorithm process is crossover. The crossover method developed by Moon was named "moon crossover." To perform moon crossover, a random substring is chosen from parent A (P_a). This is shown by the grayed elements in P_a in *Figure 3*. That substring is then placed into the offspring. Elements to the left and to the right of the substring are added to the chromosome from parents A and B following the procedure detailed in the publication of Moon et al. until the chromosome is complete. Generally speaking, the elements left of that substring in P_a are appended left of that substring in the offspring, and elements of P_b, starting at the beginning of the chromosome, are appended to the right of the substring one at a time. If an element already appears in the offspring, then it is

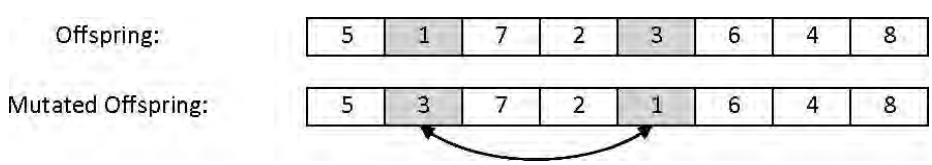

Figure 4. The swap mutation operator.

Table 1. Three near-optimal solutions to the traveling salesman problem without precedence constraints.

Method	Nearest neighbor	Insertion	TOGA
Distance	3.88	3.19	3.36

TOGA, test point ordering genetic algorithm.

skipped. This concept is demonstrated in *Figure 3(b)*. The elements left of the substring in P_a, which have not already been inserted into the offspring (5 and 1), are appended to the left of the substring, and the elements in P_b, which have not already been inserted into the offspring (3, 6, 4, and 8), are appended to the right of the substring. The moon crossover pseudocode can be found in work presented by Moon (Moon et al. 2002).

Mutation is the fifth step in the genetic algorithm process. This operation is performed on a single chromosome to modify the chromosome slightly with the possibility that the fitness will improve because of the mutation. Chromosomes are mutated based on random probability, so that some chromosomes in a generation are mutated and others are not based on some probability. In general, the mutation operation has the benefit of introducing new genes or attributes into a generation of chromosomes other than what originally existed in the previous parent generation. The mutation operator used in this genetic algorithm implementation was a simple swap operation, where the locations of two random elements in a chromosome were exchange as shown in *Figure 4*.

After crossover and mutation are performed, the priority is converted back to a valid test point order using the topological sort. The fitness function is then used to determine the "goodness" of the test point order.

Step 6 in the genetic algorithm process is to repeat parent selection, crossover, and mutation until *N* children are generated. In step 7, elitism is used to determine the next parent generation. In elitism, the fitness of the children and parents are compared, and the *N* chromosomes with the best fitness become the next parent generation.

Step 8 is to repeat steps 2 7 until some stop criterion is met. In TOGA, there were two different stop criteria implemented. The algorithm stops after 2,000 generations have been iterated or after all of the parents converge to the exact same test point order. At the end of the process, the fittest chromosome of the final generation is deemed the "near-optimal" solution.

→

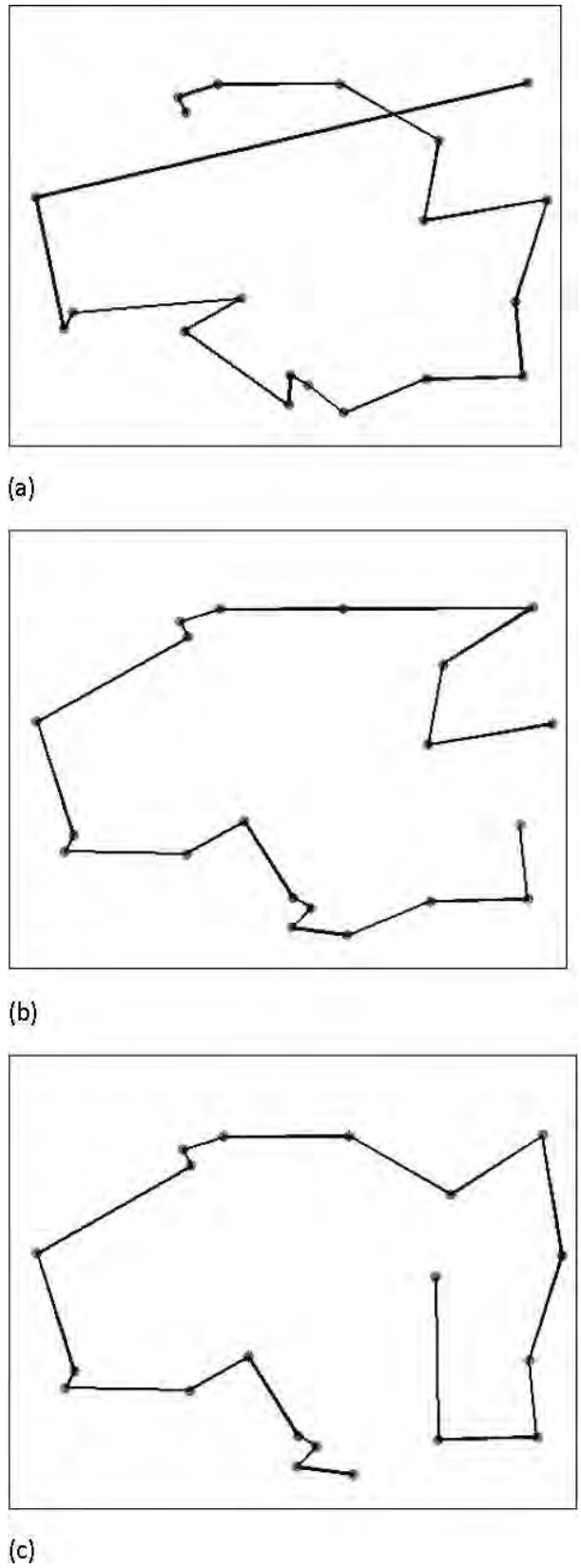

Figure 5. (a) Nearest neighbor solution to Traveling Salesman Problem (TSP); (b) insertion solution to TSP; (c) test point ordering genetic algorithm solution to TSP.

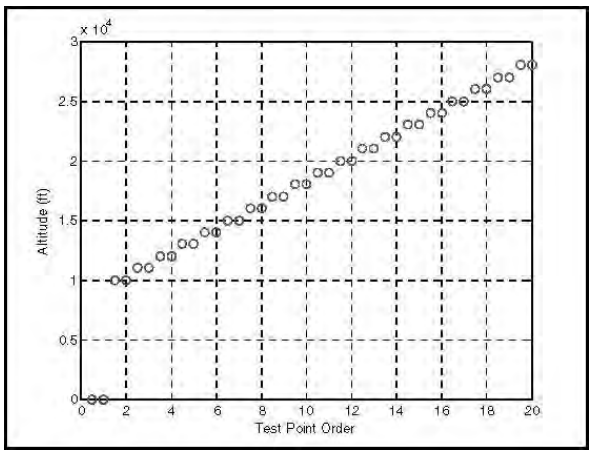

Figure 6. Altitude of test points for optimal sequence.

Results

This algorithm was compared with some simple heuristic methods (nearest neighbor and insertion) in a classic TSP to demonstrate its validity. A set of 20 cities was randomly generated, and the three algorithms were run on the same set of cities. There were no precedence constraints given, since nearest neighbor and insertion cannot satisfy precedence constraints. The TOGA fitness function was modified to calculate distance between cities instead of flight time for this example. The distances for the algorithms are shown in *Table 1*, and the plots are shown in *Figure 5(a c)*.

TOGA gives a solution comparable to the two heuristic methods, but the insertion method performed better. This is not too surprising, since TOGA is designed to solve the TSPPC and is not optimized for solving the TSP without precedence constraints.

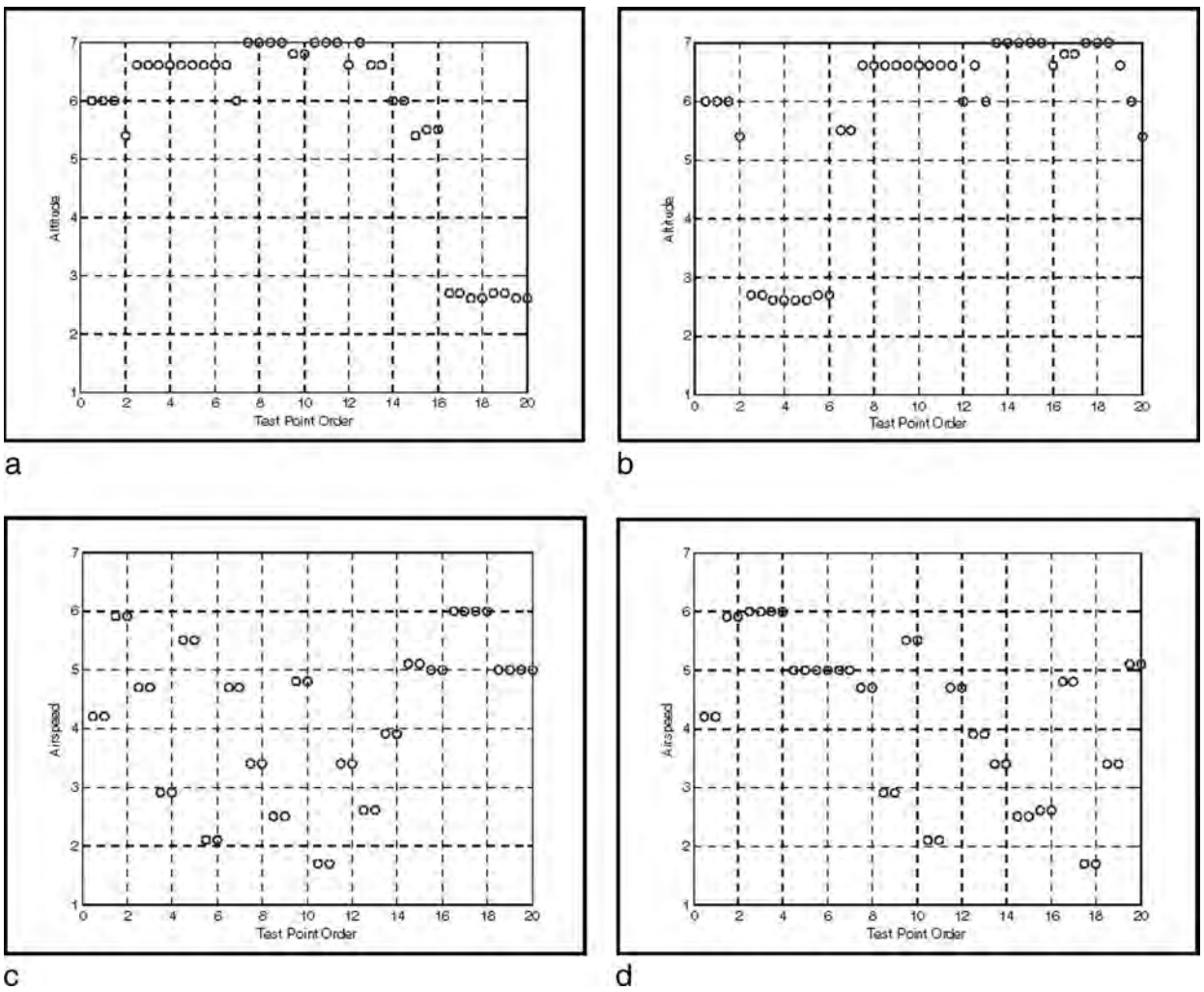

Figure 7. (a) Altitude of test points for near-optimal sequence calculated by Test Point Ordering Genetic Algorithm (TOGA); (b) altitude of test points for actual flight; (c) airspeed of test points for near-optimal sequence calculated by TOGA; and (d) airspeed of test points for actual flight.

To further validate the effectiveness of TOGA, the algorithm was tested on a set of fictitious flight test points with an obvious optimal solution. The test points increase sequentially in altitude with no change in airspeed. The results shown in *Figure 6* give a plot of the altitude of the test points in the order generated by TOGA. The algorithm did converge to the optimal solution, which further validated that TOGA can generate at least a near-optimal solution for a given set of test points.

TOGA was also tested against a set of lightweight flying qualities test points flown in the RQ-4 Global Hawk Block 40 flight test program. These test points did have precedence constraints owing to safety requirements for the build-up approach used in testing. The results are shown in *Figure 7(a c). Figure 7(a)* shows the altitude of the test points for the near-optimal test point order calculated by TOGA. *Figure 7(b)* shows the altitude of the test points for the test point order that was actually flown. That test point order used was determined by test engineers and not by any computer software. The y-axis scales have been changed from the actual altitudes by an arbitrary positive scaling factor for security purposes, but the general trend in altitude order is still apparent. *Figure 7(c d)* shows the airspeeds for the test point orders from TOGA and the actual flight respectively. Again the y-axis airspeed scales have an arbitrary positive scaling factor applied to them for security reasons.

The flight time between test points for the order generated by TOGA (as calculated by the fitness function in TOGA) was 313 seconds, and the estimated time between test points for the actual flight (also as calculated by the fitness function in TOGA) was 507 seconds. For this set of test points, estimates made using TOGA could have saved over 3 minutes out of approximately 2 hours of flight time to perform all the test points at those conditions. This number may seem small, but when it is extrapolated out to include the midweight and heavyweight test points for the same flight, and the additional dozens of flights that have also been flown to perform almost 1,600 test points, several hours could potentially have been saved. For this set of data, the algorithm converged in about 100 generations and did so in approximately 25 seconds on a 2.99 GHz Dual-Core desktop computer.

Conclusion

Efficiently ordering test points with precedence constraints is a mathematically complex problem. For problems involving few test points and with simple precedence constraints, humans are able to order test points in a near-optimal order without the help of optimization techniques. As the number of test points increases and the precedence constraints become more complex, applying Moon's genetic algorithm for solving the TSP with precedence constraints to the test point ordering problem provides an automated way to determine a near-optimal test point order. This algorithm was tested using RQ-4 Global Hawk Block 40 test points and was able to determine a near-optimal ordering, and it improved upon the test point order that was flown in the flight test. ❑

Daniel Carlson is an Electronic Warfare engineer at the U.S. Air Force Flight Test Center at Edwards Air Force Base. He spent 6 months working on Performance and Flying Qualities for the RQ-4 Global Hawk Unmanned Aerial Vehicle (UAV) and is currently doing Electronic Warfare work on the Joint Strike Fighter. He received his bachelor of science and master of science degrees in mechanical engineering from Brigham Young University in 2008 and 2010, respectively. E-mail: daniel.carlson@jsf.mil

Travis Millet is a Performance and Flying Qualities Engineer who conducts flight testing of the RQ-4 Global Hawk UAV at the Air Force Flight Test Center at Edwards Air Force Base. He received his bachelor of science and master of science degrees in mechanical engineering from Brigham Young University in 2007 and 2009, respectively. Travis is a member of the American Institute of Aeronautics and Astronautics (AIAA). E-mail: paul.millet@edwards.af.mil

Endnotes

[1]A chromosome is a representation of the parameters being optimized, in the case of the traveling salesman problem, it is an ordering of the cities to be visited. For the test point ordering problem, a chromosome represents an ordering of test points to be completed.

[2]The fitness of a chromosome is a quantity that describes how much that chromosome exhibits some desirable trait that has been defined by the user. A genetic algorithm can either try to maximize or try to minimize the fitness of a population.

[3]Possible selection methods include tournament selection (where two or more chromosomes are selected at random, and the chromosome with the highest fitness is chosen as one of the parents), and proportional selection (where the probability of a chromosome being selected as a parent is proportional to a chromosome's fitness).

[4]Elitism takes the best N chromosomes based on fitness to create the parent generation. In this sense, parent and offspring chromosomes compete with each other to be part of the new parent generation.

[5]A topological sort as pertaining to the test point ordering problem is an ordering of the test points that does not violate precedence constraints.

[6]There are two feasible paths for the directed graph shown in *Figure 1*: they are *v1 v2 v3 v4 v5 v8 v7 v6* and *v1 v2 v4 v3 v5 v8 v7 v6*.

[7]This technique is known as solving the problem by "brute force" or "exhaustive search" because all possible solutions are evaluated.

[8]In this implementation, a larger priority number takes priority over a smaller priority number.

[9]Different test programs will likely have different fitness functions than that presented in Equation 1. Whereas the Global Hawk test program was trying to minimize flight time, other test programs might be trying to minimize fuel burn, flight path length, etc., or to maximize a parameter such as the amount of time a sensor has usable data. For this reason, the fitness function will change according to the specifics of the optimizing parameter and could be a function of various other parameters such as latitude, longitude, throttle setting, fuel flow, or the orientation of the aircraft or sensor, to name a few.

[10]A 4 knot airspeed change was used because the Global Hawk flight envelope was characterized with 4 knot resolution during testing.

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Association News

ITEA WANTS YOU! Call for Volunteers

Volunteers are at the heart of our association, and our strength is a result of the time and effort provided by those who volunteer to serve. ITEA offers many opportunities at the local, regional, and international levels for its member to contribute their time, talents and energy by giving back to the test and evaluation industry, helping us advance the profession, and supporting the association. If you want to become part of the ITEA volunteer team, now is the time to let us know.

There are many volunteer opportunities to volunteer at either your ITEA Chapter or to serve on an ITEA Board Committee, such as: Awards Committee; Chapter and Individual membership Development Committee; Corporate Membership Development Committee; Communications Committee; Education Committee; Elections Committee; Event Committee; History Committee; Publications Committee; Rules and Bylaws Committee; Strategic Planning Committee; Technology Committee; and the Ways and Means Committee. If you have experience, passion and a willingness to share, please consider participating as a volunteer on one of these committees. One of our goals is to have volunteer groups that represent the diversity of backgrounds, experience and demographics of the test and evaluation community.

If you have a desire to contribute to ITEA's ongoing development and management of the Association's governance, services, and guidance for the profession, you are encouraged to learn more about our volunteer opportunities. Please contact James Gaidry, ITEA Executive Director, by e-mail at jgaidry@itea.org, or at 703-631-6220, x204, for more information.

This notice is to announce the 2012 election process for the ITEA Board of Directors and to advise the ITEA membership of the nominating process.

The purpose of the Board of Directors is to undertake management of the business and affairs of the Association. The goal of the elections process is to ensure the Board represents a broad spectrum of the T&E community; a mirror of the functional diversity of the community to include members of the technical, management, policy, and analysis sectors.

There are two categories comprising the Board of Directors, **elected** members and **appointed** members.

Elected Members: The number of elected Directors of the Association is currently eleven. An elected member will serve for a period of three (3) years. An elected Director may not serve for more than two (2) consecutive terms.

Appointed Members: For the purposes of diversification, the Board of Directors may ***appoint*** up to four additional Board members for terms of one (1) year; renewable no more than two (2) times.

For the 2012 elections, the committee will seek candidates to fill the following vacancies:

a. **Elected Members:** Four (4) Positions
b. **Appointed Members:** Not to exceed four (4) Positions

Elected directors will each serve 3-year terms from September 2012 through September 2015, and will be presented to the membership during the 2012 Annual Symposium in Huntington Beach, CA, September 17-20, 2012. Any member **appointed** by the Board will serve for one year (2012-2013).

The Elections Committee, a standing committee of the Board chaired by Mr. Rick Shelley, oversees the nomination and election of Directors. Nominations are openly solicited from ITEA Chapters, the Board of Directors, the Senior Advisory Board, Corporate members and Individual ITEA members.

Nominations for elected or appointed positions are to be submitted via the attached nomination forms. Nomination forms are also available on the ITEA web site at: **www.itea.org**.

ITEA LAUNCHES NEW WEB SITE WITH "SELF-SERVICE" FOR MEMBERS

ITEA has partnered with Brand Design (www.branddesign.com) and Avectra NetForum (www.avectra.com) to launch a new and improved Web site for our members and others in the test and evaluation profession. Significant enhancements to the Web site include:

Listing of all current ITEA Corporate Members on the Home Page.

Searchable ITEA Membership Directory.

Searchable ITEA Corporate Member Directory.

Access to the current issue of *The ITEA Journal*, *The ITEA Journal* archives, and *ITEA Tech Notes* archives.

Access to online resources such as conference proceedings, recorded webinars, and other presentations.

Online Store with easy registration for an event or renewing your ITEA membership.

Access to your contact information for real-time updating.

Access to your historical event registrations and other transactions.

Access to Committee information for volunteers serving on one of ITEA's Committees.

Access for Chapter Presidents to resources and other helpful documentation.

Listing of all ITEA Chapters, Committees, and Board members with contact information.

Coming soon the ITEA Web site will be expanded to provide individual Chapter Web pages for quick access to local events and news.

So go to www.itea.org today and let us know what you think!

ITEA DEVELOPING PROFESSIONAL CERTIFICATION FOR "TESTERS"

Elevating the Test and Evaluation Profession with a Globally Recognized Credential

ITEA will be working with subject matter experts in the test and evaluation industry to develop a Competency-Based Professional Certification Credential, which would be accredited under ANSI/ISO/IEC 17024, to establish a global professional standard that provides the test professional with a recognized designation demonstrating that they have attained the knowledge, skills, and abilities required to ensure their success in the T&E career field. Availability of the credential is currently scheduled for mid-2013.

Please note that a "professional certification credential" is quite different from the "certificate" programs that are currently available to test professionals. "Certificate" programs award a certificate of completion or achievement to individuals after they successfully complete a course of study or meet some minimum requirements.

In contrast, a professional certification credential is:

- A time-limited recognition and use of the credential's designation in conjunction with their name (e.g. CSE, CPA, or CPM) by an individual after an assessment and verification that they have met predetermined and standardized criteria;
- Confers occupational identity and provides a method for maintaining quality standards of knowledge and performance, and stimulating continued self-improvement; and,
- Provides differentiation among test professionals, using standards developed through a consensus driven process and based on existing legal and psychometric requirements.

This professional certification credential also differs from "certificate" programs in that the individual is required to:

- Adhere to a Test Professional's Code of Ethics;
- Maintain their currency, proficiency, and competency in their field through full-time active employment and completion of continuing education; and,
- Submit for recertification every five (5) years in order to maintain their professional certification credential.

Visit the ITEA Web site for news and updates as this effort continues throughout the year.

ITEA ANNOUNCES EXPANDED PROFESSIONAL DEVELOPMENT COURSES

As you can see below, we have a full slate of courses being offered, not only at ITEA's Professional Development Center in Fairfax, VA, but also at the Aberdeen Proving Ground (Francis Scott Key Chapter) and the Southern Maryland Higher Education Center (Southern Maryland Chapter). In 2012 we have also committed to taking ITEA's courses on the road and into your own backyards. Please note the courses scheduled in Mesa, AZ (Valley of the Sun Chapter) and Colorado Springs, CO (Rocky Mountain Chapter).

For those chapters not yet offering local short courses, there is still time to do so and partake in the WIN-WIN-WIN-WIN experience: a WIN for ITEA National in fulfilling its primary mission; a WIN for the Chapter in offering educational programs that expand its members' knowledge; a WIN for the Chapter Member who can expand his industry expertise; and a WIN for the Students who are awarded scholarships from the educational funds the Chapter receives for hosting the course. So why are you still waiting?—jump on the ITEA bandwagon and come along for the exciting ride!

PROFESSIONAL DEVELOPMENT COURSE SCHEDULE

Information Assurance and Cyber Security
February 8-9 ~ Fairfax, VA
June 21-22 ~ Colorado Springs, CO

Fundamentals of Agile: A Pragmatic Approach to Adopting Agile
February 21-22 ~ Fairfax, VA
May 7-8 ~ Fairfax, VA

Systems Engineering, T&E, and Project Management: Integrated Processes
February 22-23 ~ Aberdeen, MD
April 4-5 ~ Fairfax, VA

Combinatorial Testing with Design of Experiments (CT-DOE)
March 5-9 ~ Aberdeen, MD
April 16-20 ~ Mesa, AZ
May 21-25 ~ California, MD (Patuxent NAS)
June 4-8 ~ Fairfax, VA

Fundamentals of the Test & Evaluation Process
March 6-8 ~ Fairfax, VA
April 23-25 ~ Aberdeen, MD
June 26-28 ~ California, MD (Patuxent NAS)

ITEA WELCOMES NEW CORPORATE MEMBER

Integrated Defense Applications, LLC (dba IDA Technology)

IDA Technology, a 8(a), Service-Disabled Veteran-Owned, Minority Small Business, is a small business industry leader in full scale, joint, interoperable test and evaluation providing the innovative application of technology, science, and project management to optimize systems analysis and evaluation. We provide project management, test planning, development of test evaluation criteria, analysis and reporting of test data. IDA has a robust in-house Geographical Information Systems (GIS) capability which supports our scenario development capabilities. Data Universal Numbering System (DUNS) Number: 801896312; Commercial and Governmental Entity (CAGE) Code: 4ZPM3 (TS); Texas Historically Underutilized Business (HUB) Vendor Number 58482; and Primary NAICS Codes: 541712, 519190, 518210, 531311, 541511, 541513, 541519.

IDA's depth of technical expertise, extensive project management, operational military experience and successful history of government contract support provide a highly valued skill set to our clients. The same qualities which enabled us to successfully defend our nation carry over into our business through our leadership, management and work ethic.

TAPE, LLC is a service-disabled veteran-owned, woman-owned, small business (SDVO/WOSB). TAPE' s expertise includes Program Management, Acquisition Support, Information Technology, Logistics, Operational Readiness, Training, Modeling and Simulation, Test and Evaluation Support, and Cyber Security/Warfare/Operations. Over the years, TAPE has been recognized by organizations like Inc. 500 and Washington Technology for its achievements within the government contracting sector. For more information about TAPE, please visit www.tape-llc.com.

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Chapter News

Antelope Valley Chapter

Remembering Scott Crossfield

Jan. 18, 2012 marked a special date in time for the Crossfield family, friends, and colleagues, as **Scott Crossfield** was recognized at the monthly Antelope Valley ITEA Chapter luncheon for his many accomplishments in the world of flight test and research.

Crossfield became the first pilot in history to reach Mach2—twice the speed of sound—in the Douglas D-558-II rocket plane on Nov. 20, 1953. He then went on to fly more rocket-powered flights over the next five years as a test and research pilot at the National Advisory Committee for Aeronautics (NACA) High-Speed Flight Station, now known as the National Aeronautics and Space Administration's (NASA) Dryden Flight Research Center, on Edwards Air Force Base (AFB). In addition to these accomplishments, Crossfield later helped design the cockpit of the famed X-15 rocket plane while employed by North American Aviation in the late1950s. He also flew the first 14 developmental demonstration flight tests of the craft before it was turned over to the Air Force and NASA for the joint -15 hypersonic flight research program.

The luncheon was widely attended, with dignitaries from Edwards AFB, to include **Brig. Gen. Robert Nolan II** [Photo 1]. Also in attendance were Crossfield's daughter, **Sally Crossfield-Farley; Eugene Deitrich** , former Test Pilot School Commandant, and close family friend; and **Ed Schneider**, retired NASA Dryden research pilot and

Doyle Janzen (right), current Antelope Valley ITEA Board president, presented Ed Schneider (left) with three books written and signed by Dr. James Young, former AFFTC Historian, as a token of appreciation.

Brig. Gen. Nolan II (left) of Edwards AFB and Sean McMorrow (right) of NASA's Dryden Flight Research Center and former AV ITEA Chapter president, presented Sally Crossfield-Farley (center) with several NASA books, which included many stories about her father.

keynote speaker for the event [photo 2]. Schneider shared many personal and fun-filled stories with the audience while detailing Crossfield's contributions to the advancement of aeronautics and flight research. He recalled Crossfield as "a humble man whose accomplishments spoke volumes."

The luncheon was the optimum platform for honoring such a distinguished and recognized individual who contributed greatly to the world of flight test and research. Family members and dignitaries were greatly appreciative to have participated in this event, as it offered a motivating and gratifying experience related to the accomplishments of such an inspirational man. It also provided an opportunity to publicly honor Crossfield and show appreciation to the Crossfield family as accolades were extended from Schneider as well as others in attendance [photo 3].

■ ■ ■

Central Florida Chapter

After exceeding our 2011 goals to get the Chapter up and running, establish bylaws, begin to host events, establish name recognition, and establish viable partnerships, ITEA-CF is moving on to its 2012 program goals. We thank ITEA-George Washington Chapter for their newsletter format, which

Members of the Crossfield family visit with Brig. Gen. Nolan II (left) of Edwards AFB after a street naming ceremony on Jan. 18, 2012 in honor of Scott Crossfield.

allowed us to start 2012 with the release of our first Chapter newsletter. We welcome friends of the ITEA-CF Chapter to request to be included in distribution of our new quarterly publication.

ITEA-CF has begun to expand its coverage of the peninsula region of Florida, working with the International Council on Engineering's Space Coast Chapter to bring programs and events to Melbourne, FL on top of the current concentration in the Orlando area. A presentation on what transpired at the Pentagon on 9/11/01 was provided in October as our first joint event in Melbourne, and already events are planned for January and February as well. January will bring a high priced speaker to ITEA-CF, who has offered to waive his approx. $10K fee if we facilitate his presentation in the Melbourne area. We are working to establish a broadcast and recording capability to share his presentation with other Chapters, and are offering it to our Orlando members through a broadcast facility at the University of Central Florida (UCF), so both our core cities can participate. Two other ITEA Chapters have expressed interest in the broadcast, which will cover Android technologies and security issues therein. In February, Gaze Metrics will be covered in Melbourne as a topic.

ITEA-CF is also working with UCF's Business Incubation Program to establish a full array of programs for 2012 within the UCF facilities, and to bring together government, industry, and academia therein which focus on Orlando.

ITEA-CF is currently establishing a scholarship planning committee to firmly craft our scholarship and education programs, led by **Dr. Steve "Flash" Gordon** of Georgia Tech Research Institute. Orange and Seminole County Public Schools are identifying their representatives to that panel at this time.

The Chapter has also engaged with Lyman High School's (Seminole County Public Schools) Institute for Engineering to sponsor internships for six of their students, and is reaching out to other local professional organizations to join us in the final presentations, where the Chapter intends to invite the local media to hear the work of the students.

The Chapter is also participating in the Orlando Combined Professional Associations Group in sponsoring a Defense Forum Breakfast in January, and will be distributing information on ITEA to the more than 150 attendees already registered.

ITEA-CF would also like to thank the great folks who visited Orlando for the International Symposium. One of the comments in our first newsletter shows the character and spirit of the many great folks involved in ITEA: "DID YOU KNOW - That at the conclusion of the 2011 ITEA International Conference in Orlando, ITEA-CF worked with ITEA HQ and the vendors to obtain the used signage and also excess stock used as handouts by the vendors. These items were collected by the Chapter and donated to the Rainbow Elementary School Parent Teacher Association in Seminole County, making for a successful recycling effort and a donation that may serve as an incentive for our region's school children. We thank ITEA HQ, Electronic Warfare Associates, Advanced Systems Development, Wyle Laboratories, JT3, Northrop Grumman, and Calculex for their kind donations to our Central Florida community and students."

Thanks to the entire ITEA family for making our 2011 such a success. We look forward to a brighter 2012, and hope many of you will return to our community and join us in our programs, or serve as presenters to our diverse audience.

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Emerald Coast Chapter

The Emerald Coast Chapter is pleased to announce that the 3rd quarter winner of "Tester of the Quarter" was the F-15E Radar Modernization Program (RMP) Test Team of the OFP CTF, 46th Operations Group (46 OG). The Test Team brilliantly managed the F-15E RMP upgrade effort, an ACAT II acquisition program that was the 46 TW's largest fighter upgrade. The Team planned, executed, and reported the multiple aircraft effort, and upheld an aggressive schedule through the challenging quarter. The Team piloted the Development Test (DT) flight test, and planned, briefed, conducted, and reported missions at a blistering pace. A number of problems were found during this testing, and the Team was able to recognize, fix, and/or recommend solutions to the SPO, averting costly delays to the program.

In other news, the Emerald Coast Chapter and George Washington Chapter are diligently planning the upcoming Test and Training Crosstalk Forum scheduled for 21 – 22 Feb 2012 in Sandestin, FL. The theme of the event is "Maximizing Testing and Training Collaboration on Sharing of Range Resources and Events". Using Eglin Air Force Base as a background, efforts to de-conflict and integrate Testing and Training missions into a seamless process that ensures overlapping needs for space, time and spectrum

with minimal disruption to either's needs will be examined.

As a final note, the Emerald Coast Chapter would like to thank our 2011 President, **Mr. Bob Guidry**, for a job well done. His outstanding leadership throughout the year helped guide this organization to support and sustain the T&E community at Eglin AFB, Florida. Carrying on this duty for 2012 are the following elected chapter officers:

Mr. Doug Davis, 2012 President
Mr. Tony Vitale, 2012 President-elect
Mr. Robert Hill, Secretary
Mr. Buff Tibbetts, Treasurer
Mr. Dale Bridges, Board Member
Ms. Jeri Ghosh, Board Member
Mr. Andrew Gosnell, Board Member
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Mr. Harry Strittmatter, Awards Chair
Mr. Rob Crist, Symposium Chair
Mr. Alan Colthorp, Publications Chair
Mr. Ron Higdon, Election Chair
Mr. Jonathan Kilpatrick, Webmaster

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Francis Scott Key Chapter

During this past fall, the Francis Scott Key (FSK) Chapter stayed busy hosting monthly luncheons. In October, **Mr. David Jimenez** (Technical Director, AEC) briefed the new ATEC Command structure. In November, **Mr. Stephen Kreider** (Deputy Program Executive Officer, PEO IEW&S) briefed the challenges facing his organization. FSK thanks both Mr. Jimenez and Mr. Kreider for their time and support of our chapter.

The Francis Scott Key Chapter concluded 2011 with a marquee event. During the Army Test & Evaluation Command's (ATEC) Advanced Planning Brief to Industry on December 6, FSK hosted the luncheon event at the Top of the Bay on the Aberdeen Proving Grounds. Close to 200 people registered for the luncheon where **Dr. Steven Hutchison** (Principal Deputy, Developmental Test and Evaluation) briefed them on the initiatives of both Developmental Test & Evaluation (DTE) and Test Resource Management Center (TRMC). We sincerely thank Dr. Hutchison for his time and hope to see him again soon at another FSK event.

As with any big event, the success of the event comes down to those who volunteered their time to make it successful. FSK thanks **Brian Simmons**, **Lisa Murter**, and **Diana Reeves** from ATEC for their help and support with the coordination of this event. Additionally, I would like to thank **Cathy Pritts** (ATEC), **Danny DeMarinis** (MITRE), **Drew Ellis** (Battelle), **Jim Myers** (AEC), **Fred Merchant** (SURVICE), **Chris Susman** (SURVICE), **James**

Dr. Steve Hutchison.

Two-hundred luncheon attendees at the "Top of the Bay" on Aberdeen Proving Grounds.

Fielder (ATC), and **Martha Miller** (GTRI) for all of their help with this event.

The Francis Scott Key Chapter continues its support and promotion of STEM education. This year, FSK invited four seniors (**Jackie Le**, **Hunter Bachman**, **Zachary Litsch**, and **Kamini Mallick**) from the Aberdeen Science and Math Academy to brief their senior capstone projects this past fall. In the spring, each student will be invited back to brief their results from their projects.

FSK has also taken an aggressive approach to hosting ITEA short courses in Aberdeen. Through our great relationship with Harford Community College and the assistance of **Jay Weaver**, FSK was able to co-host its first class in December. We currently have 3 additional courses scheduled for the spring. Keep an eye open for them, and if you are in the Aberdeen area, please consider enrolling in one of them.

Finally, FSK has updated its new website. We can now be found on the web at http://fskitea.org Special thanks again goes to **Cathy Pritts** for her work on developing the website. Who would have known Cathy could moonlight as a webpage designer? For all those BRAC transplants who now work in Aberdeen, FSK is always looking for additional help. Please contact chapter president **John Schab** (GTRI) at john.schab@gtri.gatech.edu if you would like to become involved.

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George Washington Chapter

October Town Hall Meeting & Luncheon

At its monthly meeting on October 20th at the Army Navy Country Club in Arlington, Virginia, the George Washington Chapter participated with three invited panelists in a discussion of Test and Evaluation for Cyber Security. The panelists were **Mr. David Aland**, staff assistant in the Office of the Director of Operational Test and Evaluation (DOT&E); **Mr. Ryan Norman**, senior engineer in the Defense Test Resources Management Center (TRMC); and **Mr. Charles Smutz**, lead software engineer at Lockheed Martin. The discussion was moderated by **Mr. Lee Schonenberg** of WBB

In 9 the opening comments Norman pointed out that both war-fighting and information systems are vulnerable to attack and that existing labs and ranges must be leverages to measure effects, impact, effectiveness of defenses, utilizing AGILE concepts. Aland opened by noting that cyberspace T&E is in its early primitive stages and operational evaluation shows some surprises, for example that when software written for one use is repurposed for an unanticipated use, vulnerabilities may unexpectedly appear. Coining the expression: “When all you’ve got is nails, anything will do as a hammer”, it is tempting to take software into untested applications. Smutz, noted that persistent net attackers are seen every day in both Defense and civilian targets including political networks. He said we need to engineer security into cyberware and test it.

After these opening comments lunch was served and Schonenberg moderated a lively exchange for over an hour among all attendees. A question about recent attacks that could have been prevented by T&E led to a description of Operation SHADY RAT, an email attack in which a hacker penetrated one machine to become an administrator and plant a worm with broad impact across a whole network. It was noted that most attacks are Spear Phishing and that in addition to testing, training of users is vital. For example, a message with “Phish” right in the subject line was opened by 85% of users, and its attachment titled “Do Not Open” was opened by 75% of users.

T&E for Cybersecurity Panelists (from left) Ryan Norman, David Aland, and Charles Smutz.

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Other questions and answers resulted in observations that there is a problem in trying to test software like hardware testing; that upgrades sent by email increase vulnerability; that reliance on the Internet is good for broad communications but bad for vulnerability; that a more operationally realistic cyber environment would be useful for T&E and would probably have to be a distributed live-virtual-constructive facility; that proactive security measures would be more valuable than the currently common reactive practices; and that Defense cyber security measures should be more integrated with the non-Defense world. After the discussion chapter vice president **Lou Husser** presented the panelists crystal paperweights embossed with the ITEA logo.

November Luncheon At its monthly luncheon November 17th at the Army Navy Country Club in Arlington, VA, the George Washington Chapter heard a three member panel discuss "Test and Training Collaboration".

Mr. Mark Rindle of Chesapeake Synergy, Inc., Operational Liaison to the Joint Atlantic Range Cooperative said the Cooperative is looking for synergies between ranges. The 13 members of the Cooperative have surveyed the range users for needs and are matching them to capabilities. He noted that there have been some successes, for example, the Navy's fleet target service provides to both training and testing. He estimated that about 20% of Navy training is done on test ranges, but a major flaw in greater cooperation is that a unit funding for training does not include funding for range instrumentation.

Dr. Steve Hutchison, Principal Deputy Director of Developmental Test and Evaluation for the Defense Assistant Secretary of Defense for

ITEA Executive Director James Gaidry was among luncheon attendees

Acquisition, questioned why there should be tension between the testing and training communities, saying that in 1998 he was a test evaluator at the Army National Training Center and saw tension there. He observed that every test is also a training event, which should be appealing to both communities.

Mr. Frank DiGiovanni, Director of Training Readiness and Strategy for the Defense Assistant Deputy Secretary for Readiness, showed slides illustrating potential areas for training and testing partnership. He said there have some success in cooperation. For example Eglin Air Force Base and China Lake Research Center have collaborated, particularly in instrumentation development. He commented that test and training cooperation has been an issue for a long time, showing a slide from a 1996 ITEA briefing slide. He commented that much more remains to be done and that the testers and trainers should look to the same operational warfare community they both serve.

In a lively Q&A session it was noted that one obstacle to more partnership is neither side wants to jeopardize its mission to the other side, but both get their funding to support the same operational warfare owner of the requirements both. Perhaps upcoming funding cuts will encourage the requirements community to force test and training mission consolidation because forces in testing are getting some training and forces in training could benefit from test measures of force performance. Also, in Q&A it was noted that embedded instrumentation in systems is valuable to both tests and training, and when testers develop new range capabilities for advanced technology such as cyber warfare, it is likely to attract trainers. After discussion, chapter president **Mike Wetzl** thanked all three panelists in turn and presented them gift mementos of the occasion.

Panelists (from left) *Mark Rindle, Frank Diovanni, and Steve Hutchison*

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Valley of the Sun (Phoenix) Chapter

The Valley of the Sun Chapter ended 2011 on a positive note. The leadership met with the local International Council on Systems Engineering (INCOSE) and Armed Forces Communications Electronics Association (AFCEA) Chapters and is exploring holding joint activities with each of them in 2012. The Valley of the Sun Chapter provided a grant of $600.00 to the INCOSE Student Chapter to help pay the cost of sending a student to the INCOSE Workshop to be held in Florida in January 2012. The student will be reporting on the trip at an ITEA Chapter meeting in the spring.

The Chapter is looking forward to a number of activities during the coming year. We are planning to join with the INCOSE Chapter for the UCF Incubator broadcast sponsored by the ITEA and INCOSE Chapters in Central Florida on February 2nd, and will be hosting a training course on Design of Experiments in the Phoenix Area in April. We are looking forward to 2012.

Chapter president Mike Wetzl thanks panelist Steve Hutchison.

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2012 *ITEA Journal* Themes

The ITEA Publications Committee has established themes for the 2012 issues of *The ITEA Journal* and invites articles in the following areas:

T&E at the Speed of Need (March issue). The speed of need is the time between definition of a user need and initial operation of the capability. The demands of war have shortened the timeline on requirements for military systems. Rapid acquisition and rapid fielding initiatives arising from urgent operational needs have created an entire industry in the defense community. Commensurately hastened is the pace at which transportation security and border protection measures need to be deployed. We see information technology (IT), especially software, change with a frequency of months not years. Test and evaluation (T&E) must be responsive to the acquisition timelines. The Federal Aviation Administration, Border Patrol, law enforcement and many other organizations have adapted to the changing speed of need. This issue takes a candid look at agile software development processes, cyberspace T&E, defense IT acquisition reform, rapid acquisition and fielding, reconfigurable test capability, testing on demand, reuse and other ideas for streamlining the T&E process in support of accelerating deployment of new products, services and capabilities. ***(Manuscript deadline: December 1, 2011)***

Drowning in Data, Thirsty for Information (June issue). Digital technology and Moore's law provide us with the ability to acquire, create, and store data at unprecedented rates and volumes. Literature searches that would have taken days or weeks in the age of library card catalogs can be accomplished in seconds over the internet. Data, or more generally information, has become big business in addition to being the business of T&E. Yet technological solutions also come with their own problems and the morass of data has not led to a commensurate growth of knowledge or ability to exploit the data. This issue examines the plethora of data, which is growing exponentially, and the ever critical demand to extract meaning and value. Articles are invited on such topics as data acquisition, storage, archiving, access, validation, exploitation, and visualization; data as a service; cloud computing; service oriented architecture; metadata syntax and semantics; instrumentation; accelerating the process from acquiring data to implementing a decision; data and sensor fusion; data preservation; distributed and non-relational databases, and related topics. ***(Manuscript deadline March 1, 2012)***

Strategic Partnering: We are Doing More Without More (September issue). Shrinking budgets and accelerating technology development put ever-increasing pressure on product development and T&E organizations: shorter schedules, fewer personnel, less access to facilities. Extreme environments and complex systems add additional demands. To provide the requisite test capabilities, the T&E community must be agile and responsive as well as innovative. The automobile and aircraft industries have long spread liability and gained benefit from seeking standard parts production from independent manufacturers or specific systems development parceled to risk sharing partners. Strategic partnering takes such forms as outsourcing, reuse, and collaboration; common test and training infrastructure; integrating developmental and operational testing; shared facilities among government, industry, and academia. Cooperation comes with its own issues: some loss of control, policy or statutory impediments, protection of proprietary rights, and conflicting goals of leadership. This issue addresses all forms of partnering, allowing testers to do more without having more resources to accomplish their task. ***(Manuscript deadline: June 1, 2012)***

Cultivating the T&E Workforce (December issue). Test and evaluation are professions not academic disciplines and as such we can't merely recruit more as needed. We recruit engineers, physicists, computer scientists, mathematicians, chemists and other degreed professionals and train them in test and evaluation. As technology changes and systems and instrumentation become more complex, T&E professionals need to continue formal education as well as improve T&E expertise. In addition, we need to consistently attract young people to the disciplines of science, technology, engineering, and mathematics. Cultivating the T&E workforce requires asking the question: what should the T&E professional's background consist of today? The internet gives us nearly immediate access to the four W's – who, what when and where – but can't provide why and how, which require human reasoning. Appealing to younger professionals means communicating with them in their preferred mode, such as social networking media, and recognizing that T&E will evolve as IT drives us in new directions and as younger leaders assume their roles in legacy organizations. We need to prepare the future workforce for T&E, and prepare T&E for them. This issue solicits ideas on improving the current workforce and growing the next generation: the use and benefit of certification, such as T&E, modeling and simulation, project management; Science-Technology-Engineering-Mathematics (STEM) initiatives; educating leadership; the role of the service academies in DoD; internships; and many more topics. ***(Manuscript deadline: September 1, 2012)***

Articles and Submission: T&E articles of general interest to ITEA members and *ITEA Journal* readers are always welcome. Each issue includes specialty features, each 2-3 pages long: **"Featured Capability"** describes unique, innovative capabilities and demonstrates how they support T&E; **"Historical Perspectives"** recall how T&E was performed in the past or a significant test or achievement, often based on personal participation in the "old days" of T&E; **"Tech Notes"** discusses innovative technology that has potential payoff in T&E applications or could have an impact on how T&E is conducted in the future. **Interested authors:** Submit contributions to the ITEA Publications Committee Chairman (itea@itea.org, attention: Dr. J. Michael Barton). Detailed manuscript guidelines can be found at **www.itea.org** under the ITEA Publications tab.

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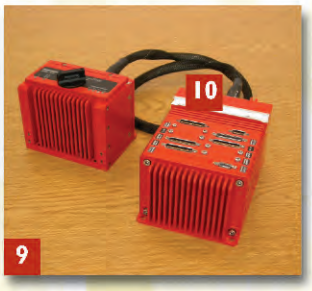
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Address 26845 Point Lookout Road
Leonardtown, MD 20650
Business Manufacturer of data acquisition, recorders, network switches and ground station products
General Manager Diarmuid Corry
ITEA Rep Ashley Campbell
Tel (301) 475-6757
Fax (301) 475-6786
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Address 20 East Taunton Rd., Suite 301
Berlin, NJ 08009
Business Government Contractor for Engineering Support Services
President Frank A. Valenti
ITEA Rep Frank A. Valenti
Tel (856) 719-9001 x102
Fax (856) 719-9007
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Advanced Systems Development, Inc. (ASD)

Address 2800 S. Shirlington Road, Suite 800
Arlington, VA 22206-3612
Business Enterprise-wide Information Technology Solutions Provider
President Richard L. Bennett, President/CEO
ITEA Rep John Rose
Tel (703) 693-5302
Fax (703) 824-5699
E-Mail John.Rose@asd-inc.com
Web Site www.asd-inc.com

Since 1979, **ASD** has focused on providing outstanding Enterprise IT Solutions to the Federal Government. ASD has a Nation-wide presence with work sites in most GSA regions, as well as OCONUS. Our nationwide presence, our available contract vehicles, and our depth and breadth of successful experience, we are well postured to support the IT needs of every DoD component. At ASD, we believe that excellence requires offering superior IT services to select clients, rather than being all things to all people. Our service offerings have evolved over time as we have responded to the changing needs of our clients, innovations in technology, and the escalating knowledge and technical expertise of our staff. We have built a solid corporate infrastructure while retaining the nimbleness of a small business. ASD is well positioned to support its customers with a corporate office in Arlington, Virginia, offices in Herndon, Virginia, Huntsville, Alabama, and 22 client-site locations across ten states, Washington, DC, and Kwajalein Atoll, Marshall Islands. Our staff of almost 300 highly-skilled personnel holds more than 300 IT certifications. Approximately 96% hold clearances (Secret/Top Secret/SCI). In order to provide our customers with the assurance that they will receive the highest level of support, ASD employs Capability Maturity Model Integration (CMMI) Level 3 processes and procedures. About 50 staff have received ITIL v3 certification and 20 are Project Management Professional (PMP) certified. ASD has the combined strengths, resources, and proven track record to perform an outstanding job for our customers throughout the 21st century.

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Advanced Test Equipment Rentals

Address 10401 Roselle St.
San Diego, CA 92121
Primary Business Equipment Rentals
President James P. Berg
ITEA Rep Chris Reed
Tel (800) 404-ATEC (2832)
Fax (858) 558-6570
E-Mail Rentals@atecorp.com
Web Site www.atecorp.com

Since 1981, **Advanced Test Equipment Rentals (ATEC)** has shown its commitment to providing quality customer service by meeting our customer's equipment rental needs. Our primary focus is providing a complete rental solution of test and measurement equipment to industries such as Aerospace, Defense, Communications, Environmental and more. Our wide inventory, custom solutions, flexible rental terms, and quality customer support differentiates us from our competitors as a complete solution for all test and measurement needs. Our expansive facility houses test gear for EMC, Communications, Power, Environmental, Microwave/RF, and General Purpose applications. Located in San Diego, California, Advanced Test Equipment Rentals is HUB Zone & ISO certified. For more than 30 years of experience, ATEC is chosen by the world's leading corporations and government institutions as their test equipment solutions provider. Additional information about Advanced Test Equipment Rentals is available at http://www.atecorp.com.

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Agency for Defense Development

Address P.O. Box 35
Yuseong
Daejeon, Republic of Korea
Business Research & Development of Weapon Systems
President Park, Chang Kyu
ITEA Rep Kim, Jong Hwan
Tel (+82) 42-821-3758
Fax (+82) 42-823-3400
E-Mail jonhkim@korea.com
Web Site www.add.re.kr

Agency for Defense Development-(ADD) is conducting research, development, test and evaluation of weapon systems, equipments and developing advanced technologies to reinforce defense capabilities for self-reliant national defense. Since the establishment in 1970, ADD has developed various weapon systems including K9 thunder self propelled howitzer, K21 infantry fighting vehicle, K2 main battle tank (MBT), K11 multi assault rifle/grenade launcher, K745 light weight torpedo (Blue Shark), anti-ship missile-(Haeseong), SSM (Hyunmoo), MANPADS SAM (Singung), KT-1 basic trainer aircraft (Woongbee) and URC-700K Korean military satellite communications system (K-MILSATCOM). ADD is also developing weapon systems such as smart munitions, medium-range SAM, anti-submarine missile, medium altitude UAV and high-tech electronic warfare systems. For test and evaluation of weapon systems, ADD has test ranges and proving grounds for guided missiles, artilleries & ammunition, naval weapon systems, electronic warfares, aircraft & armaments, and ground vehicles. We also run laboratories for T&E, such as wind tunnel test lab, hardware-in-the-loop simulation (HILS) lab, underwater acoustic lab, propulsion & power lab and EMI/EMC magnetic lab.

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Air Academy Associates

Address 1650 Telstar Drive
Suite 110
Colorado Springs, CO 80920
Business DOE Training and Consulting, Continuous Process Improvement
President Mark Kiemele
ITEA Rep Kathi Swagerty
Tel (800) 278-1277
Fax (719) 531-0778
E-Mail kswagerty@airacad.com
Web Site www.airacad.com

Air Academy Associates has spent more than two decades assisting clients in reducing variation, improving efficiency and creating better, faster and lower cost products and services. We support organization with our practical experience and tools to implement change and generate return on their investment. Based on industry proven strategies and tools our programs target improvements in development, design, manufacturing, testing and operations. The key element of our strategy is our "Keep it Simple Statistically" (KISS) approach to gaining knowledge. This strategy allows non-statisticians in industry, government and the service sector to embrace the philosophy and effectively apply continuous process improvement needed to optimize the bottom line. Our foundation lies in our passion for efficient, effective and accurate data collection and analysis through the use of Design of Experiments (DOE). We have helped a variety of groups within the DoD realize the need for improved testing and validation through DOE and Combinatorial Testing.

Our network of more than 35 highly qualified and certified consultants have extensive experience in government, business and industry. This background, combined with targeted statistical software applications, allows us to meet the demands of a diverse client base. In addition to structured training, we provide on-site project mentoring, independent data analysis, experimental design analysis, and advanced testing solutions. Our training aids, textbooks and powerful, user-friendly software packages are integrated in our materials and set us apart from our competition. For more information on our products and services, see our Website at www.airacad.com or call 800-278-1277 for more information.

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Alion Science and Technology

Address 1750 Tysons Blvd.
Suite 1300
McLean, VA 22102
Business Science and Technology
President Bahman Atefi
ITEA Rep Charles "Chas" Mckee
Tel (202) 756-4049
Fax (202) 646-0145
E-Mail cmckee@alionscience.com
Web Site www.alionscience.com

Alion Science and Technology is an employee-owned professional

engineering and technology solutions company delivering technical expertise and operational support to the Department of Defense, civilian government agencies and commercial customers. Building on 70 years of R&D and engineering experience, Alion brings innovation and insight to multiple business areas: naval architecture & marine engineering; defense operations; modeling & simulation; technology integration; information technology and wireless communications; energy and environmental science. Based in McLean, Virginia, Alion has 3,700 employee owners at major offices, customer sites and laboratories worldwide. For more information, call 877.771.6252 or visit Alion online at www.alionscience.com.

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AMPEX Data Systems Corp.

Address Ampex Data Systems
500 Broadway
Redwood City, CA
94063
Primary Business
Airborne Ruggedized and Ground Digital Recording and Mass Storage Systems
President Larry Chiarella
ITEA Rep Don Downing
Tel (303) 697-9499
E-Mail don downing@ampexdata.com
Web Site www.ampexdata.com

AMPEX Data Systems is a legendary supplier of ruggedized Airborne Recording and Network Data Acquisition Systems used in Flight Test, Instrumentation, and ISR Mission applications. Ampex designs, develops, and manufactures their line of IRIG106 Chapter 10 Solid-State recorders, Network File Servers, and family of mission recorders at their Redwood City, CA facilities. Made in the USA.

.....

Applied Resources, Inc.

Address 1700 N. Moore Street, Ste. 1500
Arlington, VA 22209
Primary Business
Technical, programmatic engineering and intelligence support to the Department of Defense
President Maynard A. Nagelhout
ITEA Rep Mitch Dossett
Tel (703) 243-2700
Fax (703) 243-2702
E-Mail mitch.dossett@ari2.com
Web Site www.ari2.com

Applied Resources Inc. (ARI) is a service-disabled, veteran-owned small business with corporate headquarters in Arlington, Virginia; offices in Huntsville, Alabama; and a presence in Lexington Park, Maryland, the Mark Center, Alexandria, Virginia, the Pentagon and Quantico, Virginia. ARI has been providing technical, programmatic engineering and intelligence support to the Department of Defense since 1993. ARI technical expertise includes: Test and Evaluation, Modeling and Simulation, CBRN, Targets, Threat Support, Information Assurance, Cyber Warfare, Resource Analysis, Program and Financial Management, and Security and SCIF Management.

.....

Arcata Associates, Inc.

Address 2588 Fire Mesa St., Suite 110
Las Vegas, NV 89128
Business Engineering, information technology & multimedia services
President Lawrence T. Wong
Tel (702) 642-9500
Fax (702) 968-2237
E-Mail arcata@arcataassoc.com
Web Site www.arcataassoc.com

Arcata Associates, Inc. has nearly 30 years experience supporting test and evaluation (T&E) activities for NASA and the Department of Defense. The company's experience ranges from validating aeronautical and control systems concepts and future technologies during atmospheric flight tests to assisting with the design and implementation of Earth science experiments. We establish plans and implement tests in support of human space exploration initiatives. In addition, Arcata engineers, operates and maintains telemetry systems, as well as mission control centers to support real-time testing. The company also supports operational T&E on new range system software and hardware. Arcata is headquartered in Las Vegas, Nevada, and is ISO 9001:2000 certified.

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Argon ST

Address 12701 Fair Lakes Circle
Suite 800
Fairfax, VA 22033
President Joe Carlin
ITEA Rep Ken Donahue
Tel (407) 233-1805
Fax (407) 275-1112
E-Mail kenneth.a.donahue@boeing.com
Web Site www.argonst.com

Argon ST (a wholly owned subsidiary of The Boeing Company), headquartered in Fairfax, VA is a leader in providing mission command networks and systems as well as geospatial communications for the test and evaluation community. Argon ST's 900 employees are dedicated to meeting the needs of our armed forces and defense agencies by providing quality products that get the job done. The company's Geospatial Communications group, with facilities in San Diego, CA, and Fairfax, VA, provides advanced communications, precision position/location, space-based payloads, networking and simulations, to the test & evaluation and training communities. Included within this group is the development of a common network communications infrastructure for deployment on test and training ranges. The Information Dominance group provides Provisioned and Virtualized Environment Networks, along with MLS and CDS functionality, for C2, Training and Analysis facilities of DoD. The Emerging Systems and Technology group focuses on advanced technology programs meeting future operational requirements and potential adversarial signal/communication emulations.

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ARINC

Address 1150 Eglin Parkway,
Shalimar, FL 32579
Senior Director
Bob Black
ITEA Rep Chris Short
Tel (850) 609-5800
E-Mail cshort@arinc.com
Web Site www.arinc.com

For nearly eight decades, **ARINC** has provided communications, engineering, and integration to deliver mission-critical solutions to the commercial, government, and defense industries. We have employees located in more than 100 offices in 104 countries. The Shalimar Office is part of ARINC's Advanced Aviation and Maritime Engineering based in Panama City, FL. Our office (Homeland Security/Homeland Defense) supports work at Eglin AFB and Hurlburt Field, FL (among others). Our office works with all services of the Department of Defense to aid in test and training range modernization (software, hardware and process improvement) and Advanced Concepts Engineering, to include Joint Test and Evaluation, Special Operations and Mission Planning. Our local areas of expertise include system engineering design, software integration, Concepts of Operation (CONOPS) and Tactics, Techniques and Procedures (TTPs) development, Live/Virtual/Constructive (LVC) test and evaluation, range modernization planning and special operations tactics and support. With ARINC, you can solve complex management and technical problems using a structured, proven methodology that delivers fast results. ARINC's engineering services apply advanced methodologies to solve complex management and technical challenges for military and industrial organizations. One such challenge: managing today's materiel acquisition programs for the armed forces—and ensuring adherence to their strict cost, performance, and schedule mandates. We partner with DoD, other government agencies, and private companies to include their relevant skills and knowledge, and we bring in whatever subject matter experts are needed to complement our engineering capabilities, enabling us to deliver a total solution that is effective, innovative, cost-effective and delivered on time.

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Avion Solutions, Inc.

Address 7067 Old Madison Pike
Suite 170
Huntsville, AL 35806

Business Engineering, Software, Logistical and Technical Support Services

President Gary W. Donald
ITEA Rep Michael McFalls
Tel (256) 327-7130
Fax (256) 721-7007
E-Mail mike.mcfalls@avionsolutions.com
Web Site www.avionsolutions.com

Avion, a Veteran and Employee-Owned, Small Business providing high quality Specialized Engineering, Software Development, Logistics and Technical Support services. Formed in January 1992 in response to the engineering and analytical needs of the U.S. Army Aviation community providing technical expertise support in the following areas: Engineering Services, Logistics Services, & Software Development Software Systems Engineering/Development/Fielding Automated Information Systems (AIS)/ Automated Identification Technology (AIT) Army Aviation Logistics Support—Enterprise Asset Management, Technical Data and Configuration Management Critical Asset Management: Qualification, Engineering Testing, Product Assurance Comprehensive Life Cycle Engineering and Logistics Services Test and Evaluation Management and Planning Avion supports the Department of Defense (DoD) Army customers including: OSD, Test Resource Management Center (TRMC), Program Executive Office, Aviation (PEOAVN) Project Management Offices (PMO); Research Development and Engineering Command (RDECOM) Aviation System Integration Divisions; Special Operations Aviation; and Aviation and Missile Command (AMCOM) functional elements and related organizations. Additionally Avion has a customer base in the State and local Government organizations as well as in the commercial sector. As an ISO 9001:2008 certified company, the business processes are well established and documented. With more than ten business locations across the country and approximately 150 employees Avion has the right expertise and personnel to respond to any task in the defined above technical areas.

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BAE Systems, Aerospace Solutions

Address 70 Ready Ave. NW
Fort Walton Beach, FL 32548

Business Systems engineering, systems integration, systems sustainment, test range instrumentation, operations and maintenance and technical support services.

Vice President/General Manager Gordon Eldridge
ITEA Rep Steve Whitfield
Tel (850) 664-1334
Fax (850) 664-1365
E-Mail steve.whitfield@baesystems.com
Web Site www.esdradar.com

BAE Systems is a global defense and security company with approximately 100,000 employees worldwide. The Company delivers a full range of products and services for air, land and naval forces, as well as advanced electronics, security, information technology solutions and support services. In 2010 BAE Systems reported sales of $ 34.6 billion. BAE Systems Aerospace Solutions, a Business Area of BAE Systems Inc., provides systems engineering, systems integration, systems sustainment, and technical support services to a variety of international customers, DoD and other US government customers. With more than 40 years of test range experience, the company is a recognized leader in test and evaluation TSPI support, TSPI instrumentation systems development, production, and test range instrumentation sustainment. We provide new test range TSPI instrumentation tracking systems, subsystems, legacy system upgrades and modifications. BAE Systems support over 500 tracking systems with logistics, maintenance and engineering services to over 50 test ranges worldwide. BAE Systems offers a full line of test range TSPI and range safety instrumentation tracking systems that include pulse and CW Doppler instrumentation radar systems, Electro-Optical tracking systems using visible light, IR, laser and radar sensors. Also offered are Laser Ladar monopulse tracking and laser ranger tracking systems. Other test range products include command control systems, test range unique data and graphical displays, target acquisition systems, TSPI data network distribution, remote control of tracking systems, digital video recording and data reduction systems. For your challenging TSPI solution requirements, call on BAE Systems.

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Battelle

Address 505 King Avenue
Columbus, OH 43201
Business Applied research and development
President Jeffrey Wadsworth
ITEA Rep Andrew G. Ellis
Tel (410) 306-8500
Fax (410) 306-8421
E-Mail ellisa@battelle.org
Web Site www.battelle.org

Battelle is the world's largest independent research and development organization, providing innovative solutions to the world's most pressing needs through its four global businesses: Laboratory Management; National Security; Energy, Environment and Material Sciences; and Health and Life Sciences. It advances scientific discovery and application by conducting $6.5 billion in global R&D annually through contract research, laboratory management and technology commercialization. Headquartered in Columbus, Ohio, Battelle oversees 22,000 employees in more than 130 cities worldwide, including seven national laboratories that Battelle manages or co-manages for the U.S. Department of Energy and the U.S. Department of Homeland Security, and one international nuclear laboratory in the United Kingdom. Battelle's Global National Security business applies science and technology to solve complex technical challenges for the military services and federal agencies. Including the operations of national laboratories, Battelle annually performs nearly $1.6 billion in national security-related work contributing to advances in chemical and biological defense, homeland security, armor, technology refreshment, and undersea technology. Battelle also is one of the nation's leading charitable trusts focusing on societal and economic impact and actively supporting and promoting science and math education.

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The Boeing Company

Address 100 North Riverside Plaza
Chicago, IL
60606-1596
Business Aerospace products
CEO Jim McNerney
ITEA Rep Randell Surch
Tel (714) 896-2192
Fax (714) 372-9484
E-Mail randell.e.surch@boeing.com
Web Site www.Boeing.com

Boeing is the world's leading aerospace company and the largest manufacturer of commercial jetliners and military aircraft combined. Additionally, Boeing designs and manufactures rotorcraft, electronic and defense systems, missiles, satellites, launch vehicles and advanced information and communication systems. As a major service provider to NASA, Boeing operates the Space Shuttle and International Space Station. The company also provides numerous military and commercial airline support services. Boeing has customers in more than 90 countries around the world and is one of the largest U.S. exporters in terms of sales. Boeing has a long tradition of aerospace leadership and innovation. We continue to expand our product line and services to meet emerging customer needs. Our broad range of capabilities includes creating new, more efficient members of our commercial airplane family; integrating military platforms, defense systems and the warfighter through network-centric operations; creating advanced technology solutions that reach across business units; e-enabling airplanes and providing connectivity on moving platforms; and arranging financing solutions for our customers. Headquartered in Chicago, Boeing employs more than 158,000 people across the United States and in 70 countries. This represents one of the most diverse, talented and innovative workforces anywhere. More than 123,000 of our people hold college degrees–including nearly 32,000 advanced degrees–in virtually every business and technical field from approximately 2,700 colleges and universities worldwide. Our enterprise also leverages the talents of hundreds of thousands more skilled people working for Boeing suppliers worldwide.

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Booz | Allen | Hamilton Inc.

Address 8283 Greensboro Dr.
McLean, VA 22102
Business Strategy, organization, operations, and IT consulting and implementation
Chairman & CEO Dr. Ralph W. Shrader
ITEA Rep Dr. Timothy M. Scully
Tel (719) 387-6470
Fax (719) 387-2020
E-Mail scully timothy m@bah.com

Booz Allen Hamilton has been at the forefront of strategy and technology consulting for 95 years. Every day, government agencies, institutions, corporations, and not-for-profit organizations rely on the firm's expertise and objectivity, and on the combined capabilities and dedication of our exceptional people to find solutions and seize opportunities. Providing a broad range of services in strategy, operations, organization and change, information technology, systems engineering, and program management, Booz Allen is committed to delivering results that endure.
Booz Allen is actively working to help clients meet the test and evaluation (T&E) challenges involved in complex systems of today and tomorrow. The firm is at the forefront of ensuring industry success through the seamless integration of systems engineering with a comprehensive T&E program. Booz Allen combines a deep understanding of the client's mission and environment with expert services and an absolute commitment to client success.

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CALCULEX, Inc.

Address 132 W. Las Cruces Avenue
Las Cruces, NM 88001
Business Solid State Recorders
President Martin Small
ITEA Rep Tom Beams
Tel (575) 525-0131
Fax (575) 524-4744
E-Mail tbeams@calculex.com
Web Site www.calculex.com

The MONSSTR (Modular Nonvolatile Solid STate Recorder) family of solid state recorders offers both ARMOR and IRIG-106 Chapter 10 multiplexers integrated into the recorder saving weight, volume and power for the host vehicle. MONSSTR recorders are currently being used extensively on the follow-

ing programs: F-15E fleet upgrade video recorder; B-1B Laptop Controlled Targeting Pod recorder; AIM-9X missile tests aboard F-15 at 46th Test Wing, Eglin AFB, Florida; U-2 flight test at Lockheed Martin, Palmdale, California; Global Hawk mission imaging for the United States Air Force, Edwards AFB, California (Northrop Grumman); Global Hawk LRIP at Northrop Grumman, San Diego, California; F-15 flight test Israeli Air Force, Tel Aviv, Israel; Torpedo Qualifications, Naval Undersea Warfare Center, Newport, Rhode Island; F/A-18E/F flight testing, NAS Pax River, Maryland; F-15J weapons test, Japan Defense Agency, Tokyo, Japan; F-22 flight test program, Edwards AFB, California (Boeing); EADS Airbus Ethernet recording (Germany).
The latest in the family of solid state recorders is the 2300(V2) that offers a wide range of user options including video, audio, MIL-STD-1553, PCM multiplexing in a compact, rugged enclosure. Removable media may be solid state (FlashCache II) or disk (SpinCache) in capacities ranging from 16GB to 256GB. The 2300(V2) utilizes an IEEE 1394b Firewire interface for easy downloading to a PC following a mission.

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CETEST

Address Test & Analysis Centre
J.M. Iturrioz
26 Beasain Gipuzkoa
20200 Spain
ITEA Rep Igor Alonso Portillo
Tel 34 943 02 86 90
E-Mail jalonso@cetest.es
Web Site www.cetest.es

CETEST Test and Analysis Centre is a test laboratory providing service in the world of railways and capital equipment. Its activity is centred on validation and approval of new vehicle designs (metros, tramways, commuter trains, freight trains and very high speed trains) during the manufacturing process. It also provides consultant services in this field. CETEST is a non-profit testing laboratory certified to ISO 17025:2005.

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CGI

Address 9700 Capital Court
Manassas, VA 20110
ITEA Rep Frank Murphy
E-Mail francis.murphy@stanleyassociates.com

.....

Charles Stark Draper Laboratory

Address 555 Technology Sq.
MS #18
Cambridge, MA 02139
Business Information technology
Division Leader Mark Lupo
ITEA Rep Mark Lupo
Tel (617) 258-2603
Fax (617) 258-3858
E-Mail mlupo@draper.com
Web Site www.draper.com

Draper, a not-for-profit R&D laboratory, employs expertise of guidance, navigation, and control systems; fault-tolerant computing; advanced algorithms and software solutions; modeling and simulation; and MEMS (multichip module) technology to design, develop, and deploy advanced technological solutions for our nation's challenging and important problems in security, space exploration, healthcare, and energy.

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Command Post Technologies, Inc.

Address 5400 Manuel Gameros Drive
El Paso, TX 79934
ITEA Rep Scott Bisciotti
E-Mail Info@CommandPostTech.com

Command Post Technologies, Inc. (CPT) is a Service Disabled Veteran Owned Small Business (SDVOSB) founded in 2008 and headquartered in Suffolk, VA. CPT provides an operationally seasoned team of subject matter experts with experience gained through combat and contingency operations in Afghanistan, Iraq and elsewhere around the globe. CPT plans, organizes and designs exercises to meet SOF training objectives and provides a unique combination of technical expertise and operational perspective in applications of M&S capabilities to enhance pre-deployment training for Special Operations Forces. CPT is also uniquely qualified to explore ways M&S capabilities can enhance Test and Evaluation (T&E) and C4ISR interoperability assessments. We deliver high quality, professional services in the areas of training support, program management, scenario development, M&S integration, and T&E for our commercial and U.S. Government customers. We support full spectrum Conventional and Special Operations training activities to include Village Stability Operations (VSO), and irregular warfare, personnel recovery, direct action and developmental initiatives for cyberspace and information operations. We are agile, flexible and very responsive to emerging requirements and evolving customer needs. CPT is known for superior performance in providing creative, responsive, and innovative immersive training solutions to our customers. CPT holds a Top Secret facility security clearance.

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CSC Applied Technology Group (ATG), Training and Range Support Services

Address 21841-B Three Notch Rd.
Lexington Park, MD 20653
Business Professional & technical services
President Alan B. Weakley
ITEA Rep Stephanie Clewer
Tel (410) 620-2402
Fax (410) 620-2402
E-Mail sclewer@csc.com
Web Site www.csc.com

In this time of high-performance expectations combined with ever-shrinking budgets, **CSC ATG** brings practical, experience-driven solutions. We excel at operating in dynamic environments providing responsive and flexible management with the correct skills to execute missions. Our systems integration background enables us to deploy the best mission-tailored solution, powered by technologies that provide real-time decision-making capability. Why does this matter? Because the right solution properly and efficiently imple-

mented enhances performance and lowers cost.

Today's ranges provide real-world environments whether on land, in the sea, air, or space to support multiple, concurrent missions. These missions include research, development, T&E requirements and operational performance assessments for U.S. and international clients. We respond to unique program requirements including: Information Technology, Engineering Services, Performance Assessment, Engineering, Instrumentation, Data Collection and Management, Target Handling, Environmental Support ATG employs approximately 13,842 personnel in more than 42 worldwide locations. By matching the most capable and experienced managers with the appropriate program and giving those managers the authority to do what is needed, we consistently exceed customer expectations. Because our managers share knowledge across similar programs, they can apply best commercial practices and other lessons learned to raise performance standards at all client sites. Our customers include: U.S. Army WSMR, U.S. Navy Atlantic Undersea Test and Evaluation Center, U.S. Navy Naval Air Warfare Center Atlantic Test Range, Patuxent River, U.S. Air Force Cape Canaveral, U.S. Air Force Nellis AFB, United Kingdom MOD U.S. Navy Southern California Offshore Range.

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Cubic Defense Applications

Address	1225 S. Clark Street Suite 702 Arlington, VA 22202
Business	Defense Industry
President	Bradley H. Feldmann
ITEA Rep	Robert Janssen
Tel	(703) 415-1600
Fax	(703) 415-1608
E-Mail:	robert.janssen@cubic.com
Web Site	www.cubic.com

Backed by more than five decades of experience, **Cubic Defense Applications** provides a broad spectrum of world-class integrated systems, electronic products and high-caliber services supporting the training and operational readiness of U.S. armed forces and allied militaries. Cubic also provides government and commercial customers with electronic systems and products in the areas of secure communications, combat search-and-rescue, and command, control, communications, computers, intelligence, surveillance and reconnaissance (C4ISR). Cubic is one of a few certified common tactical data link suppliers and has extensive experience in the area of data link technology. Cubic is a world leader in live combat instrumentation training systems for air and ground forces as well as providing Test & Evaluation (T&E) systems. Cubic develops open architecture systems and provides integration of live, virtual and constructive (LVC) systems using Government standards such as the Test and Training Enabling Architecture (TENA). Cubic provides everything from individual components and technologies to turnkey systems and services for joint, interagency and multinational forces and provides the complete spectrum of systems and solutions that warfighters need to survive on today's battlefield.

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Department of Defence—RANTEAA

Address	Level 2, Bldg 90 Garden Island, NSW Australia 2011
Senior Officer	CAPT Mark Kellam
ITEA Rep	Brooke Amos
Tel	61 29359 6288
Fax	61 29359 3501
E-Mail	brooke.amos@defence.gov.au

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DRS Training & Control Systems

Address	645 Anchors Street Fort Walton Beach, FL 32548
Business	Complex electronics/airborne products, engineering, manufacturing
President	Robbie Epstein
ITEA Rep	Joe Testa
Tel	(850) 302-3843
Fax	(850) 302-3371
E-Mail	jtesta@drs-ds.com
Web Site	www.drs-ds.com

DRS Training & Control Systems, LLC (TCS), (a DRS Defense Solutions company) Range Systems LOB, is a world leader in design, development and production of airborne instrumentation and ground support equipment including the P5 Combat Training System or Tactical Air Combat Training System, Advanced Range Data System, and tactical satellite communication instrumentation systems. DRS TCS's test and training products support unit-level through multi-platform, large-scale exercises/tests, while simultaneously supporting the unique, high accuracy requirements of the test and evaluation customer. DRS TCS develops and produces airborne instrumentation pods for external carriage on tactical aircraft, and internal instrumentation packages for fifth generation fighters, bombers, transports, helicopters and naval ships/ground vehicles that incorporate proven GPS and range data link capabilities. The company provides PC-based display equipment for post mission debriefing and real-time exercise monitoring of the missions performed. DRS TCS's air combat test and training systems function in a "rangeless" mode without need for ground-based equipment or can be configured with DRS TCS-provided remote ground equipment for "tethered" range applications where real-time control is an important aspect of the mission. A major feature of DRS TCS's equipment is its ease of use and flexibility of application by the range user and its support of aircraft embedded training and live-virtual-constructive technologies. The technical staff provides unmatched expertise for the integration of company products with the customer aircraft/platforms, a variety of EW equipment and other existing customer assets for providing turnkey test and training range capabilities. Following equipment installation, DRS TCS provides depot services, technical assistance and logistics support for its products. DRS TCS is a registered ISO 9001 company and provides an integral quality assurance program.

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Energetic Materials Research and Testing Center (EMRTC)

Address	New Mexico Institute of Mining and Technology 801 Leroy Pl. Socorro, NM 87801

Business University-based energetic materials & homeland security/homeland defense research & training division
Director Dr. John L. Meason
ITEA Rep Dr. John L. Meason
Tel (505) 835 5312
Fax (505) 835 5630
E-Mail meason@emrtc.nmt.edu
Web Site www.emrtc.nmt.edu

EMRTC, the major research, testing and training division of New Mexico Tech, is a world-class leader in the research, development, testing and evaluation (RDT&E) of energetic materials and related systems, microelectronics obsolescence solutions, and training of participants in a wide range of anti-terrorism and other homeland security/homeland defense skills. EMRTC conducts its activities in a 40-square-mile field research laboratory that has more than 30 test facilities to conduct explosives research and testing. A highly professional and technically trained staff performs in-depth scientific investigations and studies of energetic materials and training at this laboratory. EMRTC also owns and operates the Playas RDT&E and Training Complex at Playas, New Mexico, an entire town with its own infrastructure systems that is rapidly becoming the premier location for conducting homeland security/homeland defense RDT&E and training. EMRTC finds solutions to technology's challenges, shares its results, and teaches safe, practical and effective applications to others.

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ERC, Incorporated

Address 555 Sparkman Dr.
Suite 1622
Huntsville, AL 35816
Business Engineering services, R&D
President/CEO Dr. Ernest H. Wu
ITEA Rep Dr. Ernest H. Wu
Tel (256) 430-3080
Fax (256) 430-3081
E-Mail ewu@erc-incorporated.com
Web Site www.erc-incorporated.com

ERC provides a wide variety of engineering, scientific, software development, and other technical support services the Army, Air Force, and NASA. Experience includes more than 50 different types of systems. Projects include center-wide engineering, science and technical support services at multiple NASA Centers. The scope encompasses both advanced theoretical and "metal bending" tasks in research, engineering, fabrication, testing, mission evaluation, facility development and sustainment. T&E experience at the Redstone Technical Test Center includes test planning and test execution services, test process and analysis and complex test hardware and software ancillary support. Specialties include: electromagnetic radiation hazards and operations; advanced electro optical target acquisition systems including open-loop 6DOF and closed-loop HWIL analysis; mechanical flight safety parts for helicopters; dirty battlefield testing of infrared and optical sensors; dynamic warhead tests; flight testing of missiles; mechanical and electronic repair parts for weapon systems, from circuit cards to complete subassemblies; development of unique missile test stations. Propulsion experience includes: rocket motor and component testing, ranging from small reaction control thrusters up to the Shuttle's main engines, including atmospheric simulation chambers, and propellant combustion. ERC experience includes operation and maintenance of test and simulation facilities for DOD and NASA, such as the Stennis Space Center, Marshall Space Flight Center and the White Sands Test Facility. We provide basic research support to the U.S. Air Force Research Laboratory's Propulsion Directorate in synthesis of new chemical compounds, aerophysics research, advanced propulsion technologies, controllable thrust propulsion, advanced materials studies, laser and plasma diagnostics, and high energy density matter.

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EWA Government Systems, Inc.

Address 13873 Park Center Road
5th Floor
Herndon, VA 20171
Business EW operational technology, cyber security/defense, test & evaluation, radar simulators, radar design and development, range instrumentation, information operations, penetration testing, EW scenario simulators, wireless applications, intelligence support, homeland security, special programs, engineering, training
President Doug Armstrong
ITEA Rep Jeff Morgan
Tel (703) 904-5065
Fax (703) 904-5777
E-Mail jmorgan@ewa.com
Web Site www.ewa-gsi.com

EWA GSI is well known across the test range community, experienced in test planning, setup, and execution, autonomous calibrated instrumentation and real-time analysis, time-and-event correlated collection and reporting, and final report preparation. Our cyber test range includes participants from DOD, OGA, US allies, state governments, and cleared defense contractors to immediately apply results of research and analysis to real time network monitoring. EWA GSI has developed multiple communications architectures; we provide strategic functional support tools to the intelligence community for information acquisition, analysis and distribution; and we deal in special operations and low intensity conflict both internationally and in support of homeland defense, including a suite of tagging, tracking, intercepting, and locating tools. EWA GSI also specializes in software and hardware systems design, systems engineering, development and integration, producing a line of digital signal processing products and applications, and training systems to include mission rehearsal systems, computer and web based training, and immersion training. EWA GSI offers secure engineering and IT labs, and features a miniaturization and microelectronics design center. We recruit and retain highly skilled and dedicated professionals who are passionate about discovering ways to make a safer and more secure world, while furthering our reputation as the "go-to" company fully responsive to customers' dynamic requirements, and exceeding customer expectations.

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GDP Space Systems

Address 300 Welsh Rd.
Ste. 120 Bldg 3
Horsham, PA
19044-2273
ITEA Rep Stephen Nicolo
Tel 215-657-5270
Fax (781) 341-3983
E-Mail: snicolo@gdpspace.com
Web Site www.gdpspace.com

GDP Space Systems designs and manufactures ground-based telemetry and communications equipment. GDP provides products and services to support tracking and control as well as processing and acquisition of data. Products include Bit Synchronizers, Decommutators, Simulators, Data Link Testers, Receivers, Modulators and Demodulators for SGLS, PSK and PM. Take note of our new Multi-Channel PCM Bit Synchronizer/Best Source Selector and our Data Link Test Sets.

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General Dynamics C4 Systems

Address 8201 E. McDowell Road
Scottsdale, AZ 85257
Business Systems Integrator
President Chris Marzilli
ITEA Representative
Jean Hale
Tel (508) 880-4030
Fax (508) 880-4388
E-Mail: Jean.hale@gdc4s.com
Web Site www.gdc4s.com

General Dynamics C4 Systems is a premier provider of turnkey solutions for test and training range modernization. We develop test range instrumentation, threat simulation and training systems as well as range infrastructure upgrades for all areas of the testing and training continuum—live, virtual and constructive. GDC4S provides modeling and simulation architectures, realistic and exploitable threat environments, advanced opposing forces command and control and situational awareness capabilities that synchronize live and virtual systems to better augment the warfighter skills and systems at the tactical, operational, and strategic level. The company is uniquely positioned in its understanding of today's global threats to provide ready and realistic threat representations, technologies and integration solutions to meet any joint testing, training and mission rehearsal requirements.

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Georgia Tech Research Institute

Address 7220 Richardson Rd.
Smyrna, GA 30080
Business Sponsored Research and Engineering
ITEA Rep Russell L. (Rusty) Roberts
Tel (404) 407-6856
Fax (404) 407-7019
E-Mail rusty.roberts@gtri.gatech.edu
Web Site www.gtri.gatech.edu

The Georgia Tech Research Institute (GTRI) is a highly-regarded applied research and development organization. Each day, GTRI's science and engineering expertise is used to solve some of the toughest problems facing government and industry across the nation and around the globe. GTRI redefines innovation by tackling customers' most complex challenges with the right mix of expertise, creativity and practicality. Our expert scientists and engineers turn ideas into workable solutions and then put those solutions into action. We have been a trusted government and industry partner since 1934. As a non-profit research institute, we team with our customers and attack their problems with passion and objectivity. GTRI is in integral part of the Georgia Institute of Technology (Georgia Tech). GTRI is a tremendous contributor to, and supporter of, Georgia Tech's mission to define the technological research university of the 21st century and educate the leaders of a technologically driven world. GTRI's strong bond with Georgia Tech, and its academic units, opens the door to the vast intellectual resources of one of America's leading research universities and provides unparalleled access to the world's leading problem solvers.

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Glacier Technologies, LLC

Address 1200 Golden Key Circle, Suite 400
El Paso, TX 79925
Business Information Technology Services
President Bobby W. Trumbla
ITEA Rep Wendy Hoggard
Tel (915) 225-3691
Fax (915) 241-2605
E-Mail Wendy.Hoggard@Glacier-tech.com
Web Site www.glacier-tech.com

Glacier Technologies is an SDB founded in 2004 to provide technical services to both the DoD and Civilian Agencies across the United States. Glacier provides services around five primary competencies: Information Technology, Test and Evaluation, Range Operations and Support, Call Centers and Communications and Electronics. Glacier is ISO 9001:2008 certified with ITIL certified personnel. T&E services include test definition, test planning, test execution, data collection, test analysis and test reporting. Testing support includes instrumentation development, instrumentation modification, IT support, range support, configuration support and data reduction. Glacier develops and maintains knowledge management systems that support IT infrastructures and systems as part of its testing environment. Other ancillary functions include change management and life cycle management. Services include quality assurance and quality testing. Systems testing include both the Patriot and THAADS missile defense systems. Operational Testing for DoD systems range from night vision goggles to Real Time Casualty Assessment systems. Glacier has experience in range support from assault zone and landing zone support to tower operations during exercises. Ground services also include decommissioning targets and fire department support. Glacier assists the government in evaluating the effectiveness of its exercises and testing activities. Other support functions include exercise and test planning, exercise and test data collection and data reduction. Glacier also provides logistics support and hazard materials handling. C&E functions include operations and maintenance of DISA satellite systems. Glacier is tasked with assisting the government in developing supporting documentation to support this environment. Glacier provides a broad spectrum of information technology support.

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Herley Industries, Inc.

Address 3061 Industry Drive
Lancaster, PA 17603
Business Flight Instrumentation and Command and Control Systems
Director Sales & Marketing, Jeff Postlethwait
ITEA Representative
Jeff Postlethwait
Tel (717) 397-2777
Fax (717) 397-7079
E-Mail jeff.postlethwait@herley.com
Web Site www.herley.com

Herley Industries, Inc. is a world-class RF/microwave, millimeter-wave, solutions company focused on providing innovative, high quality products. Since its inception in 1965, Herley has evolved into a world leader in the design and manufacturing of command and control (C2) systems, telemetry systems, flight instrumentation, microwave assemblies, IFF and HF communication systems, distributed data acquisition encoders, and broadband RF power amplifiers. This wide range of products has been the basis for support to government and commercial programs alike, in both the defense and aerospace sectors. Ruggedized and miniaturized systems and subsystems have been qualified for high dynamic missile and gun projectile applications, as well as aircraft programs. The company's continuing growth in all markets throughout the world is being fueled by the ideas and designs of its talented engineering and manufacturing staff.

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IDA Technology

Address 6070 Gateway Blvd. East
Suite 100
El Paso, TX 79905
President Von Washington
ITEA Rep Von Washington
Tel 915-778-3883
Fax 915-525-3434
E-Mail vwashington@idapx.com

Integrated Defense Applications, LLC dbd IDA Technology is an 8(a), Service-Disabled Veteran-Owned, Minority Small Business. IDA Technology is a small business industry leader in full scale, joint, interoperable test and evaluation providing the innovative application of technology, science, and project management to optimize systems analysis and evaluation. We provide project management, test planning, development of test evaluation criteria, analysis and reporting of test data. IDA has a robust in-house Geographical Information Systems (GIS) capability which supports our scenario development capabilities.
§ Universal Numbering System (DUNS) Number: 801896312
§ Commercial and Governmental Entity (CAGE) Code: 4ZPM3 (TS)
§ Texas Historically Underutilized Business (HUB) Vendor Number 58482
§ Primary NAICS Codes: 541712, 519190, 518210, 531311, 541511, 541513, 541519
IDA's depth of technical expertise, extensive project management, operational military experience and successful history of government contract support provide a highly valued skill set to our clients. The same qualities which enabled us to successfully defend our nation, carry over into our business through our leadership, management and work ethic.

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InDyne, Inc.

Address 516 Perimeter Rd., Suite 1
Eglin AFB, FL 32542-5654
Business Enterprise management, range services, science & engineering, security systems services, information technology, C2 services, program management & technical services
President C. Donald Bishop
GM & ITEA Rep
Jim Heald
Tel (850) 882-4983
Fax (850) 678-0808
E-Mail james.heald.ctr@eglin.af.mil
Web Site www.indyneinc.com/

InDyne is an innovative, high-technology firm providing cost-effective, high-quality services and solutions tailored to customers' specific needs in range services, science and engineering, command and control, enterprise management, information technology, and technical and program management services. Established in 1984, InDyne has experienced tremendous growth, diversifying its expertise while retaining core capabilities. Thus, InDyne rapidly responds to changing requirements, recruits and retains a skilled workforce, and uses cutting-edge technology to improve productivity and reduce operating costs to the customer. InDyne believes customers should pay for results- not efforts. InDyne's reputation for providing innovative cost-cutting service is reflected in its growing list of satisfied customers who continue to engage its services. InDyne currently supports NASA, DoD and other federal and state agencies. InDyne operates and maintains the test and evaluation (T&E) and training ranges plus hardware-in-the-loop and installed systems test facilities at Eglin and the space launch range at Vandenberg and downrange sites. InDyne also operates IT and communications contracts at Kennedy Space Center, NASA Headquarters and Johnson Space Center, plus security installation and maintenance contracts for DoD customers.

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InfoWhere Inc.

Address 338 Whiteoaks Dr. NE
Albuquerque, NM 87122
Business Geospatial Information Software and Services
President Michael Hollis
ITEA Rep Michael Hollis
Tel (505) 681-1986
Fax (505) 858-3304
E-Mail mike@infowhere.com
Web Site www.infowhere.com

InfoWhere Inc. is a certified Service Disabled Veteran Owned Small Business (SDVOSB) that provides information software, solutions and services. Our goal of "*Putting Information in its Place*" is pursued by developing geospatial information software that puts information from common data sources such as Microsoft SharePoint into a natural, relevant geographic context. We emphasize easy to use solutions that are useful and accessible by all test team and corporate personnel, without the need to call on geographic information system (GIS) professionals. InfoWhere is an ESRI business partner

and specializes in the application of their web and GIS technologies for information visualization, sharing and management. InfoWhere also offers software customization, integration and support services.

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Integral Systems (a Kratos Company)

Address 985 Space Center Drive
Suite 350
Colorado Springs, CO 80915
ITEA Rep Hal Cornelius
Office 719-598-2801
E-Mail hcornelius@integ.com

Integral Systems' Chantilly, Virginia-based SATCOM Solutions division specializes in transportable satellite communications, antennas, telemetry, data acquisition, and signal processors. Our products include portable antennas, high data rate modems, RF equipment, IP gateways, and more. We also offer comprehensive design, integration, and installation services.

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ITT Exelis

Address 12975 Worldgate Drive
Herndon, VA 20170
Business Test equipment and test services for military and commercial
ITEA Rep Lorely Flores
Tel (571) 203-3359
Cell (571) 329-8804
E-Mail Lorely.Flores@exelisinc.com
Web Site www.exelisinc.com

On October 31st, 2011, ITT Corporation separated into three companies, ITT Corporation, Xylem, and ITT Exelis. **ITT Exelis** is a new company with a long history and an exciting future. We are now a standalone company solely focused on meeting the needs of military, government and commercial customers around the world. ITT Exelis is customer focused, ethical and honest, agile and resourceful and dedicated to making the world a safer place for soldiers and citizens. ITT Exelis has supported the Test and Evaluation community with system integration, modeling & simulation, data collection and analysis, and subject matter experts that are dedicated to providing our customers effective test and evaluation capabilities for high technology systems. Our solutions range from systems engineering and professional services, analytical instrumentation, training services, secure network solutions to cyber security and support services.

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Jacobs

Address 600 William Northern Blvd.
Tullahoma, TN 37388
Business Test & evaluation and O&M; scientific, engineering & technical services; design/build & operate test facilities & enterprise information services
President Rogers F. Starr
ITEA Rep Dan Pierre
Tel (931) 393-6551
Fax (931) 393-6389
E-Mail: Dan.Pierre@jacobs.com
Web Site www.jacobstechnology.com

Jacobs Technology (hereto after referred to as Jacobs) is a wholly-owned subsidiary of Jacobs Engineering (NYSE: JEC), one of the nation's largest engineering and technical services firms, with annual revenues of more than $12 billion and approximately 57,000 personnel. As the advanced technology arm of the company, Jacobs has a more than 60-year heritage providing advanced technology engineering services to DoD, NASA, DOE, and industry. With 23 operating segments employing more than 12,500 employees and approximately $2.0 billion in annual sales, Jacobs provides a complete range of scientific, engineering, and technical services in the following core markets: test and evaluation engineering; operations and maintenance; scientific, engineering and technical services; design/build/operate test facilities; and enterprise information services. Jacobs is a recognized leader in numerous technical fields, including: design of wind tunnels, engine test cells, and automotive test facilities; process re-engineering and management of change for highly technical operations; design of systems and mechanisms for space transportation and habitation; systems engineering and acquisition support; logistics management; asset management; complex facilities operations and maintenance; C4ISR systems development and sustainment; and range operations. Jacobs also provides a broad range of IT support, including network architecture, data center management, software development, and IT systems operation and maintenance. In addition, Jacobs provides full-scope environmental services, including assessments, investigations, design, cleanup, and disaster response; humanitarian mission support; unexploded ordnance (UXO) clearance; and remote site work.

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JDA Systems

Address 4080 Pike Ln,
Concord, CA 94520
ITEA Rep John Hueckel
Tel 800-381-3305
Fax 800-381-3305
E-Mail jhueckel@jdasystems.com
Web Site www.jdasystems.com

JDA Systems, recognized as a leader in IRIG 106 Chapter 10 technologies, develops, manufacturers and sells portable and rack mounted ground support systems for real-time data processing, analysis, display and distribution. Other products include portable tracking antennas, syncs, decoms, VuSoft, and CMDP software. JDA systems also provides engineering and technical support to military and commercial customers.

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JT3 LLC

Address 821 Grier Drive
Las Vegas, NV 89119
President Alan Hunter
ITEA Rep Ray Sommer
Tel (888) 367-4935
Fax (702) 492-2178
E-Mail Ray.somer@jt3.com
Web Site www.jt3.com

JT3 LLC is a joint venture company combining the management skills, military experience, and technical knowledge of URS and Raytheon. Supporting the J-Tech contract, JT3 provides engineering and technical

expertise to four western military ranges (AFFTC, NTTR, UTTR, and China Lake ECR) for testing of new and modified weapons systems, new tactics development, and ongoing military training.

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L-3 Telemetry-West

Address 9020 Balboa Ave
San Diego, CA 92123
President Burt Smith
ITEA Rep James Yates
Tel (858) 694-7500
E-Mail James.Yates@L-3com.com
Web Site www.L-3Com.com/TW

L-3 Telemetry-West is a premier provider of tailored flight hardware and systems solutions for missile telemetry/flight termination, spacecraft telemetry tracking and control (TT&C), and tactical intelligence receivers. Additionally, Telemetry-West leads the telemetry and test industry in the design and manufacture of advanced real-time commercial-off-the-shelf ground hardware and software solutions for spacecraft command and control, satellite manufacturing, on-orbit operations, launch support and monitoring, flight test, weapons test and development, surveillance and detection, and general-purpose data acquisition. Finally, Telemetry-West supplies a variety of terrestrial HF and microwave radio solutions for both the military, paramilitary and commercial communications markets.

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ManTech International Corporation

Address: 12015 Lee Jackson Highway
Fairfax, VA 22033
Business: Systems Engineering & Advanced Technology
President: Terry M. Ryan
ITEA Rep Kenneth Maddox
Tel (703) 907-3698
E-Mail Kenneth.maddox@mantech.com
Web Site mantech.com

Headquartered in Fairfax, Va., with approximately 10,000 professionals around the world, **ManTech** is a leading provider of innovative technologies and solutions for mission-critical national security programs for the intelligence community; the departments of Defense, State, Homeland Security, Energy and Justice, including the Federal Bureau of Investigation; the space community; the National Oceanic and Atmospheric Administration; and other U.S. federal government customers. ManTech's expertise includes command, control, communications, computers, intelligence, surveillance and reconnaissance (C4ISR) lifecycle support, cyber security, global logistics support, intelligence/counter-intelligence support, information technology modernization and sustainment, systems engineering, and test and evaluation. ManTech supports major national missions, such as military readiness, terrorist threat detection, information security and border protection. The ManTech-developed Web 2.0 intelligence community collaboration tool was chosen by *TIME® Magazine* as a 2009 top 50 invention. *R&D Magazine* selected ManTech's CORIN™ XLS, a transparent polyimide film used in space and electronics, as one of 2009's top 100 most innovative technologically significant new products. In 2010, ManTech was selected for *FORTUNE®* magazine's 100 fastest growing companies list; received the NASA Goddard Space Flight Center Contractor Excellence Award; was named a top 10 best employer for veterans by *Military Times EDGE* magazine; and, for the fourth year in a row, was selected as a top 10 military-friendly employer by *G.I. Jobs* magazine. ManTech's additional recognition includes the Northern Virginia Family Services CARE award for family-friendly policies (2009) and most valuable employer for the military by *CivilianJobs.com* (2009). ManTech has received a top rating for ethics and compliance programs from the Ethisphere Institute (2008).

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MEI Technologies, Inc.

Address 2525 Bay Area Blvd, Suite 300
Houston, TX 77058
215 Wynn Drive, Suite 415, Huntsville, AL 35805
Business System engineering and integration; test and evaluation; payload integration; system design, analysis and development; and technical support services in support of NASA, Army and Air Force
President/CEO Ed Muniz
COO Vic Walczak
ITEA Rep John R. Williams & Beth Rogers
Tel (256) 799-5221
Fax (256) 922-5713
E-Mail: John.Williams@meitechinc.com & Beth.Rogers@meitechinc.com
Web Site www.meitechinc.com

MEI Technologies, Inc. (MEIT) is a growing technology company with dynamic people making extraordinary advancements in engineering services, IT/cyber security, payload integration, test and evaluation, advanced power systems and advanced communications.
Founded in 1992 as Muñiz Engineering, the company employs more than 800 individuals that serve more than 60 clients in the civil, commercial and defense industries. Headquartered in Houston, the company operates satellite offices in six additional states: Colorado (Denver and Colorado Springs), New Mexico (Albuquerque), Alabama (Huntsville), Maryland (Greenbelt), Mississippi (Stennis Space Center) and Florida (Fort Walton Beach). Since 2000, company sales have steadily increased from $18 million (in 2000) to more than $150 million for 2010. **Highlights/Certifications:** AS9100 Certified; ISO 9001:2008 Certified; CMMI Maturity Level 3; NAICS Codes 541712 and 517110; GSA schedules for engineering and management; Owned by a Vietnam and Service-Disabled Veteran.

The MIL Corporation

Address 46655 Expedition Drive, Ste 100 Lexington Park, Maryland 20653
Business Information Technology, C4I Solutions; Financial Systems/Management; Program Management; E-Travel
President Maurice I. (Butch) Long, Jr.
ITEA Rep Thomas E. Bailey III
Tel (301) 863-9566
Fax (301) 863-9597
E-Mail Tbailey@milcorp.com
Web Site www.milcorp.com

The **MIL Corporation** has been providing information technology, financial systems and financial management solutions to Federal government clients for over 28 years. Services include information assurance; information security, enterprise LAN/WAN design and operations, technical and functional help desk support; web/database/applications design and administration; ERP support; C4I services; financial systems accounting and operations support; IV&V; e-Travel support; Quality Assurance; training and end-user support; engineering and program management support.

NetAcquire Corporation

Address 12000 115th Avenue, NE Kirkland, WA 98034
President Preston Hauck
ITEA Rep Steve Proudlock
Tel (425) 821-3100 x148
Fax (425) 952-0468
E-Mail stevep@netacquire.com
Web Site www.netacquire.com

NetAcquire Corporation offers real-time telemetry and data acquisition products. Their proven COTS architecture creates a cost-effective environment for any mix of I/O signal, data format, and real-time data processing. Products include a range of network-centric distributed solutions that support low-latency, deterministic system operation common in airborne avionics and aerospace applications.

NewTec

Address 8201 Lockheed Drive Suite 211 El Paso, TX 79925
Business Government contract services
President/CEO Charles R. Garcia
ITEA Rep Patricia Holguin-Lucero
Tel (915) 775-0003
Fax (575) 678-3381
E-Mail plucero@traxintl.com
Web Site www.newtecllc.com

NewTec–TRAX International, LLC, a wholly owned subsidiary of TRAX International, provides a comprehensive range of support services to U.S. Army White Sands Missile Range (WSMR). NewTec–TRAX International, LLC supports the WSMR Mission Support Services contract with a wide array of test and evaluation services, including engineering design and analysis, software development, technical operation and maintenance of equipment and instrumentation used in T&E environments (for example, C4I, optics, radar, telemetry, timing and other systems), test planning, nuclear effects and electromagnetic testing, fabrication, environmental services, and other mission support services. NewTec–TRAX International, LLC provides excellence by ensuring we have highly motivated and highly qualified personnel helping our customers develop leading edge test technologies and procedures to support Department of Defense 21st century initiatives.

New Mexico State University/Physical Science Laboratory

Address MSC PSL P.O. Box 30002 Las Cruces, NM 88003-8002
Business Research, Development, Test, and Evaluation
Director Jay Jordan, PhD
ITEA Rep Stephen B. Hottman
Tel (575) 646-9202
Fax (575) 646-9600
E-Mail shottman@psl.nmsu.edu
Web Site http://www.psl.nmsu.edu

The **Physical Science Laboratory (PSL) of New Mexico State University (NMSU)** is a multi-discipline, aerospace- and defense-oriented scientific and technical organization. PSL's key capabilities are grouped into two departments: 21st Century Aerospace and Information Science and Security Systems. PSL's 21st Century Aerospace supplies complete solutions through leadership and preeminence in aerospace systems and technologies and through our critical partnerships with advanced organizations from around the world. Areas covered include unmanned aircraft systems (UAS), scientific ballooning, education, and training in aerospace programs. Other areas covered include mission planning and operational support services to the aerospace and weapons testing industry and development of a wide variety of high quality, reasonably priced PSL avionics products. PSL operates the only T&E facility for UAS in the National Airspace System. The Information Science and Security Systems Department strives to provide our customers with the best available hardware and software solutions. Areas of expertise include systems development, including real-time telemetry data acquisition and processing systems; electronic countermeasures; modeling and simulation; and information technology. PSL conducts major RDT&E programs for NASA, the Army, Navy, Air Force, and intelligence agencies, as well as the commercial sector. PSL personnel participate in research and development programs conducted in laboratory facilities located on the campus as well as in government facilities, such as the White Sands Missile Range, New Mexico; Holloman Air Force Base, Alamogordo, New Mexico; The Joint National Test Facility at Shriver Air Force Base, Colorado; Goddard Space Flight Center, Wallops Island, Virginia; and the NASA Columbia Scientific Balloon Facility, Palestine, Texas.

Photo-Sonics, Inc.

Address 820 South Mariposa Street
Burbank, CA 91506
Business TSPI tracking systems and photo instrumentation and motion analysis software
Vice President of Operations Philip Kiel
ITEA Rep Raja Bamrungpong
Tel (818) 842-2141 x3208
Fax (818) 842-2610
E-Mail raja@photosonics.com
Web Site www.photosonics.com

Photo-Sonics designs and manufactures mobile optical tracking systems (MOTS) and produces a turn-key ready to use Time Space Position Information (TSPI) system for use by Test Ranges around the world. Photo-Sonics regularly interfaces best of class high speed, high resolution sensors in visible and IR bands with complimentary optical configurations providing a complete system for TSPI data capture. The Argus software supports remote operation of the MOTS with a high level GUI. We offer TSPI tracking systems in various sizes/price ranges supporting larger telescopes and heavier payloads. Photo-Sonics is the manufacturer of the hypervelocity tracking Mobile Multi-Sensor TSPI System (MMTS), Cine Sextant, Compact Tracking Mount (CTM), Nano-Sextant, and Super Radot. The range of tracking pedestal sizes starts with the Nano-Sextant, as a two man portable system, and goes up to the Cine-Sextant supporting up to 3,000 pounds of payload and 340 aperture telescopes. Photo-Sonics tracking systems are known for their high dynamic performance and accuracy. Photo-Sonics manufactures a range of instrumentation accessories including auto focus tables, ruggedized cameras, trigger control boxes, and target boards. Photo-Sonics also handles distribution of specialized photographic instrumentation including TrackEye Software, TEMA software, film scanners, and Lens Intensifiers through its subsidiary Instrumentation Marketing Corporation. Finally, Photo-Sonics is a manufacturer of Heads Up Display (HUD) cameras and video recording systems for fighter aircraft. We also manufacture high speed airborne cameras used on aircraft to document stores release.

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Power Ten, Inc.

Address 10422 NE 37th Circle
Kirkland, WA 98033
Business Professional, Technical, and Engineering, Services
President Harry C. Spies
ITEA Rep Mick Rovenstine
Tel (425) 284-1468
Fax (425) 284-1464
E-Mail info@powerteninc.com
Web Site www.powerteninc.com

Power Ten, Inc. is a Service-Disabled Veteran-Owned Small Business (SDVOSB) that provides professional, technical, and engineering services to government and industry customers. Power Ten, Inc. was founded and is managed by former Marines with extensive operational and management experience who share common proven leadership and business principles–QUALITY PEOPLE, WHO DELIVER QUALITY PRODUCTS, AT A FAIR AND REASONABLE PRICE. Our people, our partners, and our customers share a bond of trust, confidence and a commitment to actionable products. Our services are provided in the areas of Test & Evaluation (T&E); Command, Control Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR); Marine Air Command tactical and operational Unmanned Systems (UxS); Waste, Water & Energy; and the Marine Aviation Training System.

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Quadelta

Address 2450 Crystal Dr.
Suite 1020
Arlington, VA
22202-4812
Business Engineering, technical and administrative support to DoD
President Michael A. Schall
ITEA Rep Michael A. Schall
Tel (703) 413-3001
Fax (703) 413-3002
E-Mail business@quadelta.com
Web Site www.quadelta.com

Quadelta, Inc., is a veteran-owned, small business with headquarters in Arlington, Virginia. The company has a successful history providing a broad range of engineering, technical and administrative support to the Department of Defense (DoD) and other Federal Agencies. The company's business focus is in the following areas: Test & Evaluation; Safety & Readiness; DoD Acquisition Process System Engineering; and Modeling, Simulation & Data Visualization. Our customers include the Joint Chiefs of Staff; Deputy Assistant Secretary of the Navy, Safety; the Deputy Under Secretary of Defense, Acquisition, Technology and Logistics; Defense Information Systems Agency, Joint Interoperability Test Command; U.S. Transportation Command; Naval Air Systems Command; Naval Surface Warfare Center, Carderock Division; Office of Naval Research; and several large prime contractors. The Quadelta technical staff has extensive technical and management skills, coupled with Army, Navy, Air Force and Marine Corps operational program experience. All technical staff have a Bachelors degree, and over half have advanced degrees. Many of the Quadelta staff also have specialized technical education or certifications. Typical projects include the development and review of TEMPs, SEPs and associated acquisition documents, interoperability testing support, operational readiness and safety analysis, aviation safety program support, communications and outreach support, engineering risk assessments for major acquisition milestone reviews, acquisition workforce training, development of physics based models and simulations to support mission planning and test & evaluation efforts, development of unique processes for visualization of data, and software development and support using the Mathworks' MATLAB and Simulink products.

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Rockwell Collins, Inc.

Address 400 Collins Road NE
Cedar Rapids, IA 52498
Business Government and commercial contractor
President Clay Jones
ITEA Rep David McClure

Tel (319) 295-9610
Fax (319) 295-4317
E-Mail dmmcclur@rockwellcollins.com
Web Site www.rockwellcollins.com

Rockwell Collins is a pioneer in the design, production and support of innovative solutions for our customers in aerospace and defense. Our expertise in flight deck avionics, cabin electronics, mission communications, information management, and simulation and training is strengthened by our global service and support network spanning 27 countries. Working together, our global team of 20,000 employees shares a vision to create the most trusted source of communication and aviation electronics solutions, applying insight and foresight to help our customers succeed. Our aviation electronics systems and products are installed in the flight decks of nearly every air transport aircraft in the world. Our airborne and ground-based communication systems transmit nearly 70 percent of all U.S. and allied military communication. Whether developing new technology to enable network-centric operations for the military, delivering integrated electronic solutions for new commercial aircraft, or providing a level of service and support that increases reliability and lowers costs for aircraft operators throughout the world, we deliver on our commitments.

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Rotating Precision Mechanisms, Inc.

Address 8750 Shirley Ave. Northridge, CA 91324-3409
Business Antenna, Optical and Sensor Positioning Systems and Controls
President Daniel P. Flynn
ITEA Rep Mark H. Mathews
Tel (818) 349-8680
Fax (818) 772-7577
Web Site www.rpm-psi.com

Rotating Precision Mechanisms, Inc. (RPM), is a supplier of antenna, optical and sensor positioning systems and controls. RPM products service five main application areas, including test, evaluation and instrumentation (RF/Optical/Telemetry), military radar (land/air/sea), satellite communications (TT&C), unmanned aerial vehicles (UAVs) and air traffic control (ATC). RPM supplies commercial off-the-shelf (COTS) and non-developmental items (NDI) for both commercial and military uses. RPM, a small woman-owned business in operation since 1975, has a team with more than 300 man-years of direct engineering experience in pedestal/rotator and controls design. RPM uses modern computer technology for both design and manufacturing. RPM works as a major team member with government and commercial primes. A few typical products include CW Doppler, WRP, Midas, TARS, TCDL, STARS, ASR-II, Predator GDT, CBSP-FLV, GCA 2000, TARS, GEP, PSTAR, JTE, FTS, UCARS-V2, and TALS.

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RoundTable Defense LLC

Address 306 Garrisonville Road, Suite 201 Stafford, VA 22554
Business Test and Evaluation, Operations Research and Systems Engineering services to DOD.
President David L. Thomas, Managing Member
ITEA Rep David L. Thomas
Tel (540) 318-8247
Fax (866) 238-9408
E-Mail dave@roundtabledefense.com
Web Site www.roundtabledefense.com

RoundTable Defense LLC is a systems engineering services Company, specializing in Test & Evaluation, Operations Research and Systems Analysis. RTD delivers a unique, well-rounded team with expertise in both requirements analysis and operational test & evaluation. Systems engineering is the fundamental discipline and approach RTD uses in delivering many of its products. Developing requirements traceability, determining interfaces and identifying potential issues and risks are typical processes utilized by RTD analysts. RTD uses DOORS® and other tools to support these processes for customers. As an application of our Systems Engineering approach, our capabilities in Test and Evaluation is our strongest asset. Our skills in T&E management enable our customers to conduct effective verification and validation events with minimal impacts to program cost and schedule. RTD possesses advanced capabilities in Operations Research and Design of Experiments. Mission requirements analysis, map exercises, and simulation events enable our ORSAs to deliver timely studies and analytically supported recommendations. RTD uses analytic tools such as Value Modeling, Utility Theory, and Analytic Hierarchy Process to conduct trade studies and system-level assessments.

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SA-TECH

Address 1101 Mercantile Lane, Suite 200, Largo, MD 20785
ITEA Rep Geoff DeZavala
Tel 760-384-4843
E-Mail gdezavala@satechinc.com

SA-TECH is a mature, professional services company specializing in the provision of range operations & maintenance services supporting test & evaluation and training missions executed by a variety of DoD customers. As a mid-sized company, our customers benefit from our large business capabilities delivered with small business flexibility and responsiveness.

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Sabre Systems, Inc.

Address 46655 Expedition Drive Suite 200 Lexington Park, MD 20653
ITEA Rep Tom Brown
Tel (301) 863-5090
E-Mail trbrown@sabresystems.com
Web Site www.sabresystems.com

Sabre Systems, Inc., is a software and engineering services company headquartered in Warrington, Pennsylvania, with offices located in Lexington Park, Maryland; Central New Jersey; as well as Norfolk and Alexandria, Virginia. Sabre provides technical services to various state and federal agencies, including DoJ, DoD and other federal government programs, particularly in the areas of systems and software development, test and evaluation; system and database adminis-

tration; photogrammatics analysis, systems and applications programming; software testing; technical report production; graphic presentation generation; automated data processing; configuration management; technical library services; and LAN/ WAN operations. Sabre also supports government acquisition programs— both foreign military sales—and the military program managers; including budget and financial services, installation staffing, and management of development, production and operations facilities. At Sabre, best-in-class technology and methodology remain of paramount importance. But Sabre's people—dynamic, highly trained and quality-driven—make the decisive difference. Sabre Systems, Inc., is a trusted and ethical company committed to the success of its customers and employees. Sabre will be the company of choice.

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Science Applications International Corporation

Address Crystal Gateway #4, 200 12th Street S., Suite 1500 Arlington, VA 22202
Business Applied science & technology
ITEA Rep William T. Keegan
Tel (571) 220-7439
Fax (703) 414-3862
E-Mail william.t.keegan@saic.com
Web Site www.saic.com

SAIC's extensive technical capabilities support the full spectrum of test and evaluation (T&E) activities, including test concept development; test design and planning; test instrumentation and facilities; modeling, simulation and analysis for T&E; test conduct; and test data collection, processing and assessment. SAIC is currently providing T&E services to a number of major clients, including the Army Test and Evaluation Command, Air Force Operational T&E Center, Commander Operational Test and Evaluation Force, and the Office of the Secretary of Defense. SAIC also provides significant T&E support to Non Title 10 programs. SAIC has more than 41,000 employees in more than 300 offices worldwide, solving problems in areas related to information technology, national security, energy, environmental, transportation and health.

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SAIC

Address 47332 Eagan McAllister Lane P.O. Box 986 Lexington Park, MD 20653
Business Business Defense Contractor Business Unit
General Manager James Thigpen
ITEA Rep Tom Lydon
Tel (301) 863-2192
Fax (301) 863-8140
E-Mail thomas.w.lydon@saic.com
Web Site www.saic.com

SAIC is a FORTUNE 500® scientific, engineering, and technology applications company that uses its deep domain knowledge to solve problems of vital importance to the nation and the world, in national security, energy and environment, health and cybersecurity. The company's approximately 41,000 employees serve customers in the U.S. Department of Defense (DoD), the intelligence community, the U.S. Department of Homeland Security, other U.S. Government civil agencies and selected commercial markets. Headquartered in McLean, Va., SAIC had annual revenues of approximately $11 billion for its fiscal year ended January 31, 2011. SAIC's technical experts offer state-of-the art capabilities to develop land, sea, and air systems that equip the military, make our ports safer, and help fight the global war on terror. SAIC personnel help deliver customer-specific solutions in aviation; command, control, communications, computers, intelligence, surveillance, and reconnaissance; platform integration; and enterprise architecture and information technology for the DoD and adjacent markets. Specialized capabilities include—systems engineering and integration; information technology and assurance; test and evaluation (T&E); logistics services; and program and financial management. SAIC's extensive technical capabilities support the full-spectrum of T&E activities, including test concept development; test design and planning; test instrumentation and facilities; modeling, simulation and analysis for T&E; test conduct; and test data collection, processing, and assessment.

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Scientific Research Corporation

Address 2300 Windy Ridge Parkway Suite 400 South Atlanta, GA 30339
Business Advanced Technology, Services & Products
President Mike Watt
ITEA Rep Dr. Mark Brown
Tel (256) 971-9880
Fax (256) 971-9890
E-Mail mdbrown@scires.com
Web Site www.scires.com

Scientific Research Corporation (SRC) is an advanced technology engineering company founded in 1988 that provides innovative products, services, and solutions to the U.S. Government, international market, and private industry. SRC's business activities encompass test and evaluation, instrumentation systems, networks, wireless communications, information technology, signal intelligence, digital and radar signal processing, and modeling and simulation. The company's corporate divisions include Simulation, Test and Instrumentation (STI), Communications, Networks, and Electronics (CNE), and Integrated Systems and Solutions (ISS) that together have approximately 1500 specialists located worldwide.

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Sierra Lobo, Inc.

Address 102 Pinnacle Drive Fremont, OH 43420
Business Engineering, Test, and Technical Services
President George Satornino
ITEA Rep Frankie Stewart
Tel (256) 895-9112
Fax (256) 489-0942
E-Mail fstewart@sierralobo.com
Web Site www.sierralobo.com

Sierra Lobo is a provider of choice for technical management, engineering, scientific and technical services in support of research and development, test and evaluation, systems integration, and complex facilities operations. Test and evaluation is a critical part of our core competencies. Our engineers and technicians have expertise in test planning, experiment design, hardware and software design and development, model integration, data acquisition and reduction, reporting and documentation, and technical support. We offer a state of-the-art engineering, fabrication, and testing facility in Milan, Ohio. We are a Small Disadvantaged Business, AS9100 and ISO 9001:2008 registered and have obtained CMMI, level 2 certification. Using proven methodologies, we have performed test and evaluation services on Launch Vehicle and Spacecraft Structures; Aircraft Structures, Engine, and Components; Missile and Aviation Systems; Space Flight Hardware; Advanced Air- Breathing, Rocket, and Chemical Propulsion Systems; Communications and Electronics; Sensors and Instruments; Materials and Sensors; Thermal Protective Systems for Spacecraft; Celled Fuels and Densified Propellants; and Cryogenic Fluids.

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SPARTA, Inc.

Address:	401 Diamond Drive Huntsville, AL 35806
Business	Provide Test, Engineering, Analytical and M&S technical support to the Federal Government.
ITEA Rep	Larry Pigue
Tel	(256) 837-5200
Fax	(256) 830-0287
E-Mail	larry.pigue@sparta.com
Web Site	www.sparta.com

SPARTA, Inc. has over 25 years of experience supporting major DoD and National intelligence systems with expertise in: Systems Engineering, Integration and Test; Training & Simulation, Mission Support; Cybersecurity; Information Assurance; Scientific & Technical Intelligence; Signal Intelligence; and Reengineering and Program Life Extension/Revitalization. SPARTA is the largest provider of Test and Evaluation SETA services to the Missile Defense Agency. These services assist the government in executing their responsibilities in Ballistic Missile Defense System flight and ground test planning, design, execution, analysis and reporting, documentation, test policy, risk management, test reviews, acquisition management, programmatics, support to the Warfighter and Operational Test communities.

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Spiral Technology, Inc.

Address	244 East Avenue K-4 Lancaster, CA 93535
Business	Aerospace Engineering Services, Software Products & Sales, EW/ Weapon Systems Test Engineering, Test Range Operations, RF Shielding/Acoustic Measurements and Test Facility Support
President	Archie Moore
ITEA Rep	Curtis Curry Mike Scardello
Tel	(661) 723-3148
Fax	(661) 723-1379
E-Mail	curtis.curry@spiraltechinc.com mike.scardello@spiraltechinc.com
Web Site	www.spiraltechinc.com

Spiral Technology, Inc. is a veteran-owned, small business providing professional engineering services and technology solutions to DoD, NASA, non-DoD and foreign operations through a full spectrum of R&D/T&E technical services, instrumentation design, test program engineering, program analysis and trade studies. Spiral provides engineering and technical assistance in support of the vehicle systems analysis and design activities of the AFRL Propulsion Directorate. At the US Army Yuma Proving Ground, Spiral personnel support Test Range Operations, airborne Weapon Systems Test Integration Lab (WSTIL) design and development, telemetry infrastructure upgrades, and UAV test instrumentation package design. Spiral supports/performs electronic warfare and avionics testing, with subject matter experts in EW simulations/systems test, antenna pattern measurements, EMI/EMC measurements and Comm/Nav/IFF hardware simulations. Spiral's RF Shielding and Acoustic Measurements Operation supports design and analysis of shielded enclosures and secure facility isolation characteristics for commercial and government entities. Spiral's Open Telemetry Interactive Setup (OTIS™) product family is the only complete set of software tools and applications specifically designed to support TMATS easily and cost effectively and has been supporting the TMATS since its inception in 1993.

Spectrum Sensors

Address	2236 N. Cleveland-Massillon Rd. Akron, Ohio 44333
Business	Inertial sensors, test & measurement equipment
General Manager	Don Gudaitis
ITEA Rep	Mark Hetrick
Tel	(330) 659-3312
Fax	(330) 659-3286
E-Mail	Mark.Hetrick@apitech.com
Web Site	www.specsensors.com

Spectrum Sensors Precision Inertial Products, formerly Summit Instruments (now part of API Technologies), provides inertial sensors and electronic test and measurement solutions for demanding military, aerospace, research and industrial applications. Products include:
Inertial Measurement Systems (IMS): integrated, self-contained 6 DOF and TM systems used in stores separation and captive carry testing that can be installed in under 20 minutes. User-configurable sensor ranges, IRIG telemetry, and transmitter frequencies are included. Data from external sensors can also be received.
Digital accelerometers: unrivaled for flexibility and ease of use. G range, bandwidth and serial communication rates are user-changeable with just a few clicks in the free software provided.

Analog accelerometers: adaptable and affordable, built to user-specified g ranges and bandwidths. Small, rugged, and reliable, these analog accelerometers fit any budget.
Analog rate gyros: cover rotational measurement needs from ±150°/sec to ±20000°/sec. They are temperature compensated over the 40 to +85°C temperature range. Full application support, plus NIST traceable calibration and repair services.
Standard products and custom solutions. For application assistance or product information, contact Spectrum Sensors in Akron, Ohio.

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SURVICE Engineering Company

Address	4695 Millennium Drive Belcamp, MD 21017
Business	Survivability & safety analyses & testing, weapon system effectiveness analyses & testing, & computer M&S products & services
President	Jeff B. Foulk
ITEA Rep	Chris Susman
Tel	(410)-273-7722
Fax	(410)-272-6763
Web Site	www.survice.com

A nationally recognized specialist in combat system survivability, weapon system effectiveness, and system safety, the **SURVICE Engineering Company** is a small business that's provided military and industry customers with high-quality analytical products and services for more than 25 years. During this time, we've continued to grow in size, capability, and national recognition; however, we've never lost sight of our original mission—to provide safe, survivable, and effective combat systems for U.S. military personnel. Our staff of more than 250 engineers, mathematicians, physicists, computer scientists, and technical specialists is located at eight offices near major DoD T&E facilities across the country. We are known for our four core capabilities: studies and analysis, test and evaluation, modeling and simulation, and information technologies; and our expertise across these areas allows us to provide comprehensive and customized engineering solutions for each project we support. Our T&E-related work involves ballistic and nonballistic developmental, operational, and live fire test support. In addition, we continue to expand our services and capabilities in numerous specialized technology areas, including metrology (our innovative and integrated 3-D measurement, modeling, and application development services); Rayforce™ (our highly optimized, real-time raytracing software to provide high-precision, high-speed computer-generated imagery); Fireworks (our unique team of experts and tools to understand, assess, and mitigate the threat of fire to personnel and equipment); information assurance (our integrated efforts to address the need for interdependent systems to survive, operate, and succeed in information warfare environments); and system safety (our safety-related analytical studies, program planning, and testing/verification services).

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SYMVIONICS, Inc.

Address	488 E. Santa Clara Street Ste 201 Arcadia, CA 91006
Business	Flight Test Engineering, Modeling & Simulation
President	Larry Barraza
ITEA Rep	Rich Weeks
Tel	(626) 305-1400
Fax	(626) 305-8860
E-Mail	rweeks@symvionics.com
Web Site	www.symvionics.com

SYMVIONICS provides test and evaluation engineering and technical support services for the testing of aircraft systems. Primary customers include the Air Force Flight Test Center (AFFTC), Edwards Air Force Base (AFB), California, and the Air Armament Center (AAC), Eglin AFB, Florida. Core competencies include modeling and simulation, as well as real-time and post-flight analysis software systems for flight test operations. SYMVIONICS' core products include the IADS® and DeltaSym®. The IADS® product provides more efficient Mission Control Room (MCR) data analysis, increased test safety and decreased post-flight data processing time. IADS® has been installed at the AFFTC, AAC, NTTR, Vandenberg AFB, Hill AFB, NAVAIR (Patuxent River, Maryland), and Fort Rucker, AL; and at many other aerospace prime contractor facilities worldwide. DeltaSym® is a deployable, containerized, high-fidelity, reconfigurable flight simulator that can be transported by air, sea or ground with ease. DeltaSym® is a multi-aircraft simulation platform that can be quickly changed from one single-seat fighter aircraft configuration to another. Currently, F-16C Block 50 and F-35 (Joint Strike Fighter) cockpits have been developed.

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Systems Development Center (SDC), CSIST

Address	P.O. Box 90008-6-12 Lung-Tan, Taiwan 325, R.O.C.
Business	Research & development on advanced weapon systems
President	Dr. Yu-Pen Su
ITEA Rep	Chien-Chun Ho
Tel	1 (886) 3-4455008
Fax	1 (886) 3-4452120
E-Mail	vicor.utopia@msa.hinet.net

The **Systems Development Center SDC,** founded in January 1983, is one of the divisions in Chung-Shan Institute of Science and Technology (CSIST, Taiwan, R.O.C.). The mission of the SDC is to draft and propose full-scale project plans for the development of advanced weapon systems and to execute and integrate all the projects as well, covering a broad spectrum of R&D, manufacturing and production, development and logistics. Over the past 25 years, the SDC has accumulated great experience and expertise in the development of various weapon systems, which range from project management, system engineering, quality assurance, logistics and maintenance, simulation, war-games, environmental tests, missile-relevant technologies and more. The SDC owns different laboratories and facilities for missile simulation, war-games, human factor engineering, environmental testing, missile and radar open air tests. The SDC was certified to ISO 9001:2000 in August 2002.

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Systems Engineering & Management Company

Address 1430 Vantage Court
Vista, CA 92081
Business Telemetry, Law Enforcement & Surveillance Wireless RF Products
President William Tincup
ITEA Rep Doug O'Cull
Tel (760) 727-7800
Fax (760) 727-5200
E-mail doug.ocull@semco.com
Web Site www.semco.com

Systems Engineering & Management Company (SEMCO) was founded in 1984 specializing in developing and providing wireless RF products to Department of Defense, Law Enforcement and Intelligence Agencies. SEMCO's products are recognized as the premier products in the industry based upon system design, performance, reliability and customer support. Our telemetry products are used by all of the major DOD flight test facilities and most major military system integrators. Our surveillances systems are used by law enforcement, military and intelligence agencies across the United States and our robotic systems provide superior support domestically and internationally to our military community. SEMCO maintains Engineering and Customer Support facilities on both the West Coast (Vista, CA) and East Coast (Ocala, FL) to ensure our customers receive world class service at all times.

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Systems Testing Excellence Program at the FedEx Institute of Technology

Address Fogelman College Building, Innovation Drive, University of Memphis
Memphis, TN 38152
Business Systems Testing Research, Consulting and Training
President Dr. Jasbir Dhaliwal, Director
ITEA Rep Dr. Robin Poston, Associate Director
Tel 901-283-9988
Fax 901-678-4151
E-Mail step.memphis.edu
Company URL www.step.memphis.edu

The Systems Testing Excellence Program (STEP) of the FedEx Institute of Technology at the University of Memphis was started in 2006 to strengthen both the science and industry best practices of testing and evaluation. It is a major applied interdisciplinary research initiative involving information systems, computer science, and computer engineering scholars under the umbrella of the FedEx Institute of Technology. In tandem with industry partners, STEP researchers focus on with building up applied research and curricular competencies at the University of Memphis to foster thought leadership in the science of systems testing and evaluation.
STEP defines systems testing and evaluation as a strategic and interdisciplinary area of interest encompassing all aspects of the testing and evaluation of information and related technologies including hardware, software, network, requirements and business rule test and evaluation. At a theoretical level it encompasses all forms of validation and verification of technology applications using a systems theoretic approach to ensure successful development and deployment in practical settings. STEP has a unique relation with the Software Quality Assurance group at FedEx Corporation serving as its research and training partner.
STEP undertakes customized test audit and methodology research for industry partners by focusing on the toughest challenges facing test and evaluation organizations. It also offers five-day Foundational and ten-day Advanced Certification in Systems Testing programs to provide a research-based and rigorous comprehensive survey of the latest state-of-the-art thinking in testing and evaluation. The goal of the certification programs is to provide the attendees with a solid working knowledge of the major aspects of testing and evaluation so that they can successfully work as testers and evaluators or, as other development lifecycle stakeholders, interact with testers and evaluators more effective.

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Syzygy Technologies, Inc.

Address 1450 Frazee Rd., Suite 701
San Diego, CA 92108
Business IT & Engineering Services for DoD
President Keith Sutton
ITEA Rep Keith Sutton
Tel (619) 297-0970
Fax (619) 297-0975
Web Site www.syzygy-tech.com

Syzygy Technologies is a veteran-owned small business headquartered in San Diego, California. In 2008, Syzygy had $13.1 million in revenue from its eight prime contracts and numerous subcontracts with various government agencies and business partners. Syzygy primarily provides information technology (IT) and engineering services support to DoD. Syzygy has multiple prime contracts with the Space and Naval Warfare Systems Command (SPAWAR) and SPAWAR Systems Center Pacific to provide test and evaluation (T&E), systems integration, networking and software development support on numerous intelligence (I3) and command and control (C2) systems for the Navy. Syzygy provides all ranges of T&E and IV&V services to include test planning, test documentation, and test execution in all phases of testing (development test, operational test, etc.). Syzygy has also developed several automated test tools (JFATE, MessKit) that automate the testing process for its customers.

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TAPE LLC

Address 101 Bata Blvd, Suite 102
Belcamp, MD 21017
ITEA Rep John C. Lawhorn
Tel 443-327-6366
Cell 443-252-1285
E-Mail JLawhorn@tape-llc.com
Web Site www.tape-llc.com

TAPE, LLC is a service-disabled veteran-owned, woman-owned, small business (SDVO/WOSB). TAPE's

expertise includes Program Management, Acquisition Support, Information Technology, Logistics, Operational Readiness, Training, Modeling and Simulation, Test and Evaluation Support, and Cyber Security/Warfare/Operations. Over the years, TAPE has been recognized by organizations like Inc. 500 and Washington Technology for its achievements within the government contracting sector. For more information about TAPE, please visit www.tape-llc.com.

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TASC, Inc

Address 4805 Stonecroft Blvd, Chantilly, VA 20151
Business Advisory Services
President and CEO David Langstaff
ITEA Rep Terry Wilson
Address 1993 Frontage Road, Suite 201 Sierra Vista, AZ
Tel (520) 417-8805
E-Mail Terry.Wilson@tasc.com
Web Site www.tasc.com

Founded in 1966, **TASC, Inc.** is a leading provider of advanced systems engineering, integration and decision-support services to the Intelligence Community, Department of Defense and civilian agencies of the federal government. For more than 40 years, TASC has partnered with our customers toward one goal—the success of their missions. Our broad portfolio of services includes mission operations, analysis and engineering; system and policy analysis; program, financial and acquisition management; enterprise engineering and integration; advanced concept and technology development; test and evaluation; independent verification and validation; and cybersecurity. With more than 5,000 employees in 40 locations, TASC generates $1.5 billion in annual revenue. For more information and career opportunities, visit our website at HYPERLINK "http://www.tasc.com" www.tasc.com.

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TRAX International Corporation

Address 8337 W. Sunset Rd, Suite 250 Las Vegas, NV 89113
Business Test and evaluation services; engineering, analysis, and information technology services; and logistics and maintenance information services.
President F. Craig Wilson
ITEA Rep Charles R. Garcia
Tel (702) 216-4455
Fax (702) 455-1263
E-Mail cgarcia@traxintl.com
Web Site www.traxintl.com

TRAX International Corporation (TRAX) is a large, 100% employee-owned company with 2,200 employees throughout the U.S. and various international locations. TRAX provides a wide variety of services to the U.S. Government and commercial clients. TRAX offers the following capabilities:
Range Operations Services—Provides maintenance of targets, test vehicles, electronics, munitions, and optical & geodetic instrumentation. Range operations are provided in arctic, tropical, and desert regions and include test & development engineering, telecommunications engineering, environmental engineering, and human factors engineering.
Engineering Services—TRAX provides engineering solutions to Government, commercial, and industrial customers around the world. Specialties include engineering, procurement & construction services; front-end engineering & design services; project management & execution services; and engineering analysis & NFPA 85 consultation.
Enterprise Technology Solutions—TRAX provides dynamic and responsive services on information assurance, software engineering, situational awareness, and consulting to improve business efficiency.
Simulator Systems—TRAX is the world's leading supplier of high-fidelity fossil plant operator training simulators. Currently used in more than 150 power plants worldwide, every simulator is designed and tuned to meet ANSI/ISA-77.20 standards. NewTec a wholly owned subsidiary of TRAX International, provides comprehensive range services to White Sands Missile Range.
NewTec—is the Mission Support Services contract with an array of test and evaluation services, including engineering design and analysis, software development, technical operation and maintenance of equipment and instrumentation used in T&E environments (C4I, optics, radar, telemetry, timing and other systems), test planning, nuclear effects and electromagnetic testing, fabrication, environmental services, and other mission support services.

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Trideum Corporation

Address 4946 Research Drive, NW Huntsville, AL 35805-5906
Business Professional engineering support services
President Van Sullivan
ITEA Rep Van Sullivan
Tel (256) 704-6120
Fax (256) 704-6101
E-Mail vsullivan@trideum.com
Web Site www.trideum.com

Trideum Corporation is a privately owned and operated small business headquartered in Huntsville, Alabama, with offices in Aberdeen, Maryland and Leavenworth, Kansas. The company was founded in 2005 and now has approximately 67 employees. The company has built upon extensive experience in the design, development, integration, and sustainment of technical and software solutions that support the Department of Defense test and evaluation community dating back to 1993. Trideum specializes in improving the effectiveness and efficiency of system acquisition by integrating test and evaluation technology solutions and services in the areas of modeling and simulation, operations research / systems analysis, and tailored systems engineering. Trideum has a broad range of Engineering expertise gained through hands-on program execution. The expertise ranges from technology research and development to engineering analysis and design. Test and evaluation support spans testing at all levels to include component, subsystem, system, and families of manned and unmanned systems in areas such as live and virtual distributed test resource development and integration, architecture design and implementation, knowledge management, human factors engineering, test execution and analysis support, and strategic planning. Trideum Corporation has recently extended these capabilities to prototype development of target simulators for

test and training ranges and an operator interface and knowledge base for a ground vehicle system demonstrating sensor data fusion technologies intended for Counter Improvised Explosive Device operations in the route clearance mission. Trideum has several engineering disciplines and specialties: aerospace, computer, database, electrical, mechanical, network, operations research, software, and systems.

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Weibel Scientific A/S

Address Solvang 30
3450 Alleroed, Denmark
Business Electronic measurement equipment
President Peder R. Pedersen
ITEA Rep Peder R. Pedersen
Tel (+45) 7010-85-11
Fax (+45) 7010-65-58
Web Site www.weibel.dk

Weibel Scientific A/S is a world-wide manufacturer of scientific measurement equipment for testing and experimental applications. Its principal customers are Army, Navy and Air Forces; test ranges; research and development establishments; ordnance industries; and security forces. Products include radar-based equipment ranging from small compact Doppler radar systems to high-performance, on-line, 3-D Doppler radar tracking systems for long-range (1,000 km) flight analysis. Weibel Doppler radar systems are based on the most up-to-date radar, computer and software technologies, and incorporate such unique features as self-calibration and multiobject tracking. Weibel Scientific manufactures all mechanical parts, electronics and software in-house.

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Westech International, Inc. (WESTECH)

Address 2500 Louisiana Blvd NE, Suite 325
Albuquerque, NM 87110
Business Professional, engineering, Technical, and administrative support services, including T&E, Logistics, and IT
CEO/President Betty P. Chao, PhD
ITEA Rep Tom Cavalli
Tel (505) 888-6666, x124
Fax (505) 837-9424
E-Mail tcavalli@westech-intl.com
Web Site www.westech-intl.com

WESTECH is a woman-owned small business headquartered in Albuquerque, New Mexico. WESTECH was organized by Dr Betty Chao, President/CEO, for the express purpose of providing quality services to Federal agencies and commercial enterprises. During its 17 years in business, WESTECH has developed extensive experience and expertise in test and evaluation (T&E); test range support; space systems engineering; space mission and aircraft operations; program management; information technology/information management (IT/IM); cyber and information security; logistics support; operations and maintenance; personnel security; and engineering, professional, technical, and administrative support services. WESTECH's customers have included the Departments of Defense, Energy, and Commerce; other Federal agencies; and commercial enterprises. WESTECH has a staff of over 250 employees located at 16 locations in 12 states. In the T&E area, WESTECH has provided developmental and operational T&E support for the Air Force Operational Test and Evaluation Center, Army Test and Evaluation Command (including the Army Evaluation Center, Developmental Test Command, and Operational Test Command), Air Force Space Command (Space and Missile Systems Center), Air Force Air Combat Command, Air Force Materiel Command (Electronic Systems Center), the Missile Defense Agency, and the Joint Interoperability Test Command. WESTECH has provided test and training range support services at the White Sands Missile Range, Yuma Proving Ground, Electronic Proving Ground, and the east and west coast Navy ranges based in NAS Fallon, NV, and MCAS Cherry Point, NC. WESTECH is ISO 9001:2008 certified and has a 98% average performance rating on its award fee contracts over the life of the company.

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Wyle

Address 1960 E. Grand Ave., St. 900
El Segundo, CA 90245
Business Engineering, science and research services
President George Melton
ITEA Rep Brent Bennitt
Tel (310) 563-6800
Fax (310) 563-6850
E-Mail service@wyle.com
Web Site www.wyle.com

As one of the nation's leading providers of specialized engineering, scientific, and technical services to the Department of Defense, NASA, and a variety of commercial customers, **Wyle** serves its customers in the areas of test and evaluation; systems engineering and information technology; life cycle and acquisition program management; life sciences research; space medical operations and engineering; and qualification testing for natural and induced environments. The company is headquartered in El Segundo, Calif. and employs approximately 5,000 employees at more than 50 facilities nationwide. Wyle's areas of expertise include: Test and evaluation, Systems engineering, Information technology, Life cycle management, Acquisition program management, Telemetry and data systems, Nondestructive inspection, Space launch and operations support, Foreign Military Sales case management, Test pilot and test aircrew services, Life Sciences research, Space medical operations, Science and mission integration, Space flight hardware development and fabrication, Clinical and occupational health services, Testing services, including dynamics, climatics, fluid flow, and structural, Design and construction of advanced test equipment, Acoustics research and consulting, Aerospace cost estimating and analysis Earned Value Management (EVM). ❑

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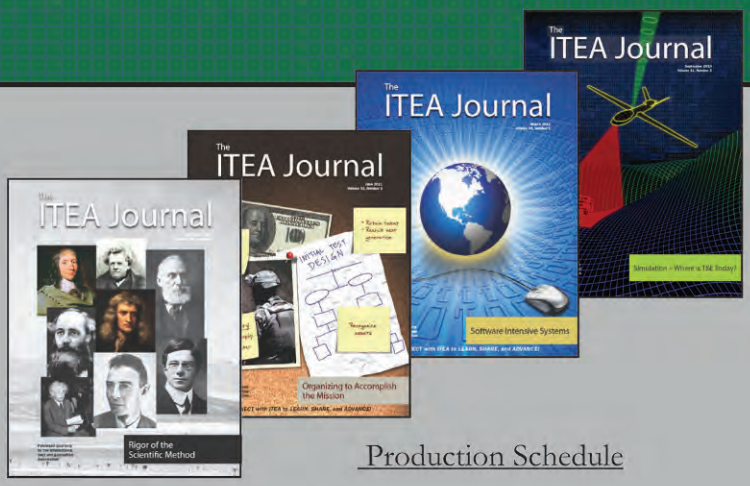

The ITEA Journal Ad Sales Contact

Bill Dallas
Ph: 703.631.6226
wdallas@itea.org
4400 Fair Lakes Court,
Suite 104
Fairfax, VA 22033
Fax: 703.631.6221

Journal Specifications

Trim Size: 8 1/2 x 11 inches. Journal trims 1/8 inch off top, bottom, and outside edge. Live matter should be a minimum of 1/2 inch inside the trimmed edges, and a minimum of 1/2 inch should be allowed for the bind.

1/2-page ad
(Lateral): Width: 6 inches; Height: 4 and 1/8 inches. (Vertical): Width: 3 inches; Height: 9 inches.

1/4-page ad
Width: 3 inches; Height: 4 and 1/8 inches

Graphics should be a minimum of 350 dots per inch. Add 1/4 inch for bleeds.

Formats: We accept TIFF or EPS format for both Macintosh and PC Platforms. We also accept files in the following native application formats: Adobe Acrobat (.pdf), Adobe Photoshop (.psd), Macromedia FreeHand (.fh), Canvas (.cvs), InDesign (.id), QuarkXPress (.qxd), Illustrator, (.ai) CorelPoint (.cdr), PowerPoint (.ppt), and Pagemaker (.pmd).

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Disclaimer: All claims for errors in advertisements must be made in writing and received within ten days of publication and will be considered only for the first insertion of the advertisement.

Production Schedule

Issue	Space Reservation	Ad Material
March	1/12	1/25
June	4/12	4/25
September	7/12	7/25
December	10/12	10/25

AD Type	ITEA Partner Rates (ITEA Corporate Members, Sponsors, and Exhibitors)			Standard Rates		
	1x	2x	4x	1x	2x	4x
Cover 2	$2500	$2200	$2000	$3000	$2700	$2500
Cover 3	$2420	$2120	$1920	$2900	$2600	$2400
Cover 4	$2740	$2440	$2240	$3300	$3000	$2800
	4-Color					
Full page	$2100	$1800	$1600	$2500	$2200	$2000
1/2 page	$1700	$1400	$1200	$2000	$1700	$1500
1/4 page	$1300	$1000	$ 800	$1500	$1200	$1000
2-page spread	$3300	$3000	$2800	$4000	$3700	$3500
	Black/White					
Full page	$1620	$1320	$1120	$1900	$1600	$1400
1/2 page	$1300	$1000	$ 800	$1500	$1200	$1000
1/4 page	$ 900	$ 600	$ 400	$1000	$ 700	$ 500
2-page spread	$2580	$2280	$2080	$3100	$2800	$2600

GET CONNECTED...*to* ADVANCE!

International Test & Evaluation Association

Your CAREER Connection for:

- Promoting YOUR Profession
- Demonstrating YOUR Commitmen to Excellence
- Investing in OUR Future Workforce

INDUSTRY PUBLICATIONS

"We are proud to have had a longstanding relationship with ITEA which has included corporate membership and executive support for ITEA's operations, as well as sponsorship for its numberous professional and educational events. The ever increasing complexity of the T&E environment merits an independent entity such as ITEA as the world in which we live progressively transitions to the development of autonomous systems for our survival."

Scientific Research Corporation
a Corporate Member since 1992

INDUSTRY AWARDS

- MATTHEWS AWARD
- SPECIAL ACHIEVEMENT AWARD
- CROSS AWARD
- PUBLICATIONS AWARD
- TECHNICAL ACHIEVEMENT AWARD
- ENERGIZER AWARD

ACADEMIC PARTNERSHIPS

GET CONNECTED...*with* ITEA!

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