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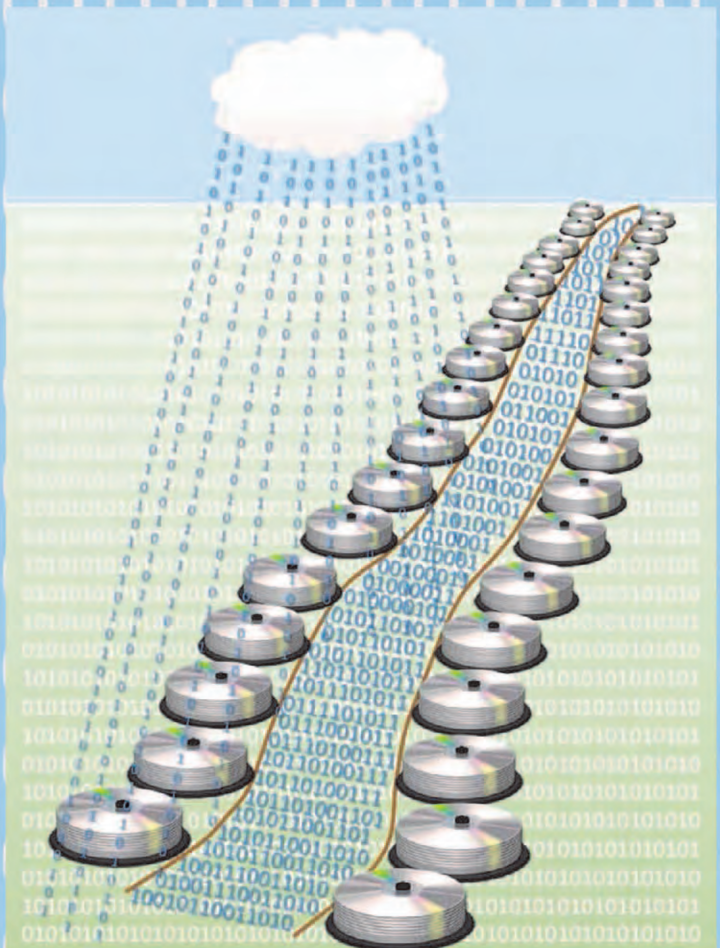

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Test and Evaluation
Association

Drowning in Data, Thirsty for Information

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TECHNICAL ARTICLES

DEPARTMENTS

ON THE COVER: Collecting data that can be transformed into information used to make decisions is one of the primary purposes of test and evaluation. Two challenges face test planners: What data to collect and how to analyze what has been collected.

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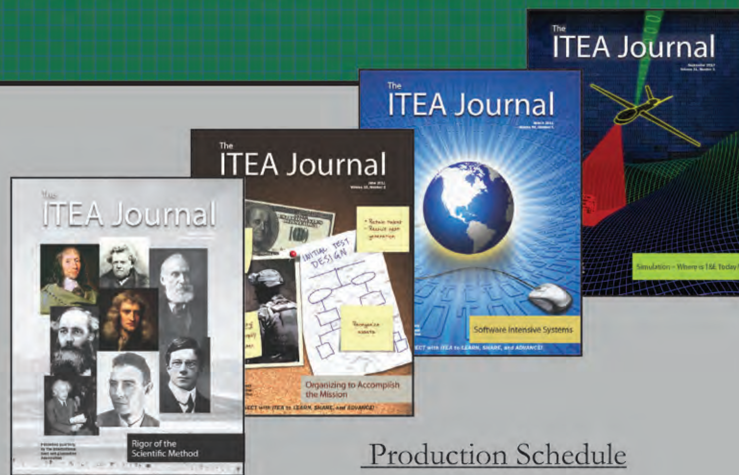

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President's Corner

ITEA Journal 2012; 33: 111

Have you heard the old adage, "the only constant is change?" It sounds trite, but it does seem to hold true. We live in an age where things are constantly changing and sometimes it becomes overwhelming. The same is true of our test and evaluation (T&E) environment. I think back to when I began working in T&E some 25 years ago supporting the Air Force. I had a dual 5 ¼" floppy "clone" on my desk, and I was a rarity. I had access to an IBM PDP-11 that we used for data collection and analysis. It used large reel to reel tapes that we had to carefully load prior to each test. My data was delivered as stacks of dot-matrix printed paper that I scoured for hours (or days) looking for specific performance data. It wasn't a lot of data, usually only a dozen or so key parameters I needed to evaluate. But the task was, at times, overwhelming. We have replaced the 5 ¼" floppies with Terabyte hard drives and flash memory. The old clunky PDP-11s are replaced by laptop computers with more computational power than We ever dreamed of in the 80's. And, if that is not enough, we have teraflop supercomputers that are available to us through the High Performance Computing (HPC) centers around the country. Data is pushed or pulled over the internet, rather than being delivered on reams of paper. Data reduction is many times performed by sophisticated algorithms and intelligent agents that search for anomalies, key performance parameters, or whatever we ask them to analyze. Yet the task of deciphering all this data has not changed. There is still a human in the loop, looking for that key data they need to provide the "E" in T&E. It can still be overwhelming.

Mark Brown, Ph.D.

And what we are testing has changed radically in the last 25 years. Systems are no longer stand-alone. Every system is interconnected. Datalinks are key to system operation and survivability. We now have this thing called "cyber" that everyone is trying to figure out how to test. The number of data sources we must draw on has expanded at the same rate as technology. Moore's Law fast at work. So what do we do?

Well, as a T&E community, we continue to evolve, to reinvent ourselves. We update technology and better equip our workforce. We have an obligation to those we serve, whether it is soldiers, sailors, and airmen, or pilots and air traffic controllers, or the commercial consumer, to be looking to the future. We must be looking now to understand the systems that must be tested in 5, 10, and 15 years. What do the emerging technologies look like and how do we need to equip our labs, ranges, and, most importantly, our workforce to test these technologies?

ITEA offers many opportunities for us to discuss how we must evolve and change. We have some of the best conferences and workshops, like the Instrumentation Workshop, the Annual Technology Review, and our new Cyber T&E workshop, where we can come together as a community, interact with key decision makers, and look at how we can address these challenges. Our Annual Symposium brings together senior U.S. and international leadership from government, academia, and industry to discuss relevant challenges to our community. This is a real opportunity to understand from the highest levels where the T&E community is going. In addition, our tutorials and training seminars provide a chance to improve and prepare our workforce to meet these challenges. But, as I have said before, maybe our most powerful opportunity to understand how this changing environment will impact us is through our local chapters. Who can better help us to understand the unique nature of T&E than our compatriots working on the same issues we face at the local level.

T&E will continue to evolve as technology does. It will be fascinating to see what someone starting out today writes about how they used antiquated Terabyte hard drives to store data 25 years from now! I look forward to seeing you at one of our many ITEA events!

Issue at a Glance

ITEA Journal 2012; 33: 112

Drowning in Data, Thirsty for Information. 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 test and evaluation. 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.

Eileen Bjorkman, Technical Adviser at the Air Force Flight Test Center (AFFTC), Edwards Air Force Base, echoes the consistent AFFTC theme of scientific rigor in test and evaluation in her *Guest Editorial*. She tempers the message with one important proviso, that "*…scientific rigor in testing should be driven by the science of the system under test and the test environment, not the statistics used to help plan the test and analyze the data.*" In *Historical Perspectives* Dr. James McCracken, Founder, Chief Scientist and Vice President of The Design Knowledge Company, presents a vivid life or death example of the solution hidden in a maze of data.

Dr. Lauren Mailman *et al.* outline the importance of and a scalable and extensible approach for automating steps in the test data process. They also outline requirements for the underlying data management system. Dae Hong *et al.* report progress by the Department of Defense Target Control Steering Group in achieving the goal of "… the operation of any target on any test range …" Interoperability is being approached through a collection of standardized interfaces and results from two demonstrations are presented. Jonathan Nolan *et al.* describe best practices developed for the Terminal High Altitude Area Defense (THAAD) missile defense test and lessons learned from the initial operational test and evaluation of a system that produced 15 terabytes of data.

Frank Alvidrez explains the growth of test complexity resulting from networked weapon systems and an approach using model based systems engineering and related tools to systematize and simplify testing. M. R. Srikrishnan and Dr. Ramesh Chandran Nayar, Anna University Chennai in Madras, India describe fundamental examinations of structural characteristics of yarns to understand the ultimate performance of military products (uniforms, body armor, helmets, etc.) made from them. Of particular note is that the cumulative effect of strain in processing the yarn impacts product quality. Finally, Andrew Brock of The Defence Science and Technology Organisation, Edinburgh, South Australia notes the absence of experience in operational testing of service oriented architectures and emphasizes the importance of incorporating the requirements of all end users.

The topic of data is vast, encompassing acquisition, storage, archiving, access, validation, exploitation, and visualization; data as a service; cloud computing; metadata syntax and semantics; data and sensor fusion; data preservation; distributed and non-relational databases, among other topics. The purpose of test and evaluation is risk reduction and to support decision making, both accomplished with data, the core of our business. We read about the Department of Defense priority in Data to Decisions, about the need to address Big Data, and we see bold evidence of the commercial value of data manifested in Google, Yahoo and elsewhere. As the Publications Committee prepared this issue, however, we became painfully aware of how little the importance of data in our business is reflected in investments to improve the tools, processes, and interoperability among test organizations and even within them.

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ITEA Journal 2012; 33: 115–118

The Science of Testing: It's Not Just About Statistics!

Eileen Bjorkman
Air Force Flight Test Center, Edwards Air Force Base, California

Collecting data that can be transformed into information used to make decisions is one of the primary purposes of test and evaluation. Two key challenges facing test planners are (a) determining what data to collect (e.g., how much, under what conditions, to what degree of accuracy and precision, etc.) and (b) how to analyze the data once it has been collected. Of course, the data collection and analysis must be done in a resource constrained environment; there is never enough funding, time, or people to conduct the perfect test.

To help address the challenge of conducting test and evaluation in a resource-constrained environment, much has been written in the past several years regarding the use of statistics (in particular, design of experiments [DOE]) to improve both test and evaluation planning and analysis. Continuing this trend, the September 2011 ITEA Journal was devoted to the theme "Rigor of the Scientific Method." Articles included many applications of scientific techniques to a variety of test and evaluation problems. These techniques included DOE, the use of physics-based models, and maximum likelihood methods, just to name a few. However, the use of these techniques by themselves does not turn testing into a science.


Eileen Bjorkman

Most of the techniques discussed in the ITEA Journal articles are already employed by the Air Force Flight Test Center (AFFTC). At the AFFTC, we have always focused on scientific principles to guide our flight test planning, execution, data analysis, evaluation, and reporting processes. The recent shift to an emphasis on incorporating statistical techniques does not change these scientific principles. Statistics is merely another instrument in our test toolbox to assist with the test process; the use of statistics does not replace the good engineering judgment required to use the results of a test to understand our systems and draw conclusions. *In other words, scientific rigor in testing should be driven by the science of the system under test and the test environment, not the statistics used to help plan the test and analyze the data.*

This article will first describe both the scientific and artistic aspects regarding test and evaluation. The next section discusses the use of physics-based models in the flight test and evaluation process. The third and fourth sections describe the use of flight sciences' test designs and the application of DOE, respectively, at the AFFTC. The last section provides concluding remarks.

Test and evaluation is both art and science

Test and evaluation is not just a science. Although science drives most of the data collection and initial data analysis processes, there is much art in assembling all of the data into a body of evidence that is used to draw conclusions about a test or series of tests. According to Searles (1968), science uses "principles and methods of logical inference, both inductive and deductive," while art uses reasoning to present "conclusions with the supporting evidence clearly, and to recognize the difference between good and bad evidence for a belief, truth-claim, or conclusions." The scientific portion of testing uses deductive and inductive logic to develop evidence, and the artistic portion of testing uses reasoning to support the conclusions drawn from the evidence.

Deductive logic is associated with formal truths; it uses accepted evidence to arrive at specific conclusions. Most test and evaluation programs do not produce the sort of evidence required by deductive logic. Test programs are instead associated with discovering things or the realm of inductive logic, which uses observations to arrive at "general conclusions of varying degrees of probability" (Searles 1968). The two logical methods are complementary not contradictory. The scientific process typically uses both types of logic in the following fashion (Searles 1968):

1. inductive logic and observation are used to generate hypotheses,
2. deductive logic is used to eliminate hypotheses supported by observed facts, and
3. induction is used to verify the remaining hypotheses.

Searles (1968) goes on to state that there are many scientific methods (this is not an exhaustive list):

- inductive inference,
- the relationship between induction and deduction,
- observation and generalization from experience,
- the use of hypotheses,
- measurement,
- indirect methods of testing, and
- calculating degrees of probability.

Both statistics and the physical sciences are used within the flight test process. Statistics is within the category of formal and abstract sciences, whereas physics is within the category of concrete or descriptive sciences (Searles 1968). The scientific process normally moves from hypotheses to theories (Newton's theory of gravity) to laws of nature (e.g., Kepler's law of planetary motion). Although laws of nature are occasionally rewritten when dictated by new evidence, they can normally be safely used to make predictions, such as where Jupiter will be located in 10 years or what sort of launch profile is needed to boost a satellite to a specific orbit. The beauty of the laws of physics is that they can be used to both explain and predict the behavior of individual units in a way that statistics cannot. For example, using a physics-based model, one can predict with good accuracy the individual takeoff performance of an aircraft by knowing its configuration and weight, along with the particular atmospheric and runway conditions of that day. This physics-based model is not normally a complicated model but is well-founded in Newtonian mechanics and proven for numerous large and small aircraft. It is the predictability of this and other physics-based models that allows thousands of aircraft around the world to operate safely under a wide variety of conditions every day.

Thus, statistical techniques are applicable to the experimental phase of the scientific method. They are not THE scientific method and, of themselves, are not tantamount to rigor in the scientific method. Statistics can support the science of testing just as recent advances in decision analysis can support the art of testing; however, statistics and decision analysis tools do not drive all aspects of the test program. In addition the science and the art of testing must be used in a complementary fashion to achieve the test program goals and objectives. However, since the focus of this article is the science of testing, the remaining sections will discuss in more detail the use of physics-based models and statistical methods as part of the science of test and evaluation.

The use of physics-based models in flight test and evaluation

The vast majority of the flight test techniques that we use during classical developmental flight testing are based on the scientific principles behind flight. Classical flight testing includes what we call flight sciences: performance, stability and control, propulsion, structures, and subsystems. All new or significantly modified aircraft must undergo envelope expansion in the flight sciences disciplines in a build-up fashion to ensure safety of flight and to ensure that nothing is missed that could cause an operational problem.

Most of the time our government and contractor flight sciences engineers use models based on physical principles (for example, Newton's laws of motion, Boyle's Law for atmospheric air, fluid dynamics, and aircraft equations of motion) to make pretest predictions about how the system will operate. These models are often the same models used by the design engineers in designing the aircraft in the first place, so they are usually high fidelity (although still imperfect) models. Even if design engineering models are not available, there are usually data available from ground testing that can be used to build models based on known scientific principles. In addition to making predictions, pretest models are also often flown in a simulator prior to live flight testing to not only investigate potential problems in a piloted environment but to allow aircrews to rehearse maneuvers and potentially increase the efficiency of the test points.

Once test data are collected, the data are analyzed and compared to the model predictions. As a result, the models may be updated based on the actual flight data by using the test data to adjust the model form or to more accurately estimate specific parameters in the model. For example, the stability and control derivatives for aircraft equations of motion are normally estimated from time-series flight test data using maximum likelihood estimation techniques. These derivatives are compared to the pretest estimates to determine if the aircraft has sufficient margins of stability to be operated safely and perform the intended operational mission. Aircraft performance models are usually updated using flight test data and are then used to generate the various performance charts (for example, takeoff, landing, climb, and cruise) in the aircraft flight manuals and planning software used by aircrews for operational flight planning purposes.

Physics-based models have become the preferred method for designing and evaluating aircraft and their supporting systems. Research efforts in the flight sciences over the past 50 years have greatly increased the fidelity of the physics-based models available, and they have largely replaced the empirical models used by some of the flight science disciplines. These models have been refined using a large body of documented evidence, so the confidence in the newer models is quite high (although not so high that testing can be eliminated altogether). As an example, older versions of the standard on aircraft flying qualities provided primarily parametric guidance to achieve good flying qualities. Design engineers would design flight control systems and aircraft aerodynamic characteristics to meet these requirements, but the results were often less than satisfactory. Current design approaches favor higher-fidelity physics-based models used in piloted simulations to develop good handling qualities. These physics-based models have been developed, parameterized, validated, and updated using computational fluid dynamics techniques, wind tunnel data, specialized laboratories, ground test cells, and prototypes. The result of using these high fidelity models in conjunction with piloted simulators has been new aircraft that often fly very closely to their predicted handling qualities in much of their flight envelope. The focus of the testing then becomes those parts of the envelope where the engineers may lack confidence in the model (for example, during high angle-of-attack flight). Improved models have not only reduced the number of major handling qualities problems discovered in flight, but they have also increased safety, aircrew training, and test efficiency by allowing aircrews and engineers significant simulator experience before actual flight testing begins.

In general, physics-based models:

- provide insight into effects that determine practical behavior and physical limitations for individual systems;
- facilitate design as part of the systems engineering process;
- facilitate analysis in the time and frequency domains (very important in aircraft, since something is always moving unless the aircraft is parked); and
- permit the combination of component-level models into more complex models of the overall system that can be used to understand physical interfaces and interactions.

Flight sciences test designs

One of the goals of most flight sciences flight testing is the confirmation and updating of a priori physics-based models that have evolved during the development process not the building of a new model. The physics-based model is verified and updated in the full-scale flight environment and is then used to make inferences and predictions about the operational performance of the fleet of aircraft. The range of test variables and settings will be chosen to cover a significant portion of the model space and will often focus on those areas predicted to have significant nonlinearities (for example, transonic or high angle-of-attack flight).

In other cases the goal of a flight sciences test may be to confirm performance measured in a wind tunnel test or propulsion cell. In these cases a physics-based model may or may not be available. If a physics-based model is not available, usually there will be a large body of ground test data available for comparison.

Thus, the flight sciences test designs used at AFFTC are usually driven by the availability of the physics-based model or the data available from a simulation or ground test. The test objectives are typically designed to collect an efficient set of data that allows the engineers to compare the flight test results to the predicted results. The goal of the test is primarily to collect data that will be used for model validation and updating instead of model building. DOE techniques such as split-plot designs may be useful in helping to plan for such data collection efforts, and AFFTC, like other test organizations, uses DOE techniques when they are appropriate.

Experimental designs for the flight sciences are normally based on a build-up approach that begins in the “heart of the envelope” and works toward the edges both faster and slower, and higher and lower. Additional test points may also be required if the initial models predict particular problem areas or if problems are encountered during testing. Randomization and other common DOE techniques are normally not appropriate during envelope expansion nor are they needed. In most cases the physics of the response variables is well understood (for example, lift is a function of angle of attack on a conventional fixed-wing aircraft); instrumentation and measurement errors are well known and characterized, and small deviations from desired test conditions can be corrected by using physical principles. As an example of an error correction, if the test point was to be flown at 10,000 feet pressure altitude, but was instead flown at 10,050 feet due to an altimeter error, the error is easily accounted for by applying the standard day atmospheric model to correct the data collected to the desired 10,000 feet. There is no need to fly multiple test points to average out the small errors. It is good practice to collect several different test points at the same test condition when possible, but this is usually done to check for test environment issues such as aircraft configuration, maneuver quality, and instrumentation integrity instead of for statistical purposes.

Use of DOE at AFFTC

While the focus of the traditional flight sciences AFFTC mission is confirmation of physics-based models, flight test techniques grounded in statistical methods are useful for many other areas of test design and data analysis. For example, tests of mission systems (such as radar and targeting pods) often do not have complete physics-based models associated with them. Under the right set of circumstances DOE approaches are practical, and we have found them to be very valuable in developing good, defensible test designs that produce defensible results. For example, DOE approaches have been used very successfully for target recognition and identification tests, as well as electromagnetic interference testing of an installed radar warning receiver. We continue to pursue additional areas where DOE approaches can increase the confidence in our test results.

In addition, our experience has been that caution must be used in applying DOE techniques with the expressed goal of achieving test efficiencies. In one example, a test program was conducted that collected over 300 individual test points on 10 flights. Several DOE techniques were examined after the test was completed that were postulated to reduce the number of test points collected to fewer than 20 percent of the original test points. The reduction was based primarily on the premise that the power of the original test was higher than needed since it could detect a very small difference in performance. However, the original test was designed specifically to detect a very small difference in performance because that was what was anticipated based on ground test data and the configuration of the test aircraft. Thus, the original experiment was properly sized to meet the test objective. In addition, a significant degradation of the system was noted after only seven flights; this degradation would not have been observed if only two or three test flights had been flown. Discovering this degradation may well have been the most valuable part of the test. This discovery emphasizes the important point that test programs should not be conducted to focus exclusively on the stated test objectives, particularly during developmental testing. Many problems noted during developmental tests are not the things we are looking for based on the test objectives but are problems that happen as we routinely operate the system (for example, generators that fail, landing gears that crack, or software that freezes in flight). If we focus solely on making our tests efficient, we may well lose the opportunities to observe these problems before the system is fielded.

Conclusion

The science in developmental testing (and some operational testing as well) is in the physics of the phenomenon we are testing, not in the statistics. Statistics is just one input (albeit a very important one) to our test planning and data analysis processes. In many cases statistics is a tool to help us plan our test and interpret our data so we can evaluate and understand the physics of our system under test in a realistic flight environment. Statistics does not evaluate or understand anything; indeed, the main role of statistics is to facilitate understanding. A famous "maxim" of Dr. Richard Hamming, a pioneer of computer science, was that "the purpose of computing is insight, not numbers" (Morgan 1998). Experienced engineers use statistical tools to help them analyze data that they then use to evaluate and understand the system or problem at hand. While statistics are useful in aiding test planning, data analysis, and evaluations, physics-based models are essential to understanding the system under test. ❑

EILEEN A. BJORKMAN is the technical adviser at the Air Force Flight Test Center, Edwards Air Force Base, California. She has over 30 years experience in flight testing, joint testing, and modeling, simulation, and analysis. She holds a bachelor of science degree in computer science and bachelor of science and master of science degrees in aeronautical engineering. She is a member of ITEA, the Society of Flight Test Engineers, the International Council on Systems Engineering, and the Military Operations Research Society.

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ITEA Journal 2012; 33: 119–122

Drowning in Data *and* Non-Potable Water

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> *"Once in a while you get shown the light, in the strangest of places if you look at it right."* (Hunter and Garcia 1974)

History provides scores of examples where researchers and testers stared into the face of solutions but could not seem to see the forest for the trees. This brief historical narrative illustrates this point and also shows how generating different perspectives on the accumulated data, largely via data visualization mechanisms, can mean all the difference.

Between 1831 and 1854, Great Britain suffered four major outbreaks of cholera. The disease took its victims one by one and rapidly spread, killing several thousand people and leading to widespread panic among the population. As one observer notes,

> *"Life was a dreaded nightmare, people fled their homes and the streets and houses were filled with the stifling smells of the dead and the odors of disease. Nobody knew how this started but nearly all could recognize the severe diarrhea accompanied by painful gut cramps, extreme thirst and dehydration, severe pain in the limbs, stomach, and abdominal muscles, and a bluish-grey change in skin color."* (Summers 1989)

Throughout this 20-year period, and despite volumes of recorded data on casualties, the situation baffled the local authorities as well as the scientific community. But one epidemic episode, focused on a particular neighborhood in London, enabled one talented researcher to test an innovative theory, successfully interpret the data, and tease out the primary cause of this dreaded disease. Taken largely from the personal narrative of Dr. John Snow, this brief paper illustrates a solid historical example of where data visualization[1] enabled effective analysis of the problem and stimulated changes in public policy.

Dr. Snow recounts that the 1854 London epidemic began rather slowly, in the Southwark and Lambeth neighborhoods. But on August 31st, "the most terrible outbreak of cholera which ever occurred in the kingdom" broke out in Soho. In the first few days, 127 people, rich and poor alike, living in or around Broad Street succumbed to the disease. In the weeks that followed, fully three-quarters of the residents fled their homes and businesses, with only those unable to leave bearing witness to a desolate landscape. Casualty figures rose to 500, with mortality rates in some subdivisions approaching 13 percent. As Dr. Snow recalled, "the mortality in this limited area probably equals any that was ever caused in this country, even by the plague; and it was much more sudden, as the greater number of cases terminated in a few hours" (Snow 1855).

Dr. Snow's local contacts made him ideally placed to monitor this epidemic, which had broken out virtually on his doorstep. Suspecting that cholera was spread by a poison passed from victim to victim through sewage-tainted water, he began to explore and document the cases in Soho.

Interviewing victims' families and overlaying the casualty data on a neighborhood map, he observed that the epicenter of the epidemic converged at a water pump on the corner of Broad Street and Cambridge Street. As Snow describes in his published account,

> *"On proceeding to the spot, I found that nearly all the deaths had taken place within a short distance of the pump. There were only ten deaths in houses situated decidedly nearer to another street pump. In five of these cases the families of the deceased persons informed me that they always sent to the pump in Broad Street, as they preferred the water to that of the pump which was nearer."* (Snow 1855)

Exploring further, Snow found several cases in this neighborhood where, expecting high incidence of disease, he could find none. He describes two notable examples,

> *"The Workhouse in Poland Street is more than three-fourths surrounded by houses in which deaths from cholera occurred, yet out of five hundred and thirty-five inmates only five died of cholera, the other deaths which took place being those of persons admitted after they were*

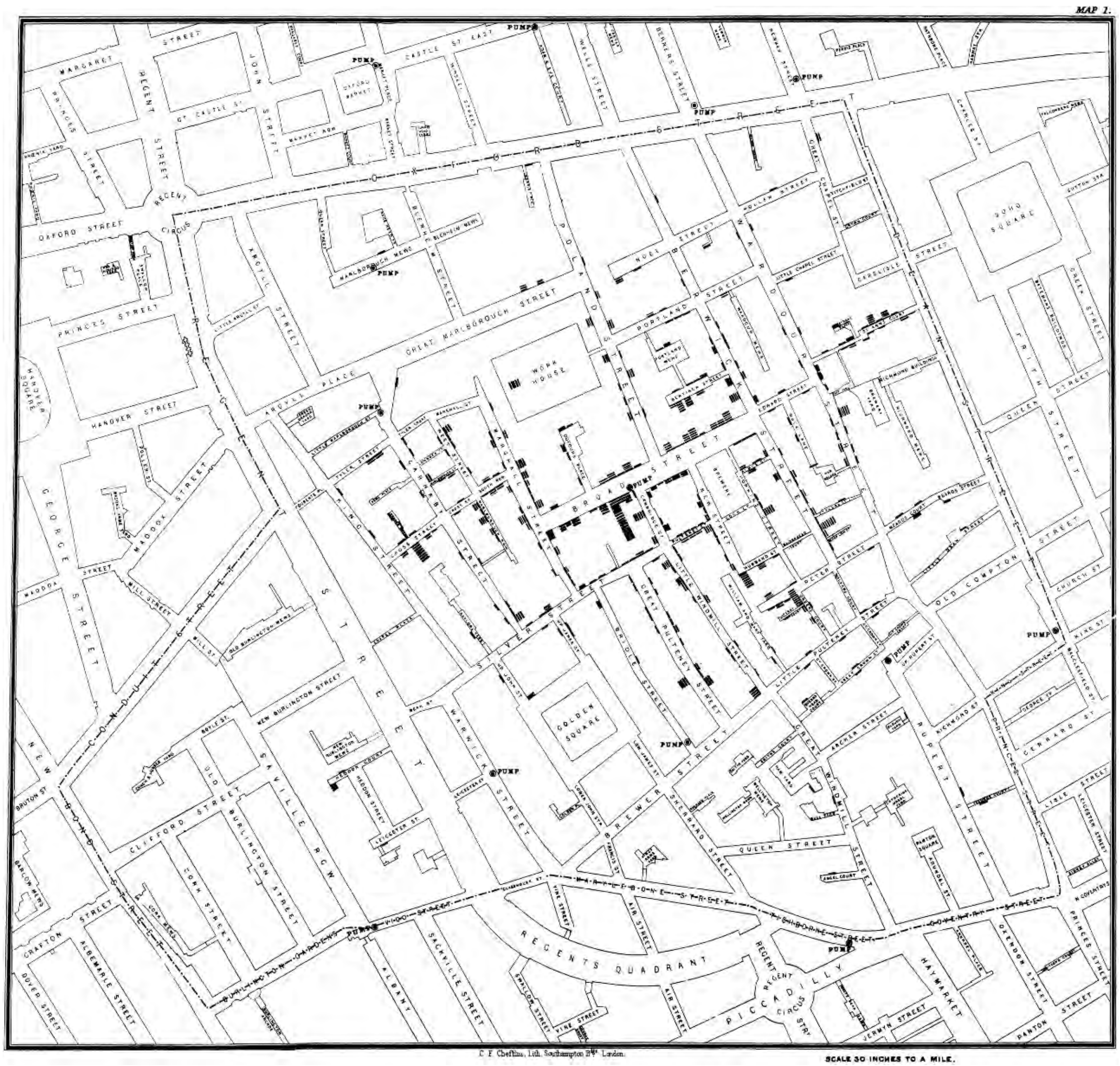

Figure 1. Dr. John Snow's Cholera Map Overlay, http://www.ph.ucla.edu/epi/snow/highressnowmap.html.

attacked. The workhouse has a pump-well on the premises, in addition to the supply from the Grand Junction Water Works, and the inmates never sent to Broad Street for water. If the mortality in the workhouse had been equal to that in the streets immediately surrounding it on three sides, upwards of one hundred persons would have died.

"There is a Brewery in Broad Street, near to the pump, and on perceiving that no brewer's men were registered as having died of cholera, I called on Mr. Huggins, the proprietor. He informed me that there were above seventy workmen employed in the brewery, and that none of them had suffered from cholera, at least in a severe form, only two having been indisposed, and that not seriously, at the time the disease prevailed. The men are allowed a certain quantity of malt liquor, and Mr. Huggins believes they do not drink water at all; and he is quite certain that the workmen never obtained water from the pump in the street. There is a deep well in the brewery, in addition to the New River water." (Snow 1855)

Examining a sample of water from the pump under a microscope, Snow found "white, flocculent particles" and concluded that the "presumed contamination of the water of the Broad Street pump with the evacuations of cholera patients affords an exact explanation of the fearful outbreak of cholera in St. James's parish." He shared his findings with the local Board of Guardians on the evening of 7 September. Initially skeptical, the authorities agreed to remove the water pump handle as an experiment. When they did so, the spread of cholera dramatically stopped. As Snow summarized,

> *"These circumstances being taken into account, it will be observed that the deaths either very much diminished, or ceased altogether, at every point where it becomes decidedly nearer to send to another pump than to the one in Broad Street. It may also be noticed that the deaths are most numerous near to the pump where the water could be more readily obtained. The wide open street in which the pump is situated suffered most, and next the streets branching from it, and especially those parts of them which are nearest to Broad Street."* (Snow 1855)

Snow's real triumph came after his death, when an explosive epidemic hit East London in July 1866. Having been convinced by Snow's theory, William Farr at the Registrar-General's office was thus "prepared to closely scrutinize the water supply." Despite official denials, Farr rapidly traced the source of the epidemic to the Old Ford works of the East London Water Company, where open ponds of water used as an emergency reserve were found tainted by sewage. As soon as this practice was stopped, that epidemic also died (Farr 1852).

Break to today, and I recall my younger days working at the U.S. Air Force's Cockpit Integration Office at Wright Patterson Air Force Base. One of the senior leaders frequently declared his "NUTS" theory (Nothing Under The Sun) based on the notion that while technology changes, the core ideas stay the same. For example, 3-dimensional displays, while a current technology trend, were actually used very effectively in World War II. Bombardiers carried cardboard models of targets on bombing missions to model the target areas with anticipated shadows. Another notable example, in the early 17th century, Christopher Scheiner introduced the notion of repeated graphic images and changes in the images to show the configuration of sunspots over time. This concept, called "small multiples" by Tufte in 1983 (Tufte 1983), is used in displays for space[2] operations today).

Even when using the most current display technology and techniques, what is invariant here is the human perceptual and cognitive apparatus that underlies the sense-making process. Thus, the relationship between and among displayed objects, their color, texture, and contours and the use of those relationships and properties in telling a story or communicating a situation to the user or operator, is critical. Display or graphics designers must be deeply aware of users' needs in the context of human perceptual and cognitive capabilities.

Graphic or interface design can either induce or reduce visual search, dependent on the task at hand and the relationship between and among display elements. Also invariant are the notions of visual momentum, visual search, isomorphism, vernier acuity, Gestalt closure, and the Stroop effect. For example, to illustrate the Stroop effect,[3] which manifests itself as interference in the verbal and visual conflicts in processing information, consider processing the name of a color when the text is written in a different color (e.g., the word "red" in blue text).

Other strategies and best-of-breed approaches include Shneiderman's "Overview first, zoom and filter, then details-on-demand" (Shneiderman et al. 2009). I would also include "progressive refinement," where the upper left of the display outlines the broad context, which is successively decomposed and refined left to right and top to bottom. This tailored design approach frames the bridge between context and data, enabling the presentation to convey levels of abstraction/levels of detail appropriate to the operational situation. Yet, another concept is the notion of surface structure versus deep structure of the interface, illustrated by issues such as system transport delays, which can manifest themselves at the user interface and thus impact the user's experience. Ignoring the effect of time delays on the delivery of data to dynamically updating displays can have deleterious and even catastrophic results (i.e., cockpit displays of friendly force locations during close air support missions).

All of these elements (and more) frame the underpinnings of competent display design. But, most notably, the human perceptual and cognitive factors must be adequately addressed in order to support "connecting the dots" or making information available "at-a-glance." This was as true in Snow's day as it is today. ❑

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Endnotes

[1]For an excellent discussion of the history of data visualization, see Friendly, M. 2007. A brief history of data visualization. In *Handbook of computational statistics: Data visualization. III*, 1 34. Heidelberg, Germany: Springer Verlag. www.datavis.ca/papers/hbook.pdf (accessed January 15, 2012). Also, for a more detailed chronology of milestones in the history of data visualization and associated references, see Milestones in the history of thematic cartography, statistical graphics, and data visuali zation. http://www.datavis.ca/milestones/index.php?page introduction (accessed January 15, 2012).

[2]For a great illustration of Scheiner's use of pantographs, or rear screen projections to identify sunspot phenomena, see The history of the discovery of cinematography. http://www.precinemahistory.net/1600.htm (accessed January 15, 2012).

[3]For a comprehensive review, see MacLeod, Colin M. 1991. Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin*, 109 (2): 163 203.

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Automating the Operational Test Data Process

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Within the test and evaluation (T&E) community, test programs are driven by requirements, duration, and cost. In many cases the sheer volume and multiple types of data combined with manual steps in the evaluation process are major contributors to the resources and time required to fulfill the test objectives. A properly conceived automated data management system in combination with a sufficient data transport network can provide enormous benefit through efficient data collection, reduction, processing, and storage in support of requirements verification, reducing test duration and cost that minimize manual processes in the analysis pathway. We identify the individual steps in the test data process and highlight the opportunities for automation. Furthermore, we describe the requirements of a properly constructed data management system that enables an extensible, scalable, and rapid data parsing, processing, migration, and storage during both the data collection as well as the analysis and system evaluation tasks.

Key words: Automation; data collection; data management system; data transport networks; subject matter expert (SME) evaluation; system evaluation; system-of-systems experimental programs; test data process.

Large-scale system-of-systems experimental programs produce an enormous quantity of data that must be parsed, processed, and migrated as well as mined, filtered, and reduced prior to being analyzed for requirement verification and system performance evaluation. While advances in sensor technology and data storage have allowed for an unprecedented amount of information to be recorded in association with systems-of-systems testing, the technology to facilitate rapid and efficient processing of these data sets has not kept pace. The result is that as the scale, cost, and complexity of systems performance tests continue to increase, the need for a streamlined data reduction process becomes more critical to making definitive and timely acquisition decisions within budget. The major challenges in the evaluation of large test data sets to produce a system evaluation report for decision-maker review include the volume and disparate nature of data, the geographic distribution of test facilities, and the reliance on manual input at various stages of the analysis pathway. In this article we discuss the complexity of the systems-of-systems test evaluation process and identify areas in which new technologies could reduce the time to process test data, leading to a shorter test duration and higher cost savings. We specifically focus on the potential for the incorporation of automation technologies to augment the traditional data analysis process, thereby reducing the timeline, required manpower, and cost associated with system performance evaluation.

In April 2011, Defense Secretary Robert Gates issued a memorandum which prioritizes Science and Technology (S&T) investments in the area of Data to Decisions to “reduce the cycle time and manpower requirements for analysis and use of large data sets” (Gates 2011). Defense programs have begun addressing this concern. For example, the U.S. Army Operational Test Command (OTC) Test Technology Directorate’s mission is to improve “planning, preparation and execution of operational tests… by acquiring and sustaining a common integrated simulation, instrumentations, and data management capability" (U.S. Army OTC 2012). The issue of very large test data processing is universal across the Department of Defense (DoD) as well as other organizations as data acquisition and storage methods have advanced beyond the capacity to efficiently process the information. The lack of a solution to this universal problem has lead to the recent focus by multiple organizations. For example, the National Institute of Standards and Technology (NIST) have organized an upcoming conference that highlights how to handle large amounts of unstructured data (McCalley 2012). Since typical performance tests are extremely complex and involve multiple interacting components, their individual data sources are inherently variable, including field and simulation tests of material that span the live/virtual/constructive (LVC) continuum. Data types themselves span a wide variety from range test engineering performance data to digital message data to video and warfighter mission statistics. The analysis and interpretation of data from these test events is challenged by the joint context requirement for a comprehensive system-of-systems evaluation. Large-scale relationships must be mined from the separate systems' data streams to garner an accurate assessment of the test's performance space, completeness, and sufficiency.

A major challenge in system-of-systems analysis is establishing a data transport network that can facilitate data sharing and joint context analysis over distributed test facilities. Emerging geographically distributed test networks, including the four-stage increment Warfighter Information Network-Tactical (WIN-T) currently being developed and deployed by the Army, provide a possible framework for realizing significant reductions in the time to parse, process, and store data and to generate evaluation reports for systems under test. Key areas are currently being investigated related to automating system-of-systems performance evaluation process, including automating the detection and processing of data within the database architecture itself, implementing rapid data reduction processes through intelligent multithreaded capabilities, and automatically generating data summaries for use in creating a system evaluation report. Maturing and expanding automation research to a viable prototype will significantly reduce the amount of time spent by the subject matter expert (SME) during the test and evaluation (T&E) process performing manual data activities, allowing the focus to be on data interpretation, validation, and verification.

One of the most pressing needs concerning the vast quantities of data acquired during systems tests is the ability for the trained analyst to make sense of what is available, as well as knowing the breadth of information available. There is then a need for improving the data availability for SME analysis as well as the development of architecture to support it. "You can go to almost any mission area or functional area in the United States Navy and think about how much of our human capital gets spent diving into various databases and then manually aggregating it," said Rear Adm. Jan Tighe. "If we could get to a place where our data is in a cloud that's understandable, that's smartly tagged, that's discoverable, we could easily get to solutions that don't require so much human intervention. That lets the humans deal with the higher-order thinking that's required to make those decisions" (Serbu 2012). If data is handled and processed in a well-planned manner as it is acquired, this then can serve to reduce vast amounts of time and money sorting through data by manual methods. Allowing for flexible data management architecture to be put in place prior to a systems test would then allow for software tools to easily integrate into the data stream to facilitate analysis for the SME.

Since 2000, there has been an increasing emphasis on linkage of individual systems into a system-of-systems operational test environment with more complex, larger data streams for analysis. This trend has manifested itself in such programs as F-35 and the Army's Network Integrated Evaluation (NIE), which required a new approach, namely use of advanced automation techniques to the T&E process. The specific steps in the T&E process have been previously defined (Merhoff 2009). These 13 steps that have been suggested for a successful test data process are as follows: (1) collection of data from the unit(s) under test; (2) transfer of selected data from the units(s) to a central or distributed collection point; (3) online monitoring of selected data during the test; (4) real-time test status and notification to test manager; (5) conversion of data to a common format; (6) transfer and storage of the raw (unprocessed) data in a central or distributed database; (7) processing; (8) authentication; (9) warehousing of processed data in a central or distributed database; (10) restricting access; (11) retrieval of the processed data; (12) mining of the processed data for trends, relationships, and statistics; and (13) generation of the test report. These sequential steps can serve to construct a viable technological framework to reduce the time and effort needed to effectively and efficiently evaluate systems under testing. Implementing these steps is essential in a timely creation of a system evaluation report. Dramatic benefits to the test evaluation process can be realized through improvements in two critical areas: creating a comprehensive integrated data storage and management network that can provide distributed, authenticated access to relevant data to those that require it as part of the analysis pathway, and introducing automation at all levels where possible to avoid the reliance on manual resources to move data or data products through the pipeline.

Of these steps one major factor that can be implemented to minimize the time from test collection to validation and performance evaluation is to automate procedures into the data stream itself. One of the requirements of automated data processing is the autonomy of the individual tasks of the processing network, such as detecting the presence of new data in the system, data parsing, data processing, and data migration. Extensible data processing architecture, when used in conjunction with a centralized database, can manage and monitor these tasks such that they are initiated when needed and can be queried for status or validation. The choice in the specific software object to perform these tasks is limited only by the requirements that the object be able to perform its desired function and interact with a centralized database manager. To be most useful, any automated data processing solution prototype must be constructed to be scalable and extensible as well as designed to be sufficiently general to be applicable to a wide variety of test scenarios and requirements.

Recently, OTC has sponsored a Small Business Innovative Research (SBIR) topic, which is focused on researching technologies to automate the 13 steps in the test data process. Under this SBIR topic, A10-009, the Army has been working with Frontier Technology, Inc., to develop such automation technologies. The effort has progressed beyond the Phase I proof-of-concept and will soon begin Phase II work to develop a functional prototype to be tested on a live system-of-systems test. Technology developed under the Phase II effort will utilize an extensible load-adaptive processing architecture designed to automate key steps in the data processing, parsing, reduction, storage, and even in the data analysis itself. This architecture will also make the most use of available systems resources by distributing the processing loads across all machines in the network.

The development or augmentation of a centralized automated processing network to integrate the individual processes of system-of-systems performance evaluation provides a clear opportunity to dramatically reduce the time spent on manual data processing by the SME for test analysis. A successful performance evaluation test includes the collection, transfer, and storage of multisource and multitype data, subsequent computational analysis, and ultimately the interpretation of the numerical results and generation of the test report by SMEs. Each component of the test analysis pathway that requires manual input adds additional constraints based on the requirement for available qualified personnel, equipment, and communication. Additionally, reducing the amount of time spent on data processing through the use of advanced hardware implementations also has a direct impact on the turnaround for data availability for test analysis. An intelligently designed automated processing architecture can significantly reduce the need for manual input by providing the capability to assemble, validate, and process data autonomously without requiring any human interaction, thus maximizing the use of available computational resources and minimizing the need for human resources. In addition, the development of a modular architecture, which is easily configurable through a user interface and also is sufficiently generic to accommodate for third party additions, can allow for a greatly increased flexibility with regard to being valuable to evaluate all types of systems under test. Furthermore, through the creation of comprehensive preprocessed results where applicable, automated analysis can increase the efficiency of analysts by allowing them to spend their time interpreting rather than creating results. Conversion of a system-of-systems performance evaluation pathway into an automated processing architecture provides the additional benefits of 24/7 operation and real-time monitoring of data flow and data processing. Data within a centralized data warehouse can then be accessed for a real-time "quick look" assessment through existing visualization tools for data sufficiency as well as data quality. Further enhancements to such tools can provide robust data validation at any stage of processing and provide complete traceability of archived data. In addition, organizing very large and complicated data into a centralized system can enable downstream analysis such as intelligent data-mining operations to search for anomalous data or complicated trends contained in test data.

Given the inherent advantages to automated processing, the design of a central architecture to create and manage interdependent automated processing pathways would appeal to a variety of organizations that deal with large and multisource data. The creation of very large data sets from multiple sources is a near universal scenario among the Department of Defense (DoD) and other organizations that perform operational testing, and the ability to comprehensively collate, manage, autonomously process, archive, and mine data sets would be a powerful capability. Furthermore, emerging industry standards like the Joint Management Environment Test Capability (JMETC) environment and the Test and Training Enabling

Architecture (TENA) middleware have been properly conceived to be extensible, employing a toolbox approach to facilitate enhancements. Large strides in efficiency may be possible by creating innovative and flexible software tools that include not only automated processing services but are also modular and flexible with generality, which can be extended to incorporating third party processing capabilities while placing them within a user-configurable interface. ❑

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Common Interoperable Target-Vehicle Interfaces

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A 2005 Defense Science Board report on aerial targets concluded that future control systems and components must be made common across the Services so that Services may operate on any national range. This report led to a 2007 Director of Test & Evaluation memo (Daly, 2007) chartering the Target Control Steering Group (TCSG), funded through the Target Management Initiative (TMI), to facilitate a systems analysis and formulation of a joint technical approach to achieving common control elements (CCE) across the targets' commonality and, if warranted, to develop and demonstrate technical approaches. These CCE's and technical approaches could then be adopted by the Services in new systems or into existing systems, as deemed appropriate. Such adoption of CCE's and technical approaches led to increased interoperability, lower costs of operation, optimization of TMI initiative integration, and mitigation of integration risk.

This article reports on the current state of the targets environment, the TCSG charter and goals, the operation and results of the study group, and the results of sponsored demonstrations. The TCSG surveyed the technical approaches for target control across the national ranges, and through use of the Modular Open System Approach (MOSA) a set of common elements and interfaces were identified. The identified common elements and interfaces were considered by the TCSG as candidates for development of an open standard to enable common element interoperability. The TCSG also sponsored demonstrations of a portion of these interfaces, resulting in successful live tests. The TCSG also vetted several proposals for the TMI in the area of target control. Such proposals were evaluated and recommendations were made to the TMI consistent with the TMI goals of common control elements and technical approaches.

Key words: Data-link interface technology; hardware interfaces; interoperability; national test-range infrastructure; standardization; target control systems.

There are three national target-control systems deployed at three ranges implementing capabilities for test and evaluation (T&E) and training. These ranges have implemented complete target-control systems along with associated infrastructure and target drones to allow for the emulation of aerial, surface, and ground threats in test and training that reflect operational scenarios. Historically, target systems were procured and developed to operate on and are limited to their single host range.

The three national test ranges are

- White Sands Missile Range (WSMR), operated by the U.S. Army,
- Naval Western Test Range Complex (NWTRC), operated by the U.S. Navy, and
- Gulf Test Range (GTR), operated by the U.S. Air Force.

These three national ranges have been developed independently and have focused on their own unique, Service-specific test and training requirements. For example, NWTRC incorporates sea-surface targets in their T&E scenarios where WSMR does not. Likewise, the U.S. Air Force flies multiple drones in close formation, while the U.S. Navy T&E scenarios normally do not. Such operational factors lead to differences in data-link requirements and data-rate throughput.

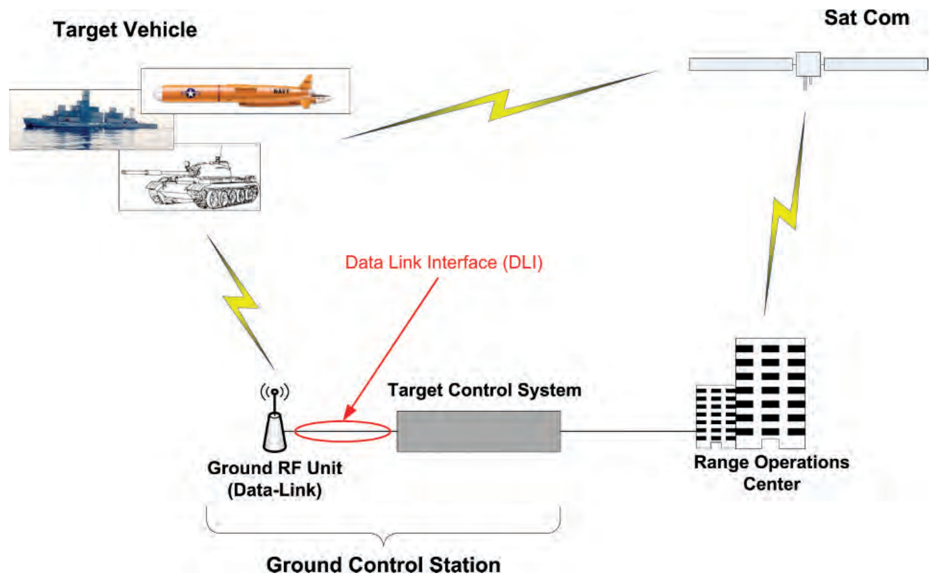

Figure 1. Range data-link interface.

In addition to specific Service requirements, these ranges are further differentiated by physical features of range geography. For example, target-control data link requires relay stations to operate in hilly terrain at WSMR and over the horizon at GTR.

These factors have led to differences across Services in target-drone capabilities, ground control software, range infrastructure, and data-link technologies procured by multiple programs over time. Consequently, target-drone vehicle interoperability across the national test ranges is limited and cross-Service operations often require utilization of a complete "borrowed" target-and-control system set to control a vehicle not native to a particular range. The Office of the Secretary of Defense (OSD) has mandated that interoperability be defined to "enable the operation of any target on any test range with minimal cost and effort."

Range characteristics

Each of the ranges are differentiated by the control systems and data-link technologies they operate. 5-D Systems Inc. conducted an OSD-sponsored Interoperable Target Control System Study in March 2007 to document national range characteristics and limitations of target interoperability. This study found that each Service operates a range and associated infrastructure for in-Service target drones using a variety of technologies specific to each system. These range systems typically communicate from a ground control station to a target drone through a radio-frequency (RF) unit that transmits and receives command-and-control data in a variety of formats. The data interface between the ground control console and the ground radio-frequency unit (GRFU) is different for each of the range facilities.

Figure 1 generically depicts the GRFU, range interface, and other range assets, including target vehicles. The three ranges operate ground-based software-centric target-control systems (TCSs) and the associated transponder infrastructure to support target command and control. WSMR operates the Drone Formation Control System (DFCS), the Target Tracking and Control System (TTCS), and the Target Tracking and Control System/Ultra High-Frequency (TTCS/U) for their control software; NWTRC operates the System for Naval Target Control (SNTC) and Integrated Target Control System (ITCS); and GTR operates the Gulf Range Drone Control System (GRDCS). The major differences between these ranges systems are summarized here:

- DFCS and GRDCS are multilateration systems, where target location is determined based on signal arrival time at various data-link transponder sites. These control systems are designed to operate coordinated multiple target-drone scenarios.
- SNTC and TTCS/U both use a single-antenna approach utilizing vehicle-based GPS positioning for target location. These systems can also control multiple target drones.
- ITCS and TTCS rely on radar tracking information for target location. ITCS supports multiple targets where TTCS only supports a single target drone.

Each range operates on different RF bands because of technology selection and localized RF restrictions (5-D Systems Inc., 2007):

- WSMR operates UHF, 915 MHz, and C-Band, while there is also some developmental work that has been done on the L-Band.

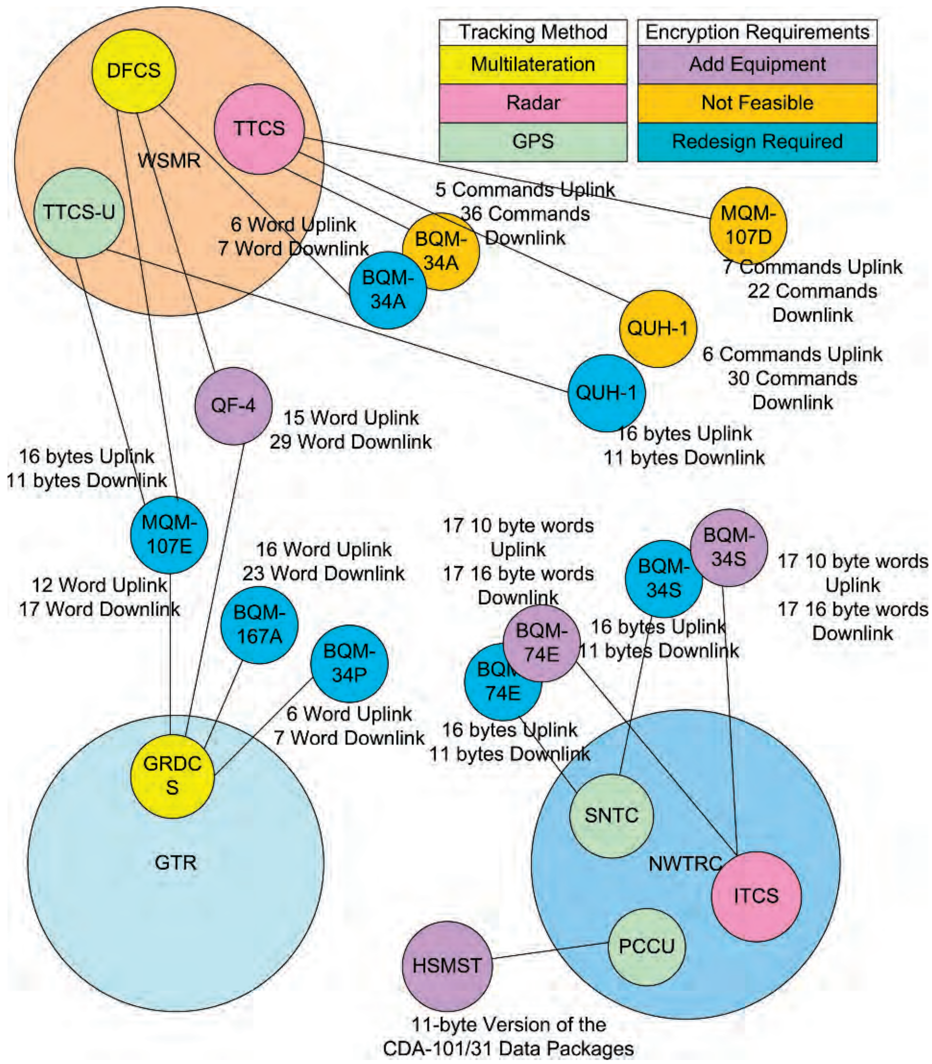

Figure 2. Range/target interoperability.

- NWTRC operates UHF and C-Band, with allocations for 915 MHz.
- GTR operates on 915 MHz, with UHF not available.

Each range operates a unique set of targets modified specifically to function within the host Service's technical infrastructure and to meet Service-specific operational requirements:

- WSMR operates the QF-4, MQM-107D/E, BQM-34A, and QUH-1.
- NWTRC operates the BQM-34S and BQM-74E as well as sea-surface targets.
- GTR operates the QF-4, BQM-34P, MQM-107E, and BQM-167A.

Because of these differences in control systems, data links, and target drones employed, the control-system components and data-link hardware are not compatible across the national ranges.

Figure 2 depicts target-drone interoperability among the national ranges (5-D Systems Inc., 2007). This figure shows the national ranges as large circles enclosing smaller circles representing specific ground control systems, and target drones as smaller circles outside the ranges. The targets are connected by solid lines to the ground control systems they are compatible with. In addition, the lines are annotated by the size of the uplink/downlink packets and can be considered a crude measure of data commonality.

Figure 2 also reflects the existence of target variants (from the data-interface standpoint) even among targets from the same Service (BQM-34A/S/P, BQM-74E, etc.). The variety of data formats is highlighted by data word count and packet length. The existence of few interconnections between targets and more than one

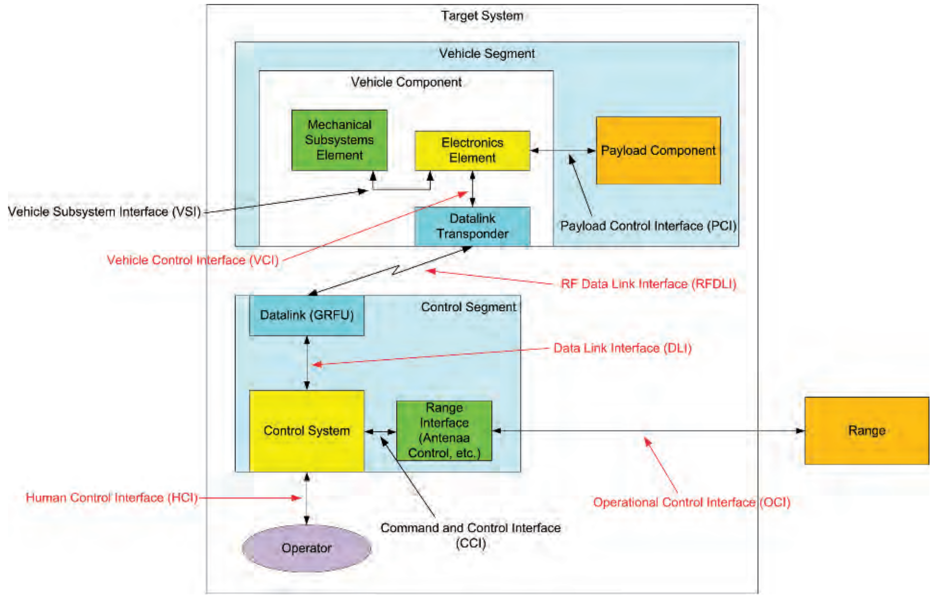

Figure 3. Target-system interface identification.

range control system represents the lack of interoperability between the various systems. The diagram also illustrates the state of data-link encryption at the time of the evaluation.

Interoperability

The specific Service needs have led to highly specialized systems tailored to differences in drone capabilities, ground control software, range infrastructure, and data-link technologies. They have also led to limited interoperability among the national test-range assets. The work-around for this lack of interoperability requires cross-Service loaning of complete sets of target and control-system assets.

The OSD goal of target interoperability would enable the operation of any target on any test range with minimal cost or effort and open the door for the development and manufacture of common components across the three Services' operating test ranges. The achievement of this goal will lead to reduced procurement costs, lower integration costs, additional resource flexibility, and increased cross-Service collaboration.

Over the years several Service-led efforts have been conducted with the goal of building common target-control systems. Each effort met with varying degrees of success and community acceptance; however, none of the efforts were able to claim significant cross-system/cross-Service interoperability.

TCSG charter and goals

The OSD drafted a memo in July 2007 recommending the creation of the Target Control Steering Group (TCSG) in order to "develop a roadmap and investment program to achieve more interoperability among existing target control systems across the services." The letter cited the 2005 Defense Science Board report on aerial targets, which "envisioned the gradual introduction of common control elements into each range to provide an increasing degree of interoperability, test flexibility, and lowered operational costs" utilizing open architectures and standards. The memo charged the Naval Air Warfare Center Weapons Division to lead the TCSG and to provide an architectural framework for future Director of Operational Test and Evaluation Target Management Initiative (TMI) investments related to target control.

The TCSG is comprised of technical and program-management representatives from the Army, Navy, and Air Force operational-test communities. The TCSG initially identified the set of interfaces that are common to all target-control systems. Utilizing inputs from the three Services, this joint effort provided a consensus definition for an objective TCS system and a prioritization for the development of identified interfaces. The group met several times throughout the year for Technical Interchange Meetings, with teleconferences between meetings to review materials, work products, and issues prior to the formal meetings. The subject of each Technical Interchange Meeting was scheduled to complete an interface definition for the ground control system to ground RF units (Data-Link Interface), Vehicle Control Interface, and Human Control Interface by the end of the study effort *(Figure 3)*.

The TCSG also served as a forum for hearing and evaluating relevant proposals made to the TMI. Several proposals were presented to and evaluated by the

TCSG in the area of target control. The results of such evaluations by the group were provided to TMI leadership as input for their own evaluations.

The TCSG work products included

- the examination of several protocols, standards, and system architectures;
- the consensus on a common TCS architecture;
- the development of several common interfaces documented through standard ICDs; and
- recommendation of TMI initiatives to TMI leadership.

TCSG approach

An important feature of the TCSG charter is the mandate that all data rights and interfaces be open and available not only to all Services, but to industry as well. The TCSG approached these goals for the TCS by using the Modular Open Systems Approach (MOSA), as mandated by the OSD as a technical-development strategy. This strategy aims to achieve affordable, evolutionary, and joint combat capability. In the context of target-control systems, the TCSG strives for the definition of a target system featuring reduced acquisition and integration costs and increased interoperability.

MOSA features three principles for systems design:

- modularized system,
- designated key interfaces, and
- use of open standards.

Employing the MOSA methodology, the TCSG examined existing range assets and systems and identified major architectural components as generic modules and interfaces between those modules, as shown in *Figure 3*.

- The *Data-Link Interface* (DLI) is the interface between the ground control system and the ground portion of the RF data link. It encompasses control and telemetry information for the operation of the data link itself as well as the target vehicle.
- The *Vehicle Control Interface* is the control and telemetry between the on-vehicle transponder and the on-vehicle electronics (autopilot) and other vehicle subsystems.
- The *Human Computer Interface* encompasses the human machine interface, including display data sets and ergonomic controls.
- The *Operational Control Interface* is the interface between the target-control system and other range and test assets.
- The *Radio Frequency Interface* is the over-the-air RF energy and data formats for transport of data between the ground systems and target vehicles.

In examining these key interfaces, the TCSG prioritized and selected them for development of a common interface specification based on the following characteristics:

- criticality of function,
- ease of integration,
- change frequency (volatility),
- interoperability, and
- commonality.

From the generic system modules, the key interfaces identified by the TCSG are depicted in red in *Figure 3*. They are, in order of priority,

- Data-Link Interface,
- Vehicle Control Interface,
- Human Computer Interface,
- Operational Control Interface, and
- Radio Frequency Interface.

The goal of interoperability will be facilitated by the creation of natural and well-defined (standardized) boundaries between the generic modules depicted in *Figure 3*. These generic modules are functional representations of the components of existing systems. As developers of these system components desire to achieve a level of interoperability with neighboring components, they will interface using the TCSG-defined common standard open interfaces.

Establishing a TCSG common interface

Where possible, the use of open standards was defined as part of the group's charter. Through the course of the study as part of the MOSA analysis, standards such as the Joint Architecture for Unmanned Systems, NATO standards for UAVs (STANAG), and IEEE standards were examined and considered for inclusion in the standard TCS interfaces.

Data formats from the Joint Architecture for Unmanned Systems were adapted for implementation of unmanned ground-target control. This adaptation allows existing ground targets and those targets in near-term acquisition to be adapted to the TCSG standard with little effort.

NATO STANAG-4586 was examined and preliminary data and functional mappings between the target-control system and the NATO standard were conducted. The TCSG study, however, did not recommend full adaption of the STANAG standard for the Data-Link Interface, since STANAG assumes a greater on-vehicle "intelligence" than is present in a number of existing target-vehicle systems.

In addition, T&E requirements for real-time human-in-the-loop control of multiple air vehicles in close proximity preclude the use of STANAG-4586.

Human-in-the-loop control requires necessary data-model and communication-channel optimizations in the control system and data link in order to enable the requisite high data rates and low latency over narrow-bandwidth channels. The existing NATO standards address real-time control only by allowing the system designer to specify an additional, system-specific interface maintained outside of the standard. This was not deemed sufficient to advance interoperability for target-drone control.

As other interfaces are considered in the future, other open standards will be considered (e.g., STANAG-7085 for the RF data link).

TCSG accomplishments

As stated previously, the DLI was identified and prioritized for initial development. Specification of the common interface broke the DLI down into two major areas of functionality: data-link control and target control.

Data-link control consists of control and data elements facilitating the communication of command and status information between the ground control system and the functions controlling the configuration and operation of the data link itself. Typical functions are

- initialization of communication parameters (frequency, time-outs, etc.),
- network configuration (addresses, relays, etc.),
- start-up or teardown of the data link,
- testing of data-link subsystems, and
- antenna control and status.

Data-link control also provides the means to address and route datagrams to participants on the data-link network. The result is that target commands and target telemetry are carried as "cargo" within a data-link control packet. Therefore, data-link addressing and routing functions are separated from the control of the vehicle and its associated payload. This scheme provides a degree of vehicle interoperability across different data links, since vehicle control and telemetry are separated from the network infrastructure control.

Target control can be categorized into two separate subfunctions, target-vehicle control and target-payload control. Separation of the data-link control and target control provides a layered architecture for communication protocols. This design isolates changes in the data-link control from the target-control portion of the standard.

Target–vehicle control, as part of the DLI, consists of data elements to support the transfer of command and telemetry information associated with vehicle state and steering. Typical functions would be commanding or reporting vehicle location, position, and orientation, or monitoring engine and throttle settings. There are three types of message sets for target-vehicle control, one for each vehicle type specific for aerial, sea-surface, or ground targets. Each message set for target-vehicle control is tailored to the specific characteristics of the type of target. For example, aerial targets are operated in three dimensions, whereas surface targets typically are not.

High-level control is defined as the ability to control a target vehicle by defining a path for the vehicle to follow autonomously. High-level control typically will allow for the upload and possible modification of waypoints to a vehicle and requires a "smart" vehicle to then follow those points. Low-level control is defined as a real-time "closed loop" control system that receives vehicle telemetry and provides low-level vehicle-control commands. An example of low-level control is a ground controller's capability to manually "fly" or "drive" a vehicle in response to vehicle-telemetry feedback.

The target-vehicle control interface features the ability for control systems to provide both low-level and high-level control of target vehicles as necessary for the specific target vehicle. The draft "standard" for the Vehicle Control Interface was generated and is currently undergoing review and amendment by the TCSG.

Target–payload control, as part of the DLI, consists of data elements to support the transfer of command and telemetry related to payloads onboard a vehicle. Such payloads would be used as part of an exercise or T&E event. Typical functions of payload control include command and reporting of electronic-countermeasures modes, activation or release of expendables, and enabling or disabling of electromagnetic-signature sources. The payload-control concept is to enable "arbitrary" (i.e., payload-specific) data and status messages to flow through the target-control interface as additional message "cargo."

Other TCSG accomplishments

During the course of the TCSG's initial effort, the group proposed a minimum set of hardware electrical interfaces to be provided by future drones (e.g., QF-16) and documented the recommendations in a memo to the Test Resource Management Center. These electrical interfaces will link the future drone-vehicle avionics package (autopilot) and the data-link transponder. The electrical interfaces agreed upon by the TCSG are the CAN Bus, MIL-STD-1553B, and RS-422. These interfaces are intended to be a minimum hardware provision for vehicle transponder interfaces. The TCSG's recommendation does not mandate functionality for any particular interface, but is defined

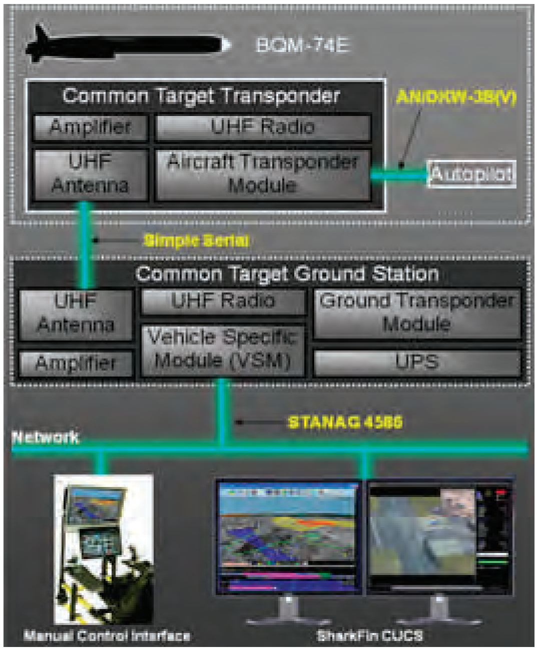

Figure 4. Std TCS interface identification.

to enable development paths for future upgrades and modifications. The proposal for the QF-16 hardware interfaces is a stepping stone to also specifying hardware interfaces for future interoperable targets.

TCSG proof-of-concept demonstrations

The TCSG approved a demonstration of the utility of the DLI standard through two demonstration projects.

- **First demonstration:** The first demonstration project was conceived as the use of a prototype target-control system called the Std TCS to manually fly a BQM-74E utilizing an adaptation of UAV data-link hardware components *(Figure 4)*. The new data link and associated GRFU first implemented STANAG-4586 and then modified the system to utilize the TCSG standard interfaces to control the BQM-74E. The Std TCS and STANAG-4586 interface were integrated and ground tested in the spring and summer of 2009 and successfully flight tested in October 2009 at NWTRC. The Std TCS and TCSG standard interface were integrated and ground tested in the summer and fall of 2009 and successfully flight tested in December 2009 at NWTRC.
- **Second demonstration:** The second demonstration project was conceived using an Army control system (TTCS/U) to control a Navy GRFU and target vehicle (BQM-74E). *Figure 5* shows the architectural layout of the demonstration system.

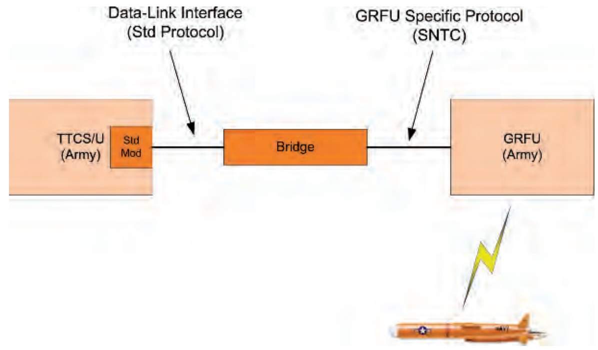

Figure 5. Std TCS interface identification.

The TTCS/U software system was modified (Std Mod) to generate the DLI using the TCSG standard interface as a means of controlling the BQM-74E. A software “bridge” was implemented as a means of translating the DLI standard interface’s messages into a protocol understood by the BQM-74E GRFU to control the target drone. Integration of the system and ground testing were completed in December 2009, and the demonstration was approved for flight test in May 2010. The flight test used a manually operated BQM-74E that was successfully flown and recovered. Postlaunch data evaluation confirmed nominal operation of flight systems within the expected flight parameters, with no transients noted in drone control.

Future directions

The focus of the initial TCSG effort was to follow the modular open-system approach to define and prioritize key components and associated interfaces for the diverse target-control systems currently in use. The TCSG has also explored various future technologies that are envisioned for inclusion in the targets community and demonstrated the ability to synthesize cross-Service asset utilization through the definition of a standard interface.

The current Data-Link Interface selected by TCSG consensus for the initial standardization effort can be described as a set of message datagrams that vary based on hardware constraints and organizational development history. The concept of utilizing a common standard across all organizations and facility assets is attractive from the future-systems perspective but is cost prohibitive for some legacy systems.

The ability to generate the necessary common protocol has been demonstrated both as a newly defined hardware system (demonstration 1) and as an adaptation of legacy systems (demonstration 2). Although the standardized DLI has been demonstrated to be adequately robust utilizing existing interface-implementation methodologies, it is the intention of the TCSG to explore the definition of the key target-system interfaces as object models expressing the required data set for vehicle control and telemetry. In this way, a functional thread specific to the system/Service will describe how this common data set is exchanged, influencing the way data objects are synchronized across host platforms.

An object model is a collection of data objects or classes presented as a software interface enabling hosting programs to examine and manipulate the data they represent. The TCSG intends to define the common object model along with an underlying infrastructure and tool set. The underlying infrastructure provides the means for hosting programs to synchronize distributed instances of objects, thus allowing for distributed hosts to exchange data. The supporting tool set provides development and test services in support of the common object model and may include such items as schema designers, automatic code generators, transport diagnostics, library utilities, and test infrastructure.

The common object model and transport infrastructure are developed, tested, and maintained as a common software product to be used by the integrating platforms. As the object model may evolve, changes to the object model and underlying infrastructure are organized into distributions and released to customers in a synchronized fashion, allowing for orderly changes to the object-interface implementation.

Interfaces based on a common object model have been demonstrated in production systems as a means enabling interoperability across heterogeneous platforms. Mandating the use of a common object model replaces the traditional over-the-wire interface specification, meaning the object model becomes the interface. The mechanics of data transport are delegated to the common infrastructure components, absolving host platforms of the need to develop, implement, and test their own implementations of a transport mechanism. Further, host platforms are isolated from changes to transport mechanisms.

The common object model, infrastructure, and tool set can be openly published and shared among integrating organizations, enabling reuse of these modular assets as future systems are implemented. Such reuse leverages the need for a common development effort to synchronize data across distributed systems. Defining and implementing this common effort reduces duplication of effort, lowers risk, facilitates the distribution of new feature sets, and ultimately lowers implementation costs.

The next step for the TCSG is to continue development of standardized interfaces for the Vehicle Control Interface, Human Control Interface, and Operational Control Interface. Additional standardized interfaces will allow greater flexibility in allowing interoperability in a wider range of assets used by the national ranges. ❑

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Implementation of an Accelerated Assessment Process for the Terminal High Altitude Area Defense System: Initial Operational Test and Evaluation Supporting a Production Decision

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The Terminal High Altitude Area Defense (THAAD) Army Test and Evaluation Command (ATEC) System Team (AST), a key subcomponent of the larger Ballistic Missile Defense System (BMDS) Operational Test Agency (OTA), is consistently challenged with processing and analyzing an ever-expanding amount of data collected during missile defense testing. This article highlights the evolution of the best practices the THAAD AST adopted for the most complex missile defense test ever conducted. In order to meet reporting requirements imposed by the Director of Operational Test and Evaluation (DOT&E), Missile Defense Agency (MDA), and Army Aviation and Missile Life Cycle Management Command (AMCOM), the THAAD AST proactively designed weapon system instrumentation requirements, data collection and authentication procedures, and analysis plans necessary to exploit critical operational effectiveness, operational suitability, and survivability data to meet a constrained reporting timeline.

Key words: Ballistic missile; initial operational test and evaluation; pretest planning process; software-intensive weapons systems; Terminal High Altitude Area Defense system.

In April 2011, the Director of Operational Test and Evaluation (DOT&E), Dr. J. Michael Gilmore, tasked the Ballistic Missile Defense System Operational Test Agency (BMDS OTA) to develop a test concept to conduct an Initial Operational Test and Evaluation (IOT&E) of the Terminal High Altitude Area Defense (THAAD) weapon system *(Figure 1)*, an element of the BMDS (DOT&E 2011). The BMDS OTA briefed the test concept in May 2011 and developed an OTA test plan, which was approved by DOT&E and forwarded to the appropriate congressional defense committees (AEC 2011b). The BMDS OTA conducted Flight Test THAAD Interceptor-12 (FTT-12) (IOT&E) from August 10 through October 14, 2011, at the Pacific Missile Range Facility (PMRF), Kauai, Hawaii. The Missile Defense Agency (MDA) assisted with the execution to ensure appropriate compliance with the safety, data collection, and target management requirements.

This missile defense flight test highlighted the effects of the exponential increase in data collected during operational testing for highly complex, software-intensive weapon systems. This unrestrained growth of test data places additional burdens on the independent evaluators as acquisition decision authorities demand meaningful analysis with greatly reduced timelines. Compounding this situation is the constant pressure for the Test and Evaluation (T&E) community to increase efficiency from diminishing resources and reduced manpower pools. This article provides the T&E community insight into how the THAAD Army Test and Evaluation Command (ATEC) System Team (AST), a key subcomponent of the larger BMDS OTA, quickly collected, handled, processed, and analyzed the data from this $150 million missile defense IOT&E that generated over 15 terabytes of data. This was accomplished through a detailed pretest planning process using well-defined roles and procedures along with a robust set of software tools to process and authenticate the data down to approximately 2.5 gigabytes. The THAAD AST also reduced the normal ATEC report development timeline by one-third to

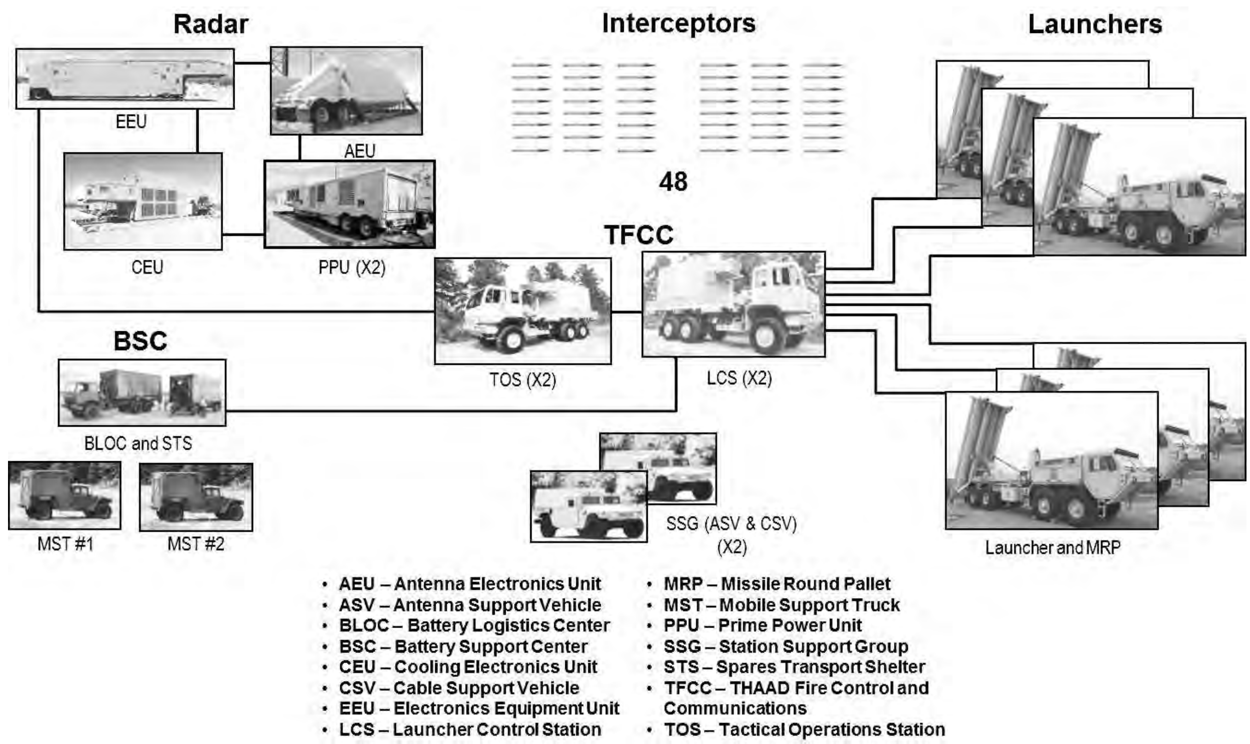

Figure 1. Terminal High Altitude Area Defense system major components.

expedite the final delivery of an assessment report to acquisition decision-makers, service leaders, and operational commanders.

THAAD mission and equipment overview

The mission of the THAAD battery is to protect the Homeland, deployed military forces, friends, and allies from short-range and medium-range ballistic missiles. THAAD provides the capability to conduct high endo-atmospheric and exo-atmospheric engagements as part of an Integrated Air Defense System (IADS) and the BMDS (DA 2011b). The THAAD system, shown in *Figure 1*, is a ground-based missile defense system consisting of the following components: missile round launchers, which serve as mobile, stable platforms for the missile rounds; a U.S. Army/Navy Transportable Radar Surveillance (Terminal Mode) (AN/TPY-2 [TM]) radar, which searches, tracks, and discriminates objects and provides updated tracking data to the interceptor; a THAAD Fire Control and Communications (TFCC) communication and data-management backbone, which links THAAD components together, links THAAD to external command and control nodes and to the entire BMDS, and plans and executes intercept solutions; and Peculiar Support Equipment including a Battery Support Center for logistics support (MDA 2011).

THAAD test and evaluation strategy

The OTA evaluation team used a Mission-Based Test and Evaluation (MBT&E) strategy to define the objectives of the IOT&E, tying the Measures of Effectiveness (MOE) and Measures of Performance (MOP) to the applicable warfighting functions and tasks as defined in the Army Universal Task List (DA 2011a) and evaluated against the performance attributes defined by the U.S. Army in the Capability Production Document (CPD) for THAAD. The CPD specifies performance attributes that the Army determined are necessary to support production, testing, and deployment of the current THAAD system (DCD 2009). The IOT&E mission was conducted under operationally realistic conditions with soldiers planning, deploying, emplacing, and operating the system using their Tactics, Techniques, and Procedures (TTP) (DA 2011b) to the maximum extent possible. The IOT&E was executed in two phases, as shown in *Figure 2*.

Phase one of the IOT&E was the ground phase, or deployment phase, and included THAAD deployment preparations, airlift, Missile Round Pallet (MRP) buildup, emplacement, and preflight test activities at the PMRF to include unit training with the Simulation-Over-Live-Driver (SOLD). SOLD is a government-owned system driver for the THAAD element. SOLD generates real-time, pulse-by-pulse

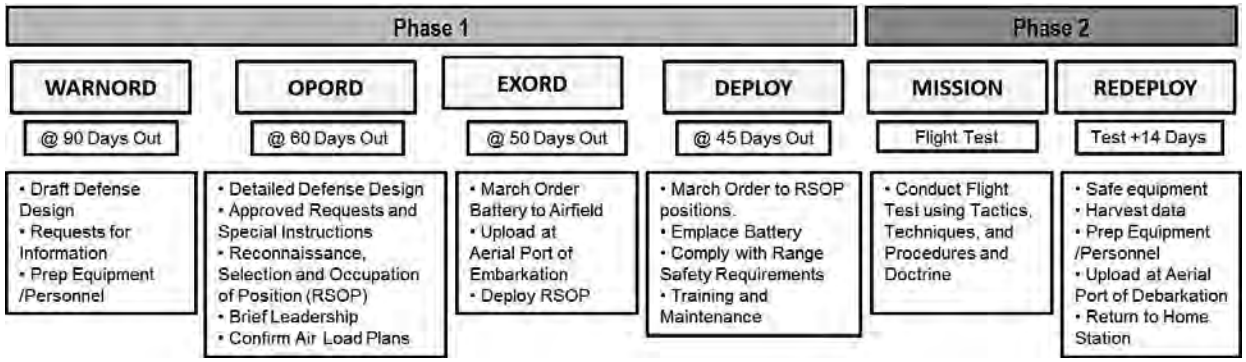

Figure 2. Flight Test Terminal High Altitude Area Defense interceptor-12 initial operational test and evaluation planning and execution timeline.

returns for radar waveforms including targets, missiles, environmental effects, and debris. The SOLD scenarios provide additional operational realism for the deployed soldiers during training periods and flight test campaign run-up activities. The THAAD unit deployed a Minimum Engagement Package (THAAD battery subset) from its Fort Bliss, Texas, home station via C-17 airlift and emplaced the THAAD system at PMRF, Kauai, Hawaii, in a tactical configuration (with exceptions to allow for range safety instrumentation and Launch and Test Support Equipment (L&TSE)). The soldiers operated the system during the entire flight test campaign. Phase two was the employment phase, where the THAAD unit was placed on alert and presented with two no-notice targets that drove the unit to conduct near-simultaneous engagements before transitioning to a follow-on simulated multiple threat scenario using SOLD to demonstrate continuity of operations. *Figure 3* graphically depicts the live event.

Data handling

In addition to extensive involvement of the THAAD AST in the IOT&E test design, it was also directly involved in the data instrumentation, collection, handling, authentication, and processing. To facilitate all evaluator requirements and ensure compliance with Title 10 requirements, an innovative approach to data management was implemented via a comprehensive Data Handling Plan (DHP) (AEC 2011a). The FTT-12 (IOT&E) DHP built upon lessons learned from a DHP originally developed to support the 2010 THAAD Limited User Test (LUT). In particular, the DHP provided

1. general data management responsibilities,
2. data flows and expected timelines for data delivery from the range to the end users,
3. high-level data item descriptions,
4. procedures and organizational responsibilities for data distribution and processing,

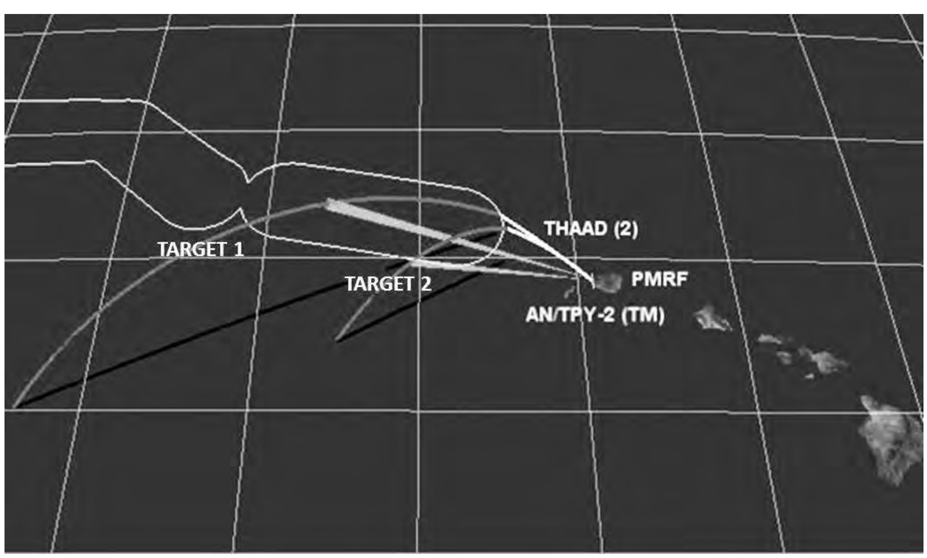

Figure 3. Flight Test Terminal High Altitude Area Defense interceptor-12 initial operational test and evaluation notional scenario.

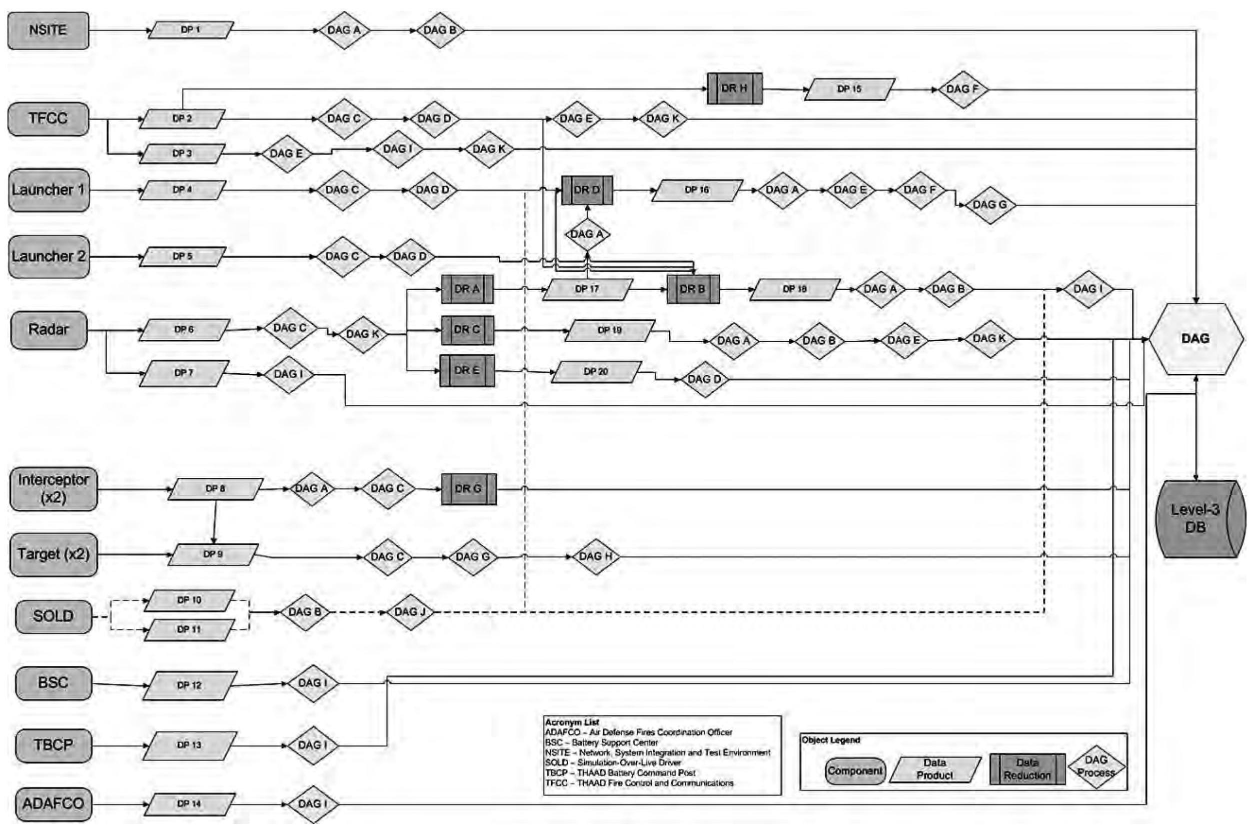

Figure 4. Flight Test Terminal High Altitude Area Defense interceptor-12 initial operational test and evaluation data collection and reduction process.

5. summary of security policies and procedures associated with data items, and
6. detailed procedures for data processing requirements.

The DHP was coordinated between the testers (in particular, the U. S. Army Operational Test Command (OTC) instrumentation crew) and the independent evaluation team. The resulting information in the DHP added a level of greater detail to the OTA test plan data management section to provide a common understanding of data processes and products between the tester and evaluator to ensure success.

Data flow and authentication

The data reduction process flow diagram shown in *Figure 4* is the heart of the DHP and represents four main areas: major instrumented THAAD components (shown in blue), data products created by the THAAD components (shown in green), automated and manual Data Authentication Group (DAG) preparation procedures (shown in orange), and automated and manual data reduction procedures (shown in red). Each block is explicitly defined in the DHP, complete with instructions for the OTC instrumentation crew, the DAG members, and the evaluation team. The entire data reduction process feeds the DAG activities that authenticate and certify that the data collected and reduced are suitable for analysis and evaluation. The DAG is a group of representatives from the testing, evaluation, user, and acquisition communities. Voting members were from ATEC, the U.S. Army Training and Doctrine Command Capability Manager Army Air and Missile Defense Command (user representative), and the THAAD and MDA Sensors X-Band Radar project managers (material developers). Additional observers came from the MDA Joint Analysis Team, MDA Truth Team, and DOT&E. The DAG authenticated that the event data were consistent, accurate, complete, nonbiased, and representative of the test events. The FTT-12 (IOT&E) DAG performed the checks identified in *Figure 5* as outlined in the data reduction process. Upon DAG authentication, the DAG chair approved the release of the complete level-3 database to the evaluation team and designated acquisition community agencies. The level-3 authenticated database consisted of data that have been checked for accuracy and arranged in a logical order for the purpose of analysis and operational evaluation of the event. Data sources for the level-3

A – File size/readability check
B – Data set complete check
C – MD5 checksum (data integrity) check
D – Tactical System Adjustable Parameter (SAP) check
E – Battle plan check
F – THAAD message consistency check
G – Track match check
H – Threat assessment check
I – Tamper check
J – Simulation stimulus consistency check
K – Software version check

Figure 5. Data authentication group checks.

database included data products generated by the reduction of level-1 "raw data" (including instrumented audio and video records, completed data collection forms and questionnaires, and test logs) and level-2 "processed data" (annotated, corrected, and filtered [delete/extract] instrumented data; and annotated and corrected data collection forms and logs) as defined in ATEC Pamphlet 73-1 (ATEC 2010b).

Test site data processing

To expedite the posttest processing timelines, the THAAD AST evaluation team deployed a customized server suite and accompanying laptops and workstations (as shown in *Figure 6*) to PMRF to enable the three core data processing analysts to begin the data reduction processes immediately after data receipt. The deployed test site computer equipment contained automated data reduction, processing, and analysis tools, allowing the evaluation team to perform all data reduction and DAG procedures as outlined in the flow

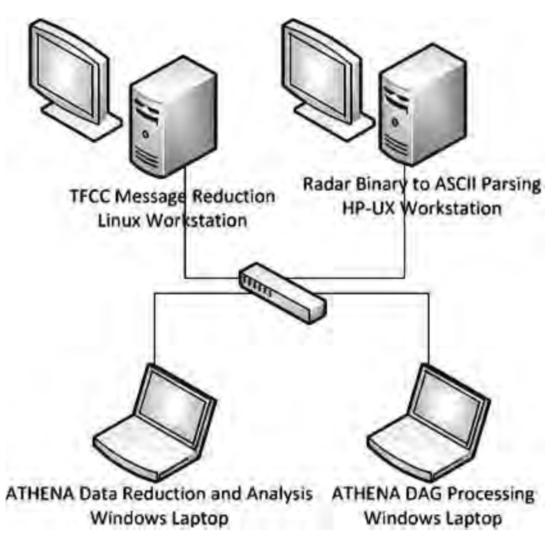

Figure 6. On-site computer network.

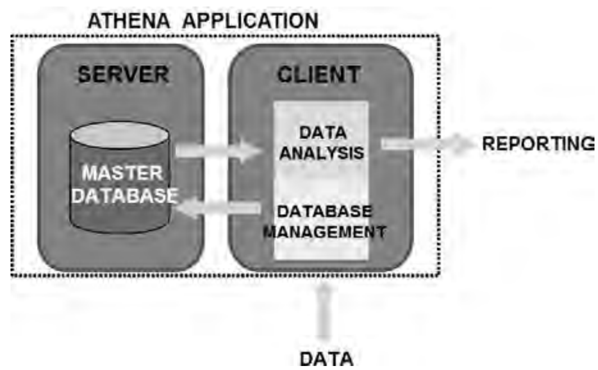

Figure 7. ATHENA client–server application design.

diagram immediately after OTC harvested the raw THAAD component data off the weapon system. The process was iterative throughout the entire test deployment timeline, and by the end of the test, over 15 terabytes of data had been collected and processed on site. The THAAD AST tools consisted of low-level binary to ASCII data conversion software along with a customized software application (ATHENA) developed by ATEC solely for the purpose of large-scale data management and analysis.

ATHENA evaluation application

ATHENA enabled the THAAD AST evaluation team to manage the multiple terabytes of test data produced, by providing the capability to import, process, reduce, analyze, and report on data from the FTT-12 (IOT&E) flight test and accompanying Modeling and Simulation (M&S) exercises. The data import engine of the application imports various raw file types (e.g., binary, comma-separated values (CSV), ASCII, XML, Microsoft Excel and Access, various image formats, and various video formats) into Microsoft SQL server databases across a Local Area Network (LAN), Wide Area Network (WAN), or across an Internet connection. Two types of importing are supported: special import format and general import format. The special import format is used for importing system-specific file formats, including the following THAAD and AN/TPY-2 data:

- Microsoft Access databases,
- Programmable Message Evaluation Tool (PROMET) (THAAD Fire Control and Communication [TFCC] message reduction software),
- Radar Logical Record Identifier (LRID) CSV files,
- binary journal logs from the AN/TPY-2,
- B-series messages (from the AN/TPY-2 to the BMDS Command, Control, Battle Management, and Communications [C2BMC]),

Format:	Binary
Frequency:	Daily
Post-processing:	None
Provider POC: Recipient:	Operational Test Command Instrumentation Personnel THAAD AST Data Manager
Content:	This data item includes raw unprocessed radar data in the form of mission log files in .mlf binary format and the data dictionary in ASCII format. The data dictionary is tied to the radar build and only needs to be provided once. For HOT mission, this data product will include both live and simulated data. This data product includes an MD5 checksum.

Figure 8. U.S. Army/Navy Transportable Radar Surveillance raw mission log files and data dictionary data product.

- J-series messages (Link 16),
- Pioneer (interceptor telemetry) output data, and
- test incident reports.

These import capabilities allowed the evaluation team to load data identified in the DHP into the FTT-12 (IOT&E) event database for further data processing to support the DAG and analysis activities.

The ATHENA software is divided into server and client components, as shown in *Figure 7*. The server component consists of one or more Microsoft SQL servers and ATHENA software overlays that extend the capabilities of Microsoft SQL server, along with a master database. The SQL server engine is scalable, secure, and allows multiple users in multiple sessions to input and process data simultaneously, while maintaining database integrity, and can manage the accessibility for different groups of users. ATHENA can also distribute databases across multiple servers for concurrent processing. Data processing involves applying scale factors and/or applying numerical analysis techniques and algorithms; executing automated or unplanned SQL queries and scripts; and building data analysis tables, charts, and reports.

The ATHENA client component main interface provides analyst visibility and easy access to all evaluation dendritic measures from the current and all previous events on a single screen. Additional interfaces provide server connectivity; data management; evaluation planning; database query and script development; math, physics, and statistical function development and execution; and template-based evaluation and assessment report outputs. The ATHENA client also provides low-level database interaction between the client and server, managing database connections, maintaining connection state, encrypting connections, and sending and receiving all ATHENA-embedded transactions and direct user transactions with the databases. The built-in query builder guides the user through developing SQL queries to be executed, saved, or automated. Any data tables residing in the application can be plotted in two or three dimensions, can be filtered using logic conditions or keywords, and can be saved or analyzed further. The expression builder graphic user interface allows the user to perform data smoothing, filtering, multi-state coordinate transformations, statistical analysis functions, state vector propagation, interpolation, and more, using simple drag-and-drop operations. Additionally, compiled Matlab functions can be executed from within the expression builder to allow for an almost infinite library of analytical routines, which are available to the analyst from within the ATHENA application without the need for a Matlab license. Users familiar with Microsoft Excel can complete their work from within the Excel spreadsheet and copy the spreadsheet directly into ATHENA for further analysis or reporting. Multiple instances of the client can be used simultaneously across multiple computers, connecting to one or more servers for distributed data processing.

ATHENA use in FTT-12 (IOT&E)

Data products and presentations were generated to support DAG and analysis activities for both phases of the FTT-12 (IOT&E). A variety of two-dimensional (2-D) and three-dimensional (3-D) plots, screen captures, and tables showing the correlation between truth and system performance, network communications throughput, requirements verification, and comparisons between Monte Carlo simulations and real events augmenting system performance analysis efforts were conducted. The following specific DAG and analysis processes were performed on site:

- determination of search methods, location, and timing for radar detection of targets;
- performance of statistical calculations of all objects tracked by the radar;

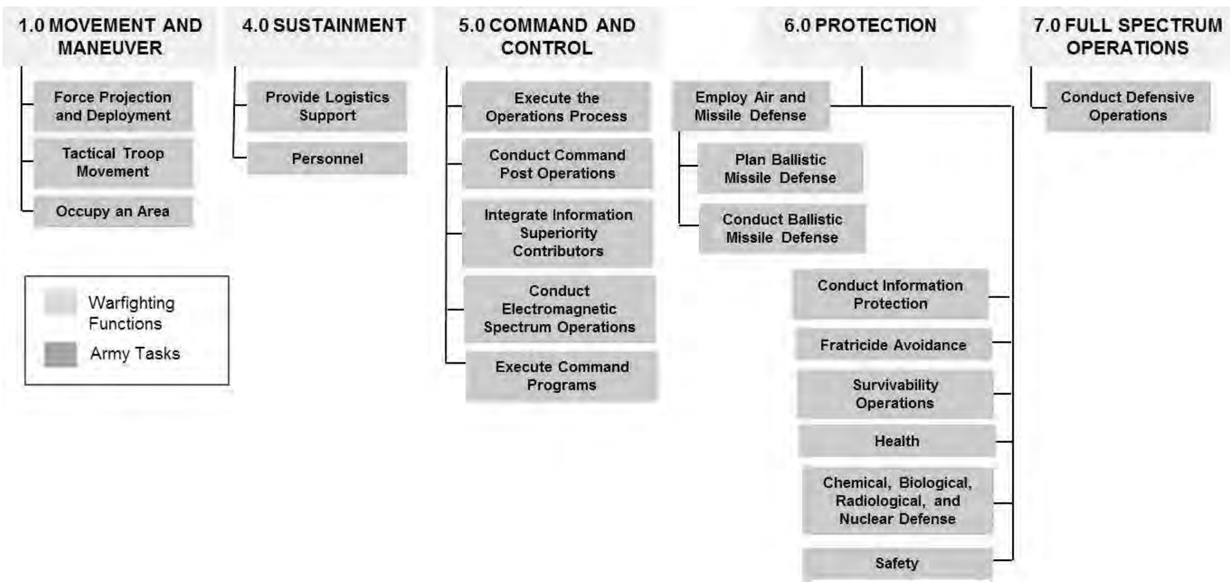

Figure 9. Warfighting functions and Army tasks identified for Terminal High Altitude Area Defense mission-based test and evaluation.

- ballistic state propagation of tracked objects to determine ground range and potential impact locations;
- generation of interactive 2-D and 3-D charts of altitude, position, signal-to-noise ratio, radar cross-section, interceptor flyout, target and interceptor velocity, and track-to-truth offsets;
- evaluation of all messages between components using instrumented data at the send and receive nodes to validate message transmission and latency;
- performance of consistency checks to ensure data had not been unintentionally modified or tampered with; and
- matching of range truth with radar track data and generation of offset calculations.

By capitalizing on the powerful data processing and automation capabilities of ATHENA, the evaluation input and presentation materials were more dynamic and informative, approaching a near-real time assessment and supporting development of a more thorough quick-look presentation of initial observations.

ATHENA radar data example

As an example of how the ATHENA automated software process was used in concert with the DHP, a particular data product is described in detail. The evaluator required raw data from the AN/TPY-2 radar to be collected by OTC to support specific measures of performance in the assessment plan. The evaluator captured this specific requirement in the form of a data product to be collected by OTC. The AN/TPY-2 Raw Mission Log Files and Data Dictionary data product from the DHP is shown in *Figure 8*.

OTC instrumented the AN/TPY-2 radar by directly connecting a network switch inside the electronics equipment unit to the collocated OTC data harvesting shelter. Prior to the radar operator shutting down the radar at the end of daily operations or upon test director request, a Linux-based computer inside the OTC shelter would execute data harvesting scripts to collect the binary log data from the radar and place it on an external hard drive. OTC immediately presented this hard drive to the evaluation team to implement the data reduction and DAG procedures identified in *Figure 4*. In the case of this data product, the DAG C procedure, MD5 checksum (an algorithm used to check data integrity) was generated to verify validity of the data received. Next, data reduction procedures A, C, and E were invoked using the radar binary-to-ASCII conversion software and scripts residing on the Hewlett Packard UNIX (HP-UX) workstation shown in *Figure 6* to convert mission log file data to a readable format. All data reduction procedures were provided as a series of step-by-step instructions for the analyst to follow. Once these procedures were complete, new data products were generated as outputs and these products entered another series of DAG procedures. For example, data reduction procedure A generated the data product containing Missile-Radar and TFCC-Radar Message Log Files in a specialized format, which was an input to data reduction procedure B, which generated the Component Message Log data product. This data product became the compilation of all message data between THAAD components during the test, and through the use of ATHENA residing on the two laptops, the remaining DAG procedures were automated with summary results provided in a series of charts and tables. These results supported DAG checks and provided initial insights to the evaluators and analysts for quick-look development.

Products and reporting

The THAAD AST was composed of cross-functional performance, lethality, M&S, Manpower and Personnel Integration (MANPRINT), integrated logistics support, Reliability, Availability, and Maintainability (RAM), interoperability, and survivability analysts. Team members that had participated in the new equipment training along with the soldiers provided additional operations expertise. ATEC policy defined in ATEC Pamphlet 73-1 provides a standard timeline of 10 days between final data collection and delivery of the level-3 database to the evaluator (ATEC 2010b). For FTT-12 (IOT&E), the OTC instrumentation team provided final data harvest within approximately 2 hours for digital data and within 12 hours for the remaining video data. The THAAD AST data processing analysts started the automated procedures for overnight data processing resulting in a level-3 database ready for DAG authentication. Additionally, THAAD AST evaluators and analysts were able to use the information available in the charts and tables generated by ATHENA to develop a quick-look briefing highlighting the initial evaluation team observations. The observations were categorized according to the warfighting functions and Army tasks following the MBT&E format shown in *Figure 9* (ATEC 2010a).

ATEC published a THAAD Operational Test Agency Milestone Assessment Report (OMAR) in May 2011 to support a THAAD Materiel Release Review Board for the first two THAAD units (ATEC 2011); this board was subsequently rescheduled to accommodate additional safety testing. During the period of additional safety testing, several significant activities including a major software update, a system reliability demonstration, and the IOT&E occurred, necessitating an update to the OMAR. The THAAD project office requested that THAAD materiel release stakeholders expedite the delivery of their documents used by the review board (DA 2010) to meet the rescheduled February 2012 review deadline. The THAAD AST completed the data analysis of the FTT-12 (IOT&E) data, along with reliability data from the July 2011 Reliability Confidence Test, and consolidated the findings and recommendations in the January 2012 ATEC FTT-12 (IOT&E) Operational Assessment and THAAD OMAR Update (ATEC 2012). This operational assessment provided the current ATEC assessment of the ability of the THAAD system to perform its combat mission by warfighting functions and Army tasks. Findings from the ATEC reports directly contributed to the February 2012 DOT&E THAAD and AN/TPY-2 Radar Operational and Live Fire Test and Evaluation Report, which provided an assessment of the adequacy of THAAD testing and the operational effectiveness, suitability, and survivability of the THAAD system and the AN/TPY-2 radar (DOT&E 2012).

Figure 10. Terminal High Altitude Area Defense system in action.

Future testing

MDA is planning a Flight Test Integrated (FTI-01) of multiple BMDS elements including Aegis, Patriot, and THAAD as a precursor event for the DOT&E-directed Flight Test Operational (FTO-01), the first operational flight test of the system-of-systems BMDS. *Figure 10* shows a THAAD missile round launcher firing an interceptor during a flight test. Multiple BMDS upper and lower tier elements are scheduled to participate in FTI-01 and FTO-01, increasing the complexity beyond the single element FTT-12 (IOT&E). The THAAD AST will build on the procedures and tools developed and successfully exercised during the FTT-12 (IOT&E) to support

BMDS OTA participation in FTI-01 and execution of FTO-01.

Conclusion

By developing sound data handling and analysis plans prior to test initiation, evaluators and analysts can implement streamlined data collection methodologies that directly feed automated tool sets to speed the pace of data authentication, compression, and analysis. Lessons learned from FTT-12 (IOT&E) and efficiencies gained through these demonstrated processes will be applied during FTI-01 and FTO-01, enabling the BMDS OTA to rapidly analyze the data and report the T&E results (DOT&E 2010a, DOT&E 2010b). This will ensure the BMDS OTA meets the common Department of Defense goal of rapidly providing key test results to program managers, service leaders, and operational commanders. ❑

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Using Model Based System Engineering in Flight Test

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Advanced modeling techniques, such as System Engineering Modeling Language (SysML) and applications of advanced architecture techniques (Department of Defense Architecture Framework [DoDAF], Ministry of Defense Architecture Framework [MODAF], and UML Profile for DoDAF & MODAF [UPDM]), are moving forward in their applications to bring value to the aerospace enterprise throughout the community. The system engineering community is leading much of this effort by adopting new techniques such as model based systems engineering (MBSE) to enhance the value of the systems engineering portfolio in traditional development of systems such as concept of operations, requirements development, detailed design, and integration, i.e., the systems engineering "V." Traditionally, flight test has not been at the forefront of the application of new modeling techniques to their discipline. This article will demonstrate the benefit of using MBSE techniques for the development of enterprise flight test architecture for an advanced unmanned combat air vehicle system. It will highlight the use of MBSE and SysML as well as the application of the DoDAF V2.0 to the flight test enterprise.

Key words: Flight test; MBSE; SysML; DoDAF; MODAF; UPDM; J-UCAS; system engineering; model-based test.

As the complexity and evolution of advanced aerospace systems have challenged the enterprise to develop and build, the test community has strived to keep up with the technical challenge of testing these new capabilities. Advances in instrumentation and communications have improved the enterprise's ability to collect large quantities of data and provide real-time telemetry to the testers. Adding to the test enterprise's challenge of keeping up with the newly fielded systems in basic flight test, many legacy systems are also being updated with new netcentric improvements in communications and interoperability to complement the development of new precision weapons. Countering the demands for thorough developmental tests to ensure that contracted systems meet their requirements, there is pressure to keep the testing to a minimum to control costs. The ability to design the right collection of limited experiments to ensure the system will do what it is supposed to do becomes the illusive prize.

Moore's Law, Metcalfe's Law, and the Flight Test Challenge

Starting in the mid-1960s, two information technology engineers put forth empirical observations that would prove prophetic in the chaotic development of technology that has exploded in recent years and does not look to taper off in the near future. Gordon Moore, a cofounder of Intel, put forth the prediction that the quantity of transistors on an integrated circuit would double every 1 2 years (Alberts, Garstka, and Stein 2000). Many thought that his predictions would not last out the century. In fact, his exponential estimation has steadfastly held true and looks to continue for the near future, overcoming technical and cost challenges with innovations in silicon development and cooling technologies *(Figure 1)*. Slightly later in time, Robert Metcalfe put forth the heuristic idea that the value of compatible information nets was proportional to the square of the number of users (n^2) which can be represented by (n 1)*n/2 (Alberts, Garstka, and Stein 2000). Metcalfe's original work was associated with networks of faxes or email but has found use in the description of netcentric effects within the Department of Defense (DoD) (Alberts, Garstka, and Stein 2000). Early analysis of the effects of network centric warfare were introduced by Alberts, Garstka, and Stein in a series of manuscripts published by the Command and Control Research Program starting in 1999. The resulting revolutionary change in warfare within

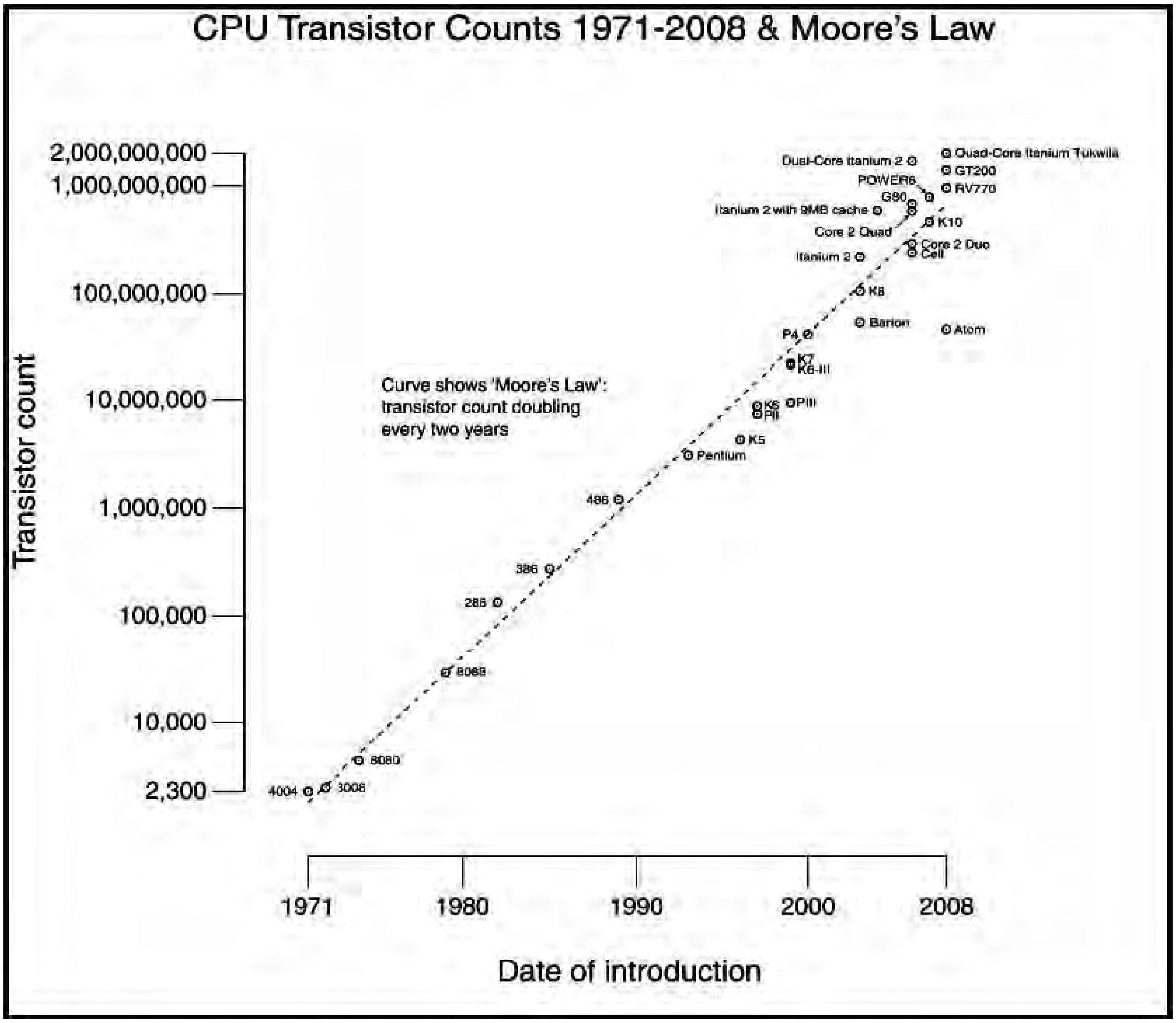

Figure 1. Moore's Law.

DoD has greatly increased warfighting capability but has presented a serious challenge to the management and execution of the explosion of technology and application of increased capabilities to new and existing platforms. Therein lies the challenge for the tester, who is at the end of the development cycle.

Testing the "Net" in NetCentric Operations and other challenges

Traditional testing of a developmental system, such as a communication system, a weapons systems, or an aerospace system that has multiple technologies at work, becomes problematic if one looks at the inverse of Metcalfe's law, which states that the potential locations that a net can break is also proportional to the square of the nodes that are connected. To assess each "leg" of a beyond-line-of-sight satellite network that has multiple nodes *(Figure 2)*, trials would need to test each connection. If the system under test is the satellite communications (SATCOM) itself, a separate SATCOM net, such as commercial IRIDIUM, would be needed to act as the test coordination net. The multiple

Figure 2. JUCAS network.

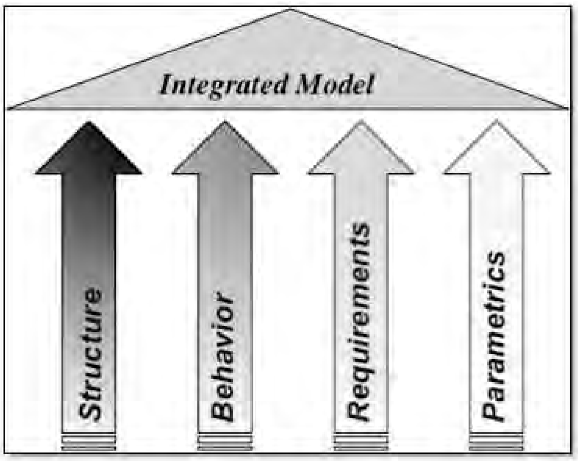

Figure 3. MBSE 4 pillars.

node-test challenge requires the enterprise to optimize limited and expensive test assets. To lend order to the ensuing test chaos, a new way of thinking needs to include a Test Enterprise Architecture approach using modern tools such as model based systems engineering (MBSE) and enterprise architectures.

First, let us discuss how MBSE can or should be used in the test domain. For design, we know that building models of systems is a natural engineering approach to describing a design. In test, one of the first items that is tested is a wind tunnel model of an aircraft. We build computer simulation (models) of our software systems as well. In the system engineering side of the house we are now starting to look at the model approach, a more abstract view of the design. The development of MBSE has been tied to the development of a modeling language that can be used to describe various aspects of the system engineering approach, SysML (System Engineering Modeling Language), put forward by the Object Management Group (OMG) and INCOSE. In the test domain it is the same system engineering principles applied to the test. From a review of the MBSE approach there are four pillars of MBSE *(Figure 3)*, and they are groupings of representations of the system under examination.

Review of MBSE and SysML

Since the production of the standard in 2005, a number of excellent publications have been produced by various authors on both MBSE and SysML *(Figure 4)*. The OMG has also produced a tutorial on both tools that has been revised several times during the period. This discussion will just touch on the basics of the method and language. SysML is a "profile" of the universal modeling language (UML). UML has been in the forefront of software development and a diagramming language (also an OMG standard). SysML was an initiative of the International Council on Systems Engineering (INCOSE) and the OMG and has its basis in the UML. SysML utilizes some of the same diagrams as UML (three diagrams), some that are modified from the UML (three diagrams), and two diagrams that are new. The major significance of adopting the OMG standard has been the development of Computer-aided Software Engineering (CASE) tools for use in developing integrated models. For this analysis MagicDraw 16.7 by NoMagic, Inc.

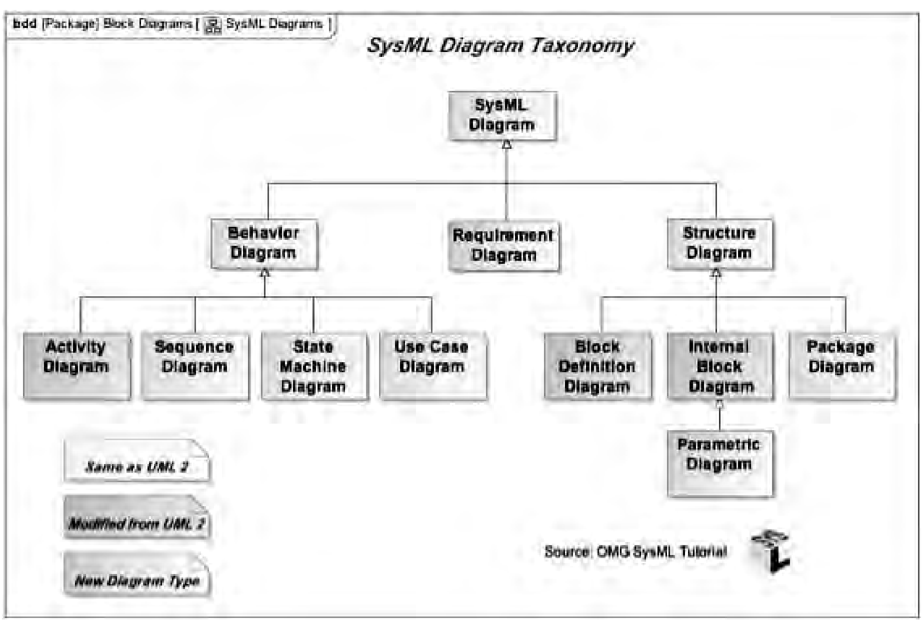

Figure 4. SysML taxonomy.

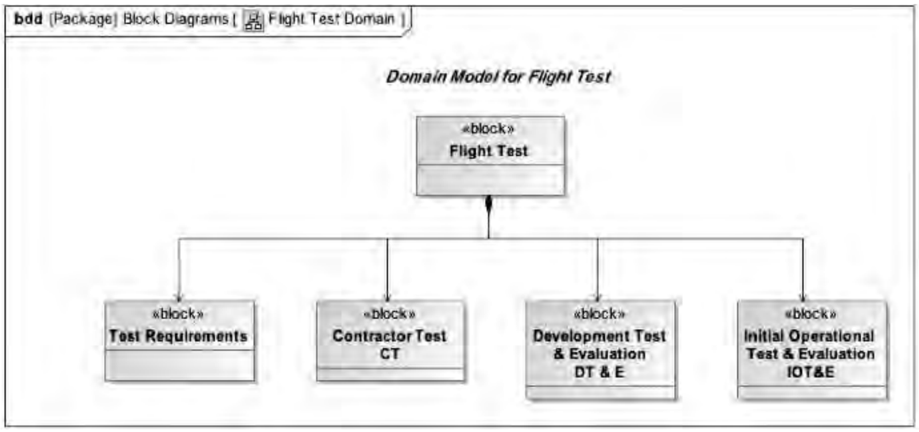

Figure 5. Flight test domain.

(MagicDraw 2011) was used. As an aside, another major development in the adoption of the OMG standard for SysML was the ability for the CASE tool vendors to be able to adopt a profile for the Department of Defense Architecture Framework (DoDAF) utilizing the SysML as the underpinning modeling language. This makes diagramming the test domain more efficient by reuse of existing top-level architecture products from original acquisition documents to the test domain.

Flight test domain

A technique in MBSE is domain modeling. This is simply diagramming the "structure" of the domain so that an early grouping of what's inside and what's outside of the domain of interest can be made. In the case of flight test there can be many groupings depending on the perspective of the stakeholder and what stage of the planning the enterprise is engaged in. In this example we have chosen to examine a developmental test as part of the larger test domain utilizing the "block diagram" from SysML. Block diagrams can be used early in our planning along with "package" diagrams for quickly viewing early test planning. Once again, the use of a CASE tool helps with planning as a way to have the enterprise "visualize" its own structure and the maturity of the planning effort. At early stages of the effort, a solid "Enterprise Architecture" effort using a framework such as Zachman (Zachman Architecture Framework; Zachman 1968 2008) or the DoDAF will help the enterprise in the planning.

In *Figure 5* a block diagram (structure) is constructed for the flight test domain. At the highest level of abstraction, this is simply a grouping of the "what" in the Zachman Framework. At this time it is important for the enterprise to understand that each of these groupings must be viewed carefully to ensure that the taxonomy is normalized (one and only one reference). When we speak of "what" (Zachman row), we understand that we are talking about one of the fundamental primitives. In the case of developmental test and evaluation and initial operational test and evaluation, the taxonomy can also refer to "who" (command), which is a different "row." The system engineer/enterprise architect's job is to ensure that discipline in the diagramming and planning taxonomy is continuous throughout the enterprise.

At a higher level of abstraction *(Figure 6)*, we can view the block diagram of the entire test domain defined by DoD (Defence Acquisition University Test 101). As we continue planning, we can generate a finer level of decomposition to develop our domain model of our test enterprise. As previously stated, the concept of domain modeling is a powerful tool in the initial start-up of any project and applies well in the initial planning phases of the flight test enterprise. The primary diagrams are the Package Diagram and the Block Diagram. In the case of package diagrams there are additional relational features such as imports,

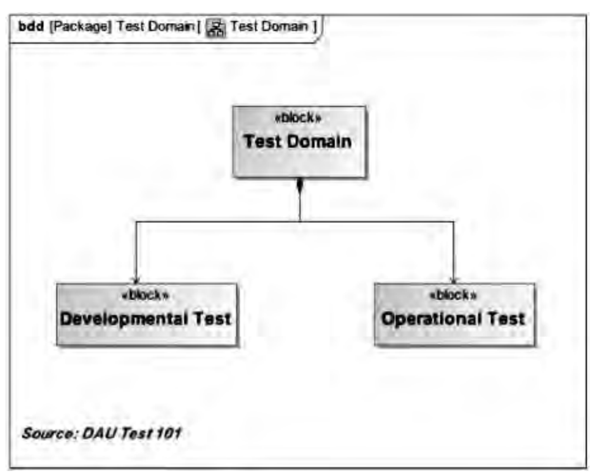

Figure 6. Test domain.

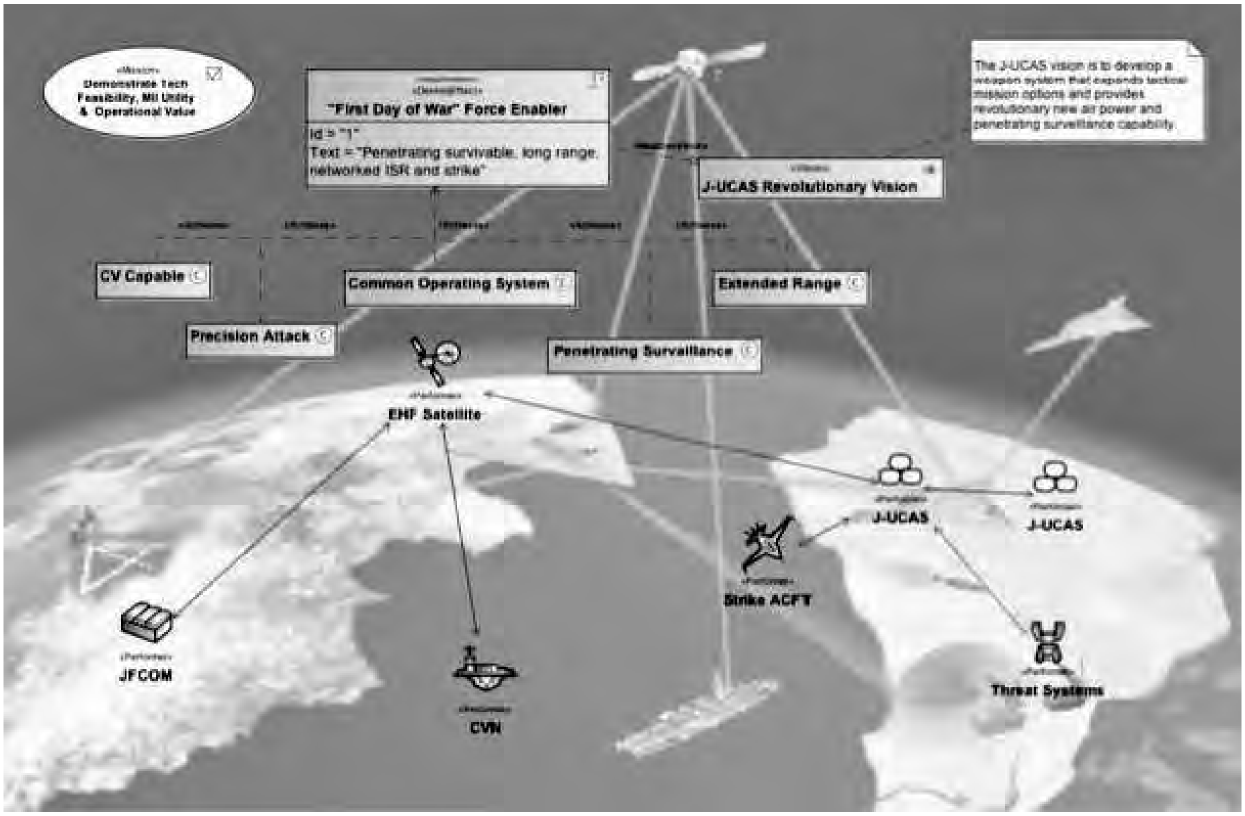

Figure 7. DARPA J-UCAS OV-1.

conforms, and views that can help the engineer organize the project early. These features and their uses can be found in the most excellent Friedenthal book (Friedenthal 2009) and the OMG tutorial.

Example diagrams from DARPA J-UCAS

To provide some examples of MBSE and SysML uses for describing the system and for test planning, the Defense Advanced Research Projects Agency (DARPA) publicly released joint unmanned combat aircraft system (J-UCAS) (X-45 and X-47) has been selected. All of the relevant information was been drawn from the publicly accessible website (http://www.darpa.mil/default.aspx). The program is no longer an ongoing DARPA project and has since transitioned. The model was constructed using MBSE methodology and a combination of SysML and DoDAF 2 diagram using MagicDraw 16.7 with the SysML and Unified Profile for DoDAF/MODAF modules. This afforded an easy creation of both types of diagrams without having to switch between perspectives in the model.

The initial diagram to construct was the DoDAF's OV-1 or high level operations concept *(Figure 7)*. In this case the diagram is constructed to show the top-level node relationships between air, space, and sea. From a test perspective we can start to visualize the types of test environments that the system under test may encounter, namely, autonomous, beyond-line-of-sight, tactical shipboard operations. Very quickly, the complexity in the test enterprise can be readily identified. The background was a DARPA-generated viewgraph graphic that the modeled OV-1 was placed on. Whereas the DARPA cartoon was meant to convey the idea of the system's use, the modeled OV-1 has a real integrated relationship internal to the model. This is actually the best of both worlds. In the next diagram the operational resources are displayed along with the most important "need lines." Of the DoDAF 2 diagrams, the OV-2 is of a critical nature because it highlights the interoperability challenges by diagramming the true nature of communication and flow requirements. In most cases it is advisable to start with the OV-2 and work "outward" from there using a spiral approach. This is where MBSE methodology pays dividends. As the engineer works the DoDAF 2 integrated model in a spiral manner (OV-2, OV-5, OV-1, etc.), the corresponding use cases, activity diagrams, and requirements diagrams can be similarly worked in the same spiral manner. An early opportunity to "drill down" to a deeper level of decomposition affords itself to the enterprise that may need diagrams

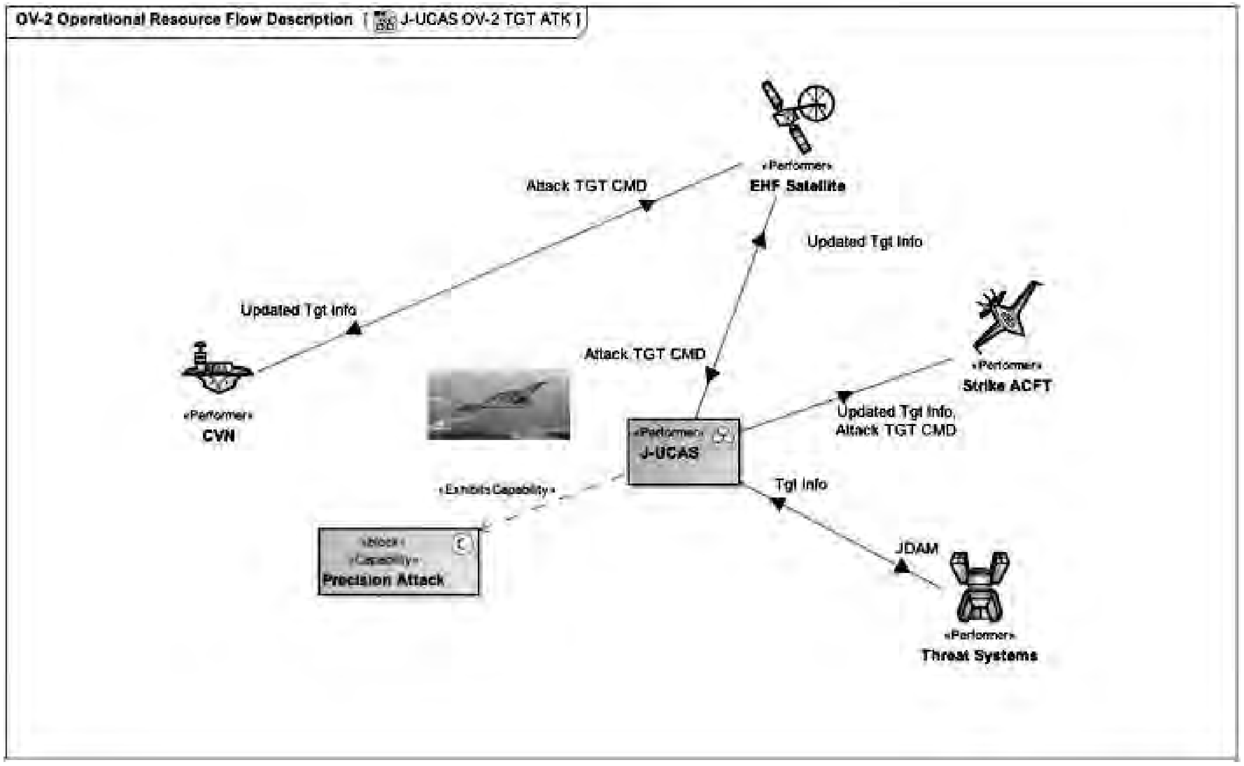

Figure 8. DARPA J-UCAS OV-2.

readily available to support early acquisition decisions. This is an important point; the DoDAF enterprise architecture and attendant SysML diagram are powerful tools for communication within the enterprise. Early communication of the program's structure, complexity, behavior, and requirements to the stakeholders is critical to the successful execution of the program.

In *Figure 8* we drill down to the OV-2 that is important to the test community. As we instantiate more detail into the model, identification of critical test support assets become apparent. For example, the resources necessary to conduct this test include beyond-line-of-sight (SATCOM) communications and available satellite networks. Often the availability of these assets can require long lead times (years) to identify and get the required priority from other agencies. Late identification of these support assets can be disastrous to the test timeline.

At this point it is appropriate to examine specific SysML diagrams to support the structure and behavior of the system. The first structural diagram *(Figure 9)* is a top-level block diagram of the system. Similar to the domain modeling but specifically attributed to the system itself, we look at the top-level breakdown of the J-UCAS system design. Block diagrams are an

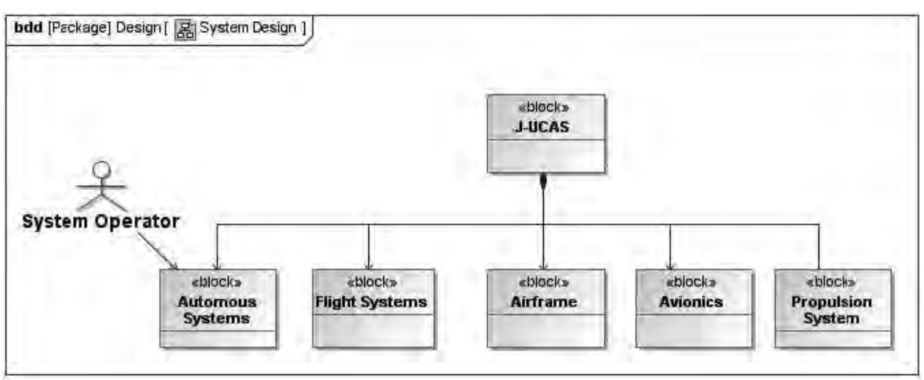

Figure 9. System design.

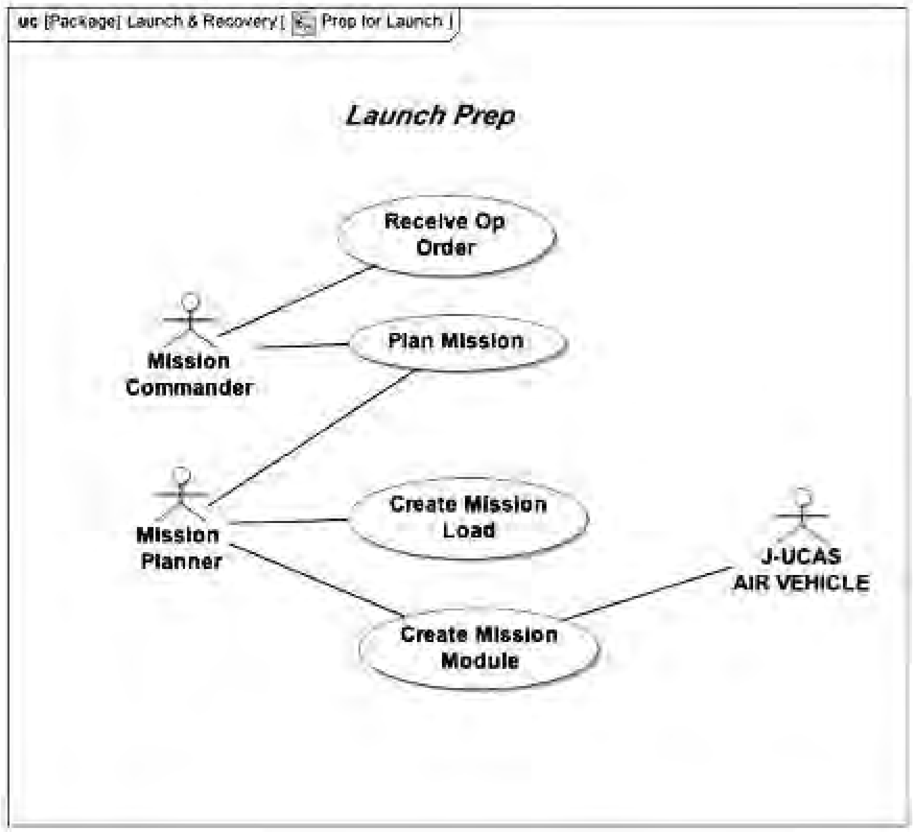

Figure 10. Launch prep use case.

important tool for describing structure and structural relationships. Further decomposition can be made with the use of an internal block diagram, but in the case of an upper-level discussion, the block diagram is sufficient for this use. Also noted, the "System Operator" represented as an "actor" can be used with its attendant relationship between the "Autonomous Systems" block in the design. This is a useful graphical representation that simply highlights that there is a relationship between the actor and the system.

It is now appropriate to examine some of the use cases that will help identify behavior and requirements for the system. In the case of software development, use cases are a very powerful tool in understanding how the system is intended to perform from the perspective of the user of that system or "actor." Use cases are often the focal point for software testing. In the case of flight test the use case can also be used to develop the test requirements, which helps to identify the test strategy in development of the test and evaluation strategy and the subsequent Test Plan. As the test team initiates its early planning, having use cases available for collaborative interaction with the test requirements working group helps the test team focus on the six principle interrogatives from Zachman (who, what, where, how, when, and why). Once again, early identification of critical assets and tasks improves chances for success. Late identification of the same incurs great risk. In *Figure 10* a use case is shown for mission preparation for launch. A number of important use cases should be developed early in the process.

Along with the use case, the corresponding activity diagram *(Figure 11)* is developed to further elaborate what needs to be accomplished by whom and in what sequence. Typically, the actors are identified in "swim lanes," and activity and objects are identified. For further timing information a corresponding "sequence diagram" and/or a "state diagram" can be constructed.

Summary

The use of advanced tools such as MBSE and its SysML modeling language has increased for development of advanced aerospace systems and their acquisition. The corresponding popularity in the test community has not reached the same levels. The application for the use of DoDAF 2 as an enterprise architecture tool with MBSE methodology shows promise for early identification of test requirements, tasks, assets, and collaboration throughout the test enterprise. For this article a simple integrated model

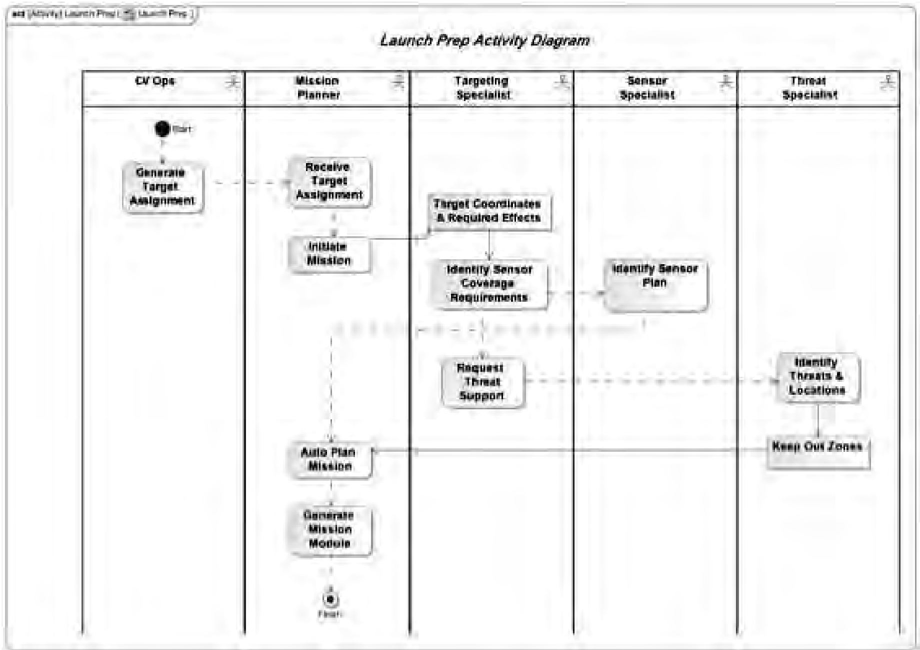

Figure 11. Launch prep activity diagram.

was constructed from publicly released information, allowing for an initial start on a model of an advanced autonomous vehicle enterprise. ❑

Biography

FRANK ALVIDREZ is a Certified DoDAF Enterprise Architect currently working at Edwards Air Force Base as a Sr. NetCentric Flight Test Engineer. He specializes in advanced architecture techniques and their applications to research and development projects. He currently supports a number of major Aerospace efforts in Flight Test, Program Management, Enterprise Architectures, NetCentric Data Strategy, SysML, and DoDAF/UPDM Training. He is a graduate of the FEAC DoDAF Enterprise Architecture Course as well as Defense Acquisition University Executive Program Managers Course. He worked 20 years for the Lockheed Martin Skunkworks and worked a number of projects to include B-1B, B-2A, B-52, X-35, Navy MRE UAV, YF-22, F-16, C-130, A-4AR, U-2, SR-71, OV-10A/D, and other classified projects. He currently teaches advanced DoDAF courses using the DoDAF Profile in UML and SysML. He is a member of the Association of Enterprise Architects (a|EA), INCOSE, and a number of other professional organizations on System Engineering and Enterprise Architectures. E-mail: frank.alvidrez@verizon.net

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Multidisciplinary Strain Analysis of Textile Materials

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In general, textile materials are subjected to repeated strains of various forms during their manufacture and in their use, both industrial and domestic. This will influence their characteristic behavior. In the spinning process the fibers are subjected to a considerable amount of strain, resulting in fiber breakages. Even the fibers that are not ruptured are strained to an extent that significantly alters their behavior in yarn and fabric structures. The yarn in many textile operations is subjected to sudden stresses at high speeds; for instance, during the insertion of weft, whether by projectile or air jet, the yarn has to stand accelerations many thousands times greater than that due to gravity. Even in the traditional apparel end use, yarns and fabrics undergo stresses and strains that are significantly different from those applied in the standard yarn and fabric tensile tests. Hence an understanding of the cumulative impact of various forms of strain on the behavior of textile materials is a matter worthy of study.

Key words: Fiber; impact loads; Kevlar; strain analysis; tensile properties; yarn strength; Zylon.

The tensile behavior of spun yarns is a function not only of the fiber characteristics, such as length, fineness and strength, but also of the nature of fiber arrangement in the yarn. Thus yarn structural parameters, in addition to physical properties of the fibers, play a significant role in determining the tensile behavior of spun yarns, namely strength, modulus, elasticity, yield stress, work of rupture, and elongation properties. In recent years, many research workers have reported on the properties and performance aspects of yarns and fabrics that represent the new spinning systems. Even in the traditional apparel end use, yarns and fabrics undergo stresses and strains that are significantly different from those applied in the standard yarn and fabric tensile tests. Thus the tensile behavior of yarns evaluated under standard test procedures cannot always be expected to fully reflect the performance of their end products. More recently, researchers have shown that yarn strength evaluated at shorter gauge lengths is a better predictor of fabric strength than is strength evaluated at the standard (300 mm) gauge length. The importance of understanding the stress strain response of yarns and fabrics under nonstandard loading conditions can be further appreciated if one considers the ever-expanding range of their nontraditional applications aircraft, space vehicles, automobiles, reinforced composites, and a host of other industrial uses.

In understanding the complex structural-deformation behavior of a textile-reinforced composite, experimental local-strain and local-damage analysis prove to be the valuable techniques. In the perspective of experimental local-strain analysis, due to the heterogeneity of textile composites, classical electrical-resistance strain gauges do not have adequate spatial resolution; only a full-field strain-measuring technique with high spatial resolution and strain sensitivity can be applied to determine local surface-strain profiles. The local strain measurements obtained from the full-field method will provide a qualitative as well as quantitative understanding of the maximum and minimum values of local strains, and their corresponding locations on the laminate traction-free surface. However, there are few publications that have studied the effect of adjacent layers in the laminate on the local strain behavior. In addition, some studies have suggested that the surface strain field is a representative strain field for all layers, which may not be a reliable assumption. As adjacent layers try to suppress the yarn-undulation effects of the laminate inner layers, they cause the local strain profile or gradient inside the laminate to vary considerably compared to the surface layers'. Moreover, it is important to understand the maximum and minimum strain locations, due to the fact that these locations indicate the probable damage-initiation zones.

Tensile straining

Standard measurement of yarn strength is executed on a gauge length of 500 mm. A clamped yarn breaks in its weakest place according to the so-called principle of the weakest link, and this strength value is assigned to the whole length. As the test sample is gripped at the two ends and maintains that static state during the testing process, the evaluated tensile properties are often treated as static tensile properties, and the strength measured by single-thread tensile one-test method is referred to as static yarn strength. Among the measurable tensile properties of spun yarn, considerable attention has been paid to the evaluation of tensile strength and breaking extension, as these properties of the spun yarns influence the efficiency of weaving and knitting machines and the quality of the fabric produced. However, the tensile strength and breaking extension of the yarns are not unique functions; they depend on the rate of extension and gauge length. From the practical point of view, it is desirable that the effect of operating speed and gauge length on the tensile properties of yarn be known, so that the results obtained from instruments running at different speeds and gauge lengths can be correlated and compared.

Tensile tests at high strain rates

In many technical applications, fiber-reinforced composites with textile high-performance fibers made of carbon or glass are being used. The fibers' high strength and stiffness is due to their physical and chemical characteristics. It is necessary to guarantee a high safety level under all possible loading conditions. Beside the usual service loads, the topic of extreme loads that work along with high forces and high impact velocity is of increasing importance. For these so-called impact loads, the processes within the structural components have to be analyzed, and material models suitable for prognoses should be derived from them. The existence of suitable test machines and test methods is a prerequisite for that, yet for filament yarns they are not state-of-the-art. Hence, tensile tests with high strain rates on filament yarns are performed on standard high-speed tensile testing machines. This leads to problems in analyzing and interpreting the results, and therefore it is necessary to develop special testing machines for filament yarns.

In the field of composite material, the topic of impact loads has been gaining more and more importance due to increasingly complex constructions and constantly increasing safety demands. One current topic is energy-intensive loads that occur suddenly and only temporarily, as in impacts or explosions. In this context, high tensile forces develop in the textile reinforcements embedded in the composite during impact times of micro- or milliseconds. Accordingly, the textiles have to absorb high strain rates and therefore need a high energy-absorption potential when deformed. In this case, the material behavior does not correspond to the known behavior under static and quasistatic loads. The development of suitable calculation and measuring models under such impact loads demands a detailed analysis of the processes occurring in the material and an exact knowledge of the failure mechanisms of the textile structures responsible for the transfer of the tensile forces.

Dabboussi, Dooraki, and Nemes (2003) worked to fabricate an instrument for testing yarns at high strain rates. Their report contains a description of a Hopkinson bar device, which had been designed specifically for the testing of yarns at high strain rates. The Hopkinson bar consists of a gas gun, striker/incident-bar assembly, transmitted bar assembly, and attachment mechanism. The design of the yarn-attachment mechanism is particularly challenging, since a method must be found that does not allow the yarn to slip and at the same time does not cause premature failure. In addition, the attachment must result in a relatively small gage section. Several attachment-mechanism designs are presented. The final design uses a combination of mechanical and epoxy means of attachment, and is shown to be quite robust and give repeated results. The Hopkinson bar device was demonstrated by testing Kevlar KM2 yarn. Specimen designs consisting of both four and six yarns are used. To assess the rate-dependent behavior of the yarns, quasistatic tests were performed on a hydraulic test machine using the same yarn-attachment mechanism.

I. H. Hall (1964) studied the tensile properties of textile yarns at high strain rates. Stress strain curves have been determined at a very high rate (330 sec. 1) and at a normal rate (8.3×10^{3} sec. 1) of straining for a range of lightly twisted yarns, covering all commercially important fiber-forming polymers. From these curves, breaking stress and extension, energy to rupture, initial modulus, and critical velocity are all obtained. Results are presented in detail to assist in the selection of fibers for applications where rapid extension is likely. At a high rate, the breaking stress is always greater and, with one exception, the breaking extension less than at normal rates. The energy to rupture increases with rate for wet-spun fibers and, with one exception, decreases for thermoplastic. The variation in magnitude of these changes is considerable even among fibers from the same polymeric base, emphasizing the importance of testing at a rate comparable to that encountered in use. Similar experiments performed with three of the yarns highly twisted have shown that the ranking of the yarns according to a particular property could be altered by the insertion of twist. The stress strain curves of the material are used to predict the curves for the twisted yarn, following a theory of Treloar and Riding. At the normal rate, agreement with experiment was fairly good, but it was much worse at the high rate.

Marques et al. (2004) studied the tensile behavior of textile yarns at high speeds. This is a problem of great practical interest. Higher speeds induce higher strains and, consequently, a higher probability of yarn breaks. In order to ensure acceptable quality even at the highest spinning or weaving speeds, tensile instruments and testing conditions have to be improved. Therefore, we have developed a new high-speed dynamometer and a new method to subject yarns to strain rates similar to those found in current textile operations. We use this high-speed dynamometer to investigate the influence of high strain rates on the tensile properties and fracture morphology of a technical viscose multifilament yarn.

Analysis of spun-yarn failure

The phenomenon of spun-yarn failure is strongly dependent on the yarn structure, namely the configuration, alignment, and packing of the constituent fibers in the yarn cross section. The structure of a yarn is solely determined by the methods of consolidating the fibers. In a particular study carried out by Ghosh, Ishtiaque, and Rengasamy (2005) ring, rotor, air-jet, and open-end friction-spun yarns were produced from identical fibers and their structural parameters were measured, namely mean fiber extent, spinning-in coefficient, fiber helix angle, percentage of different hooks and their extents, number of fibers in yarn cross section, and yarn diameter. These yarns were subjected to uniaxial loading on the tensile testers with a large range of gauge lengths (zero to 500 mm) and strain rates (5 to 400 m/min). The results show that the strength of a yarn largely depends on the structure of the yarn, gauge length, and strain rate. A combined effect of fiber extent in the yarn and gauge length

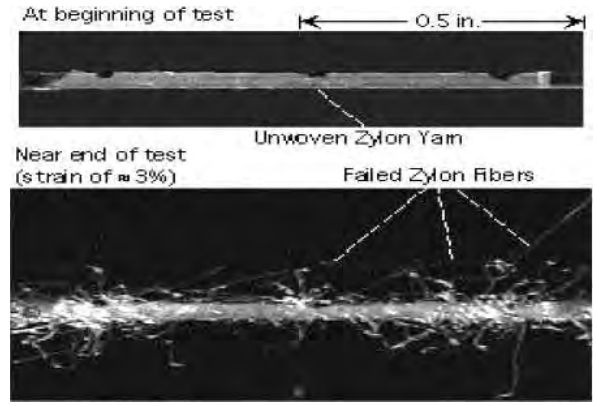

Figure 1. Zylon yarn before and after straining.

influences the yarn strength. At high strain rates, yarn failure is dominated by breakage of fibers rather than slippage of fibers. Furthermore, analysis of the region of yarn failure provides more direct evidence of the influence of yarn structure and testing parameters on the strength of different spun yarns.

High-strength polymeric fabrics, such as Zylon, Kevlar, and Spectra, consist of intersecting fill and warp yarns, each composed of several hundred fibers. The fill yarns are relatively straight, while the warp yarns are more crimped. When a single yarn is gripped tightly on both ends and pulled in tension, it stretches until the individual fibers fail at various points along the yarn. This type of failure, similar to the mode of remote yarn failure observed in fabric impact and quasistatic tests, is shown in *Figure 1*.

Stress–strain relationships of different yarns by different straining methods

(1) Stress strain curves (from load-cell and extensometer histories during tensile tests) of different Zylon yarns show that weaving reduces the tensile strength of a yarn. Yarns that are highly crimped, such as the 40-by-40-inch warp yarn, have a significantly reduced strength and failure strain (See *Figure 2*).
(2) Stress strain results for a yarn loaded in a transverse test with a cylindrical loader show nearly identical failure as in a tensile test. But when a knife-edge loader is used, the fiber failure occurs at much lower strains (See *Figure 3*).

Torsional straining of yarns

Textile fibers and yarns are subjected to torsional strains during various processes of yarn manufacturing. In staple yarns, twist is essential to hold the fibers together and to provide the required strength to the yarn structure. Twisting especially induces tension

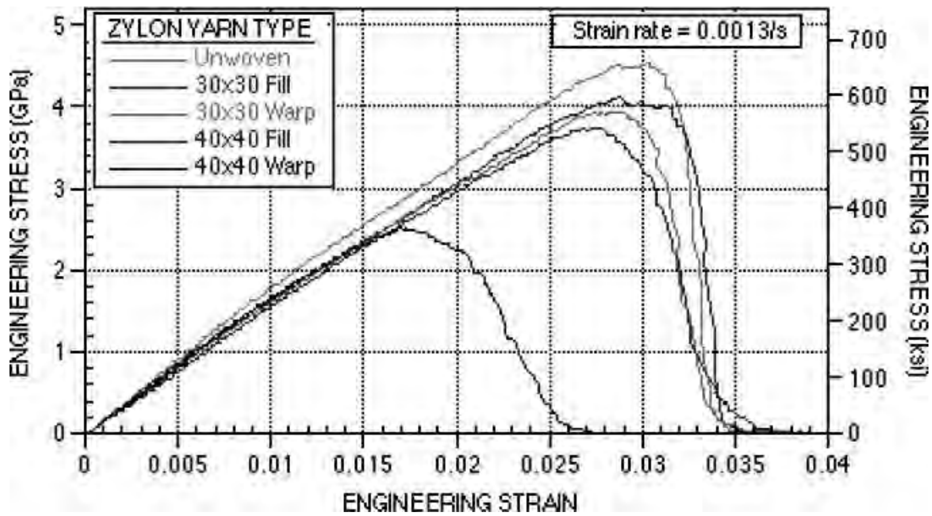

Figure 2. Tensile test results for various Zylon yarns.

within a yarn and its constituent fibers. Twist is one of the most important features influencing the properties of a yarn. It is a known fact that yarn liveliness is related to twist and strain.

Yarn-twist liveliness is affected by the twist factor, yarn fineness, and retractive forces, which in turn are determined by torsional and bending stresses in the fibers and by torque generated during yarn twisting.

A theoretical analysis was developed by S. K. Tandon, S. J. Kim, and F. K. F. Choi (1995) to gain an insight into the torsional behavior of singles yarns, which may be bulky and may have a nonuniform distribution of fiber-packing density. In their article, a detailed experimental evaluation of the theory for two different cases of yarn torsion is reported, whereby predictions of a torque twist relationship are compared with results obtained for woolen-spun carpet yarns at various twist levels. Also presented are typical theoretical results of the relative contributions to yarn torque of fiber tension, fiber bending, and fiber torsion, and of the variations in both distribution of fiber tensile strain in the yarn and yarn axial and lateral dimensions that take place as the yarn is further twisted.

The evaluation shows that, as the yarn is twisted at fixed length, it jams progressively from the inside to the outside. Initially, the outer fibers remain unstrained. In the theory of Postle et al., these outer fibers are assumed to carry a real tensile strain. They have a large helix angle and thus a large component of tension-creating torque. This is the main reason why earlier theories of yarn torque have given predictions much higher than the values observed experimentally.

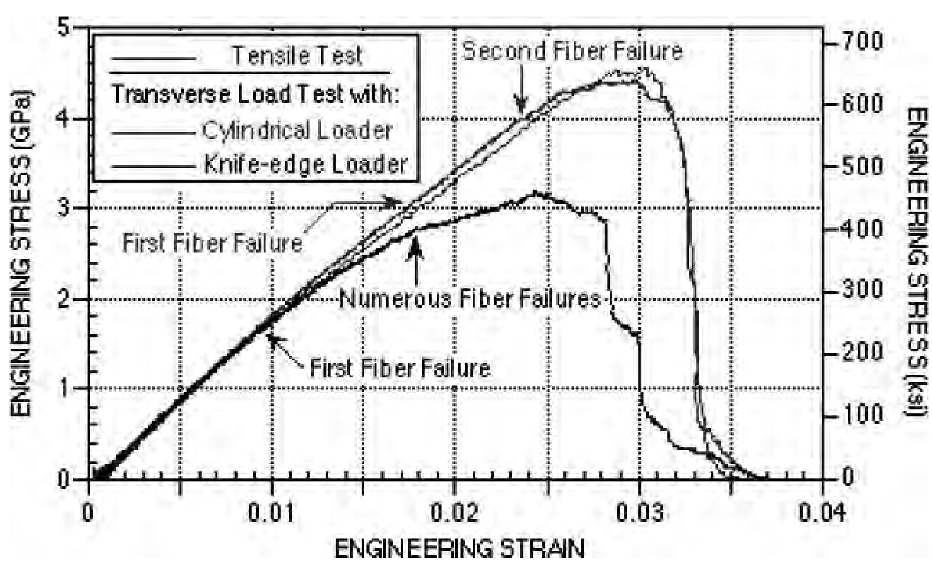

Figure 3. Test results for unwoven Zylon yarn.

In general terms, the new theory gives reasonable predictions of the observed torque behavior of woolen carpet yarns, given the precision limitations with such a material. Most interestingly, the theory clearly predicts that yarns statically twisted at constant load will become hollow in the center.

Discussion of impact straining

Freeston and Claus (1973) presented a numerical model that describes the buildup of strain level in yarns due to multiple strain-wave reflections from yarn crossover intersections in a woven fabric subjected to ballistic impact. Crossing yarns present barriers from which strain waves are partially reflected. The maximum yarn strain occurs at the point of impact and decays with distance along the yarn away from this point. The rapidity of decay is governed by the crossover-reflection coefficient. Using observations of the deformation-cone size of ballistically impacted fabric panels, the researchers conclude that the reflection coefficient is small (approximately 0.01). The strain increases with time at different rates for different reflection coefficients until failure at the impact point. Extensions of this model to other fibrous structures are discussed.

According to Smith et al. (1956), if a textile-yarn segment clamped at each end is impacted transversely at the midpoint, the stress strain curve for the yarn can be obtained from measurements on a high-speed photographic record of the motion of the yarn. The article describes the apparatus and procedure used. Stress strain curves obtained by this method for high rates of straining on the order of 5,000 percent/s are given for high-tenacity nylon, Fortisan, and Fiberglas. Comparison with stress strain data obtained at conventional rates shows that these materials have higher initial moduli, and that their stress strain curves remain linear up to higher stress values when the testing rate is high. The breaking tenacities are slightly greater and breaking elongation is slightly smaller at these high test rates.

J. Michael Pereira and Duane M. Revilock (2007) conducted a ballistic-impact test program to provide validation data for the development of numerical models of blade-out events in fabric containment systems. The impact response of two different fiber materials Kevlar 49 (E. I. du Pont de Nemours and Company) and Zylon AS (Toyobo Corporation) was studied by firing metal projectiles into dry woven-fabric specimens using a gas gun. The shape, mass, orientation, and velocity of the projectile were varied and recorded. In most cases the tests were designed such that the projectile would perforate the specimen, allowing measurement of the energy absorbed by the fabric. The results for both Zylon and Kevlar presented here represent a useful set of data for the purposes of establishing and validating numerical models for predicting the response of fabrics under conditions simulating those of a jet-engine blade-release situation. In addition, some useful empirical observations are made regarding the effects of projectile orientation and the relative performance of the different materials.

The effects of high-speed transverse missile impact upon textile yarns were observed by Wilde et al. using high-speed photography in a study of the transient behavior of a series of nylon 6/6 yarns differing systematically in mechanical properties. The loss in kinetic energy of the missile is determined directly from the reduction in the missile's velocity. The shape of the energy-loss curves is due to the partition of missile energy into yarn kinetic energy and yarn strain energy. Estimates are made of the yarn breaking strains for these impact tests. The effects of yarn tenacity and impact velocity (strain rate) upon the impact behavior of these yarns are discussed and compared to their static behavior. Comparisons are also made with the effect of strain rate upon the breaking energies of nylon yarns reported in the literature.

Ballistic vest

A ballistic vest, bulletproof vest, or bullet-resistant vest is an item of personal armor worn on the torso that helps absorb the impact from firearm-fired projectiles and shrapnel from explosions. Soft vests are made from many layers of woven or laminated fibers and can be capable of protecting the wearer from small-caliber handgun and shotgun projectiles as well as small fragments from explosives such as hand grenades.

Metal or ceramic plates can be used with a soft vest, providing additional protection from rifle rounds, and metallic components or tightly woven fiber layers can give soft armor resistance to stab and slash attacks from knives and similar close-quarter weapons. Soft vests are commonly worn by police forces, private citizens, security guards, and bodyguards, whereas hard-plate reinforced vests are mainly worn by combat soldiers, police tactical units, and hostage-rescue teams.

Modern body armor may combine a ballistic vest with other items of protective clothing, such as a combat helmet. Vests intended for police and military use may also include ballistic shoulder and side-protection armor components, and bomb-disposal officers wear heavy armor and helmets with face visors and spine protection (See *Figure 4*).

Different materials are tested for ballistic impact, and their behavior regarding impact load has been justified graphically (See *Figure 5*).

Figure 4. Ballistic vest.

Conclusion

1. Dabboussi, Dooraki, and Nemes (2003) worked to fabricate an instrument for test yarns at high strain rates. The results obtained indicate that yarn strength is highly rate-dependent, which is consistent with previously published results.
2. I. H. Hall (1964) studied the tensile properties of textile yarns at high strain rates. At a high rate, the breaking stress is always greater and, with one exception, the breaking extension less than at normal rates. The energy to rupture increases with rate for wet-spun fibers and, with one exception, decreases for thermoplastic. The variation in magnitude of these changes is considerable even among fibers from the same polymeric base, emphasizing the importance of testing at a rate comparable to that encountered in use.
3. Marques et al. (2004) studied the tensile behavior of textile yarns at high speeds. Data reveal that rapid straining usually results in higher tensile properties of yarn. SEM photos show a characteristic granular fracture morphology, but the yarn surface becomes less granular as the strain rate increases.
4. Regarding spun-yarn failure, results show that the strength of a yarn largely depends on the structure of the yarn, gauge length, and strain rate. A combined effect of fiber extent in the yarn and gauge length influences the yarn strength. At high strain rates, yarn failure is dominated by breakage of fibers rather than slippage of fibers.
5. A theoretical analysis was developed by S. K. Tandon, S. J. Kim, and F. K. F. Choi (1995) to gain insight into the torsional behavior of singles yarns, which may be bulky and may have a nonuniform distribution of fiber-packing density. The evaluation shows that, as the yarn is twisted at fixed length, it jams progressively from the inside to the outside.
6. Using observations of the deformation-cone size of ballistically impacted fabric panels, Freeston and Claus (1973) conclude that the reflection coefficient is small (approximately 0.01). The strain increases with time at different rates for different reflection coefficients until failure at the impact point.
7. According to Smith et al., (1956) comparison with stress strain data obtained at conventional rates shows that high-tenacity nylon, Fortisan, and Fiberglas have higher initial moduli, and that their stress strain curves remain linear up to higher stress values when the testing rate is high. ❑

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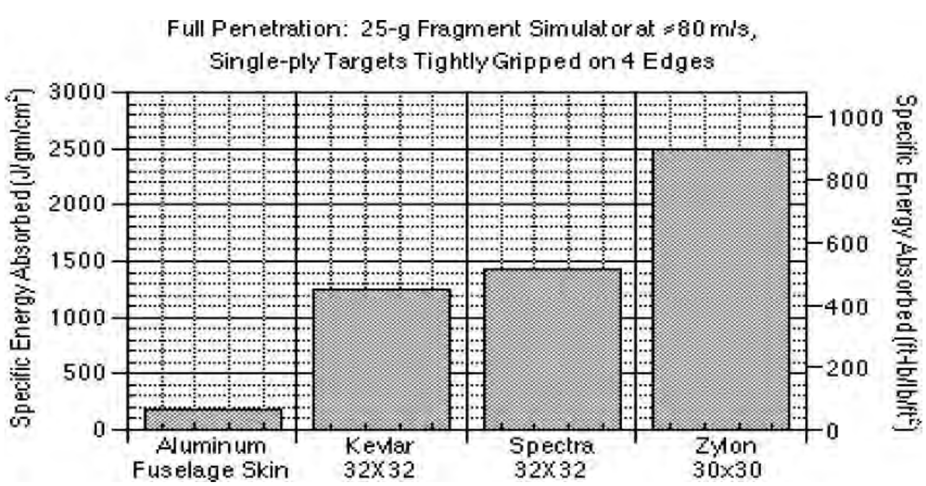

Figure 5. Ballistic results for different materials.

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The Operational Test and Evaluation of Service-Oriented Architecture

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Service oriented architecture (SOA) is a design principle rapidly gaining momentum in the design of information-technology systems. This momentum is due to both the popularity of the Web service method of SOA implementation method and beneficial SOA attributes such as reusability, discoverability, and location transparency. Conventional discussion of the test and evaluation of SOA systems focuses on functional (often black-box) testing. This testing, while important, is limited in its approach, in that a thorough and independent operational test and evaluation (OT&E) program should use testing regimes that account for the needs of all stakeholders of the system. This article identifies different classes of SOA users whose needs should be separately addressed during OT&E and discusses how the OT&E of a system designed with SOA principles should be conducted. Additionally, it outlines some considerations for system evaluators to address when constructing an OT&E program for SOA systems.

Key words: operational test and evaluation; service-oriented architecture; software test process; software test stakeholder.

Service-oriented architecture (SOA) is a design principle rapidly gaining momentum in the design of information-technology systems. This momentum is due to both the popularity of the Web service method of SOA implementation and beneficial SOA attributes such as reusability, discoverability, and location transparency. Conventional discussion of the test and evaluation of SOA systems focuses on functional (often black-box) testing. This testing, while important, is limited in its approach, in that a thorough and independent operational test and evaluation (OT&E) program should use testing regimes that account for the needs of *all* stakeholders of the system. This article identifies different classes of SOA users whose needs should be separately addressed during OT&E and discusses how the OT&E of a system designed with SOA principles should be conducted. Additionally, it outlines some considerations for system evaluators to address when constructing an OT&E program for SOA systems.

SOA is broadly defined as "a paradigm for organizing and utilizing distributed capabilities that may be under the control of different ownership domains" (MacKenzie et al. 2002, 8). The core SOA design philosophy is the breakdown of large organizational information functions into a series of interoperable services. The key characteristics of these services are that they are discoverable, reusable, stateless, autonomous, modular, and interoperable, with loose coupling, composability and location transparency (Valipour et al. 2009, 36 38; Erl 2005). Given that the interfaces for these services remain stable (regardless of whether their implementation does or not), there is great potential for the reusability of existing services when creating other interdependent services or developing applications that sit on top of a set of provided services.

An OT&E approach to SOA systems

Literature review

A review of the existing SOA testing literature shows a number of deficiencies that this paper will attempt to address. Often the position of the end user is confused, as the SOA boundaries are sometimes drawn at the service-provider level and sometimes at the end-application level. Additionally, the concept of an OT&E program to certify an SOA environment as fit-for-purpose does not seem to have much support. Rather, the existing literature focuses on development-level testing and ignores SOA characteristics that are best assessed by a group of users extending outside the traditional concept of a capability end user, such as reusability and discoverability.

Although Farooq, Georgieva, and Dumke (2008) recognize that changes to existing test models need to be made when an SOA is introduced, they do not go into detail about how an OT&E model would need to be modified to incorporate the adjustments brought about by SOA. Linthicum (2007) discusses SOA testing for autonomy, integration, granularity, stability, performance, reusability, and heterogeneity, but this is framed from the perspective of a developer (not an objective end user), and these attributes alone are not sufficient for a complete OT&E program. Canfora and Di Penta (2006a) suggest run-time monitoring as an addition to an SOA testing suite but do not suggest that this approach should extend to an OT&E scenario. Ribarov, Manova, and Sylvia (2007) focus only on testing that an implementation team might carry out (in contrast to the testing that an OT&E team would need to perform). Torry Harris Business Solutions (2007) discusses the need for OT&E in an SOA system (under the term "user acceptance testing") but only details six areas where testing should occur: function, performance, interoperability, backward compatibility, compliance, and security (not all of which are considered in this article).

"End user" definition

Bianco, Kotermanski, and Merson (2007, 7 9) provide a very detailed list of all the stakeholders that should be included in the testing activity, but they do not categorize which stakeholders should be part of which testing phase (e.g., developmental testing, acceptance testing, OT&E), nor do they allocate test areas to these stakeholder roles. Canfora and Di Penta (2006b) discuss the position of the end user in an SOA testing regime but they limit their definition of a user to only the entity that uses an application that *utilizes* the services delivered in an SOA.

Gu and Lago (2007) identify the stakeholders of an SOA as a service provider ("the development party that produces and publishes services which are ready to be executed"), a service broker (someone who provides "service location information which is contained in a service registry"), and an application provider or service consumer (someone who "integrates services into an application which eventually fulfill the requirements of the end user"). We note that in their work the concept of an end user extends only to the users of the application that utilizes the SOA services; it relegates others to a supporting role.

In this article the term "SOA software developers" is defined as the development team that produces the SOA system for the acquisition authority. They are involved in developmental testing and evaluation and acceptance testing and evaluation as part of their development role but are not involved in the OT&E program, and hence are not considered as stakeholders in this article. Additionally, the traditional capability end user is not considered, as the focus in this article is on those stakeholders that might be overlooked if a conventional OT&E process were simply applied to an SOA system without further consideration. In the context of OT&E, it is proposed that in the complete SOA life cycle the following parties should be included as stakeholders (or an extended group of end users) of any such system:

- *Service consumers.* Service consumers are software developers who interact with the SOA by consuming one of the provided services as an input to their own service or application. As they are independent from the developers of the system under OT&E, they are in a good position to test the reusability of the services provided based on the accessible documentation (i.e., without any inside knowledge). These consumers may reside within the function, within the organization, or simply within the same network as the system being evaluated.
- *Service brokers*. Service brokers fulfill a systems-administration role that ensures that all the services from the SOA are discoverable by the broader enterprise. This is typically done by maintaining a registry of available services. Service brokers may also be responsible for the implementation and enforcement of policies surrounding the SOA environment (e.g., standards to be adhered to or security policies). In the context of this article, we assume that the effectiveness of the service-brokering function has been completed outside of the activity under discussion, and the service brokers are tasked with assessing the ability of the system to integrate with the current service-brokering infrastructure.
- *Application consumers*. Application consumers are people that use the applications developed by the application providers. From their perspective, application consumers do not usually have knowledge about the underlying services that the application is consuming. Consequently, they interact directly with the software developer that produces the application (the service consumer), not the SOA software developers. This group of users is the closest analogue to a traditional capability end user.
- *Service maintainers*. Service maintainers are software developers responsible for the through-life support of the SOA system after its acquisition. It is assumed that they are not the same group that developed the services as part of the SOA project

acquisition (and hence they are independent from the development activity). Their remit includes supplementing the existing SOA services with new or modified services where this is within the project scope. They are also responsible for ensuring that the services provided as part of previous acquisitions maintain functionality (or can be reworked) if input services become unavailable (or are refactored to the point where they are no longer usable).

- *Service administrators*. Service administrators fulfill a systems-administration role that involves maintaining the software and hardware that the SOA system is deployed to in a production environment. They are responsible for installation of the system, hardware utilization and capacity, scheduled maintenance, and disaster recovery.

Unique SOA attributes

SOA requires a unique approach to OT&E for a few reasons. The first of these is the sheer number of different groups of end users (or stakeholders), all with different (but hopefully not contradictory) user requirements. As a consequence, the OT&E test authority needs to be as inclusive as possible so that the operational effectiveness and suitability for each end user is determined.

Another unique attribute of SOA is that the services produced may be used for unintended purposes. Services that are published as bare-bones services with limited or no documentation may be open to interpretation as to the format (e.g., units of measurement) of the inputs or outputs, and consequently the result of the service may not be what the service consumer expected. A lack of documentation may also result in service consumers' not knowing whom to contact for technical support.

As the SOA services are typically made discoverable, the SOA can expect a number of unanticipated users (in the form of application consumers) who discover the service through automated means. These users may heavily bombard a service with requests. Therefore, there is a need for publicly available services to be capable of servicing a large number of requests without forewarning. This produces a need for rapid scalability, which could be provided by the system automatically (e.g., through cloud-computing infrastructure) or manually via human intervention (e.g., by constant monitoring of service-load metrics). The overall solution may necessitate both formal (e.g., server capacity or well-written, scalable code) and informal (workarounds) hardware and software solutions in order to preserve an agreed-upon quality of service.

An SOA that is loosely coupled but still has dependencies on other services needs special consideration. This SOA needs to be able to switch between input services as they become available, and thought also needs to be put into the load that the service in question is placing on its dependencies. These dependent services (or rather, their service administrators) may not be aware of the SOA software developer's intention to use the dependent services in a production environment. In this case there needs to be some communication between these two parties so as to maximize the quality of service for both the service in question and its dependent services.

SOA OT&E concepts

As has been discussed and as is summarized in *Table 1*, there are a considerable number of SOA operational characteristics that need to be evaluated by a number of different types of users. It is difficult to broadly propose any one of these characteristics as more important than the others, as the operational needs of the stakeholders (and therefore the judgments of which characteristics are important) will vary in each SOA system. Consequently, the OT&E of a SOA needs to consider all of these different points of view before coming to a conclusion about the operational effectiveness or suitability of the system.

In this section, each of these attributes is defined and the manner in which OT&E would be applied from each of the different user perspectives is discussed. Depending on the system under evaluation, not all of these attributes may be deemed necessary for evaluation from each point of view (or at all). Some attributes have been omitted (such as loose coupling), as they are more suited to design-time analysis than OT&E. It may also simplify the OT&E test program if the end-user groups identified in this paper are consulted and only the group with the most stringent measures of effectiveness for any given attribute is required to participate in the evaluation of that particular attribute. This process requires careful stakeholder engagement and works best for concrete measures of effectiveness with widely agreed-upon test and measurement procedures.

Availability. In defining what it means for an SOA to be available, the telecommunications definition suffices. That is, availability means the "degree to which a system, subsystem, or equipment is operable and in a committable state at the start of a mission, when the mission is called for at an unknown, i.e., a random, time" (Alliance for Telecommunications Industry Solutions 2007). As a fundamental principle of SOA is the ability to handle unexpected users (i.e.,

Table 1. SOA characteristics requiring OT&E.

	Service consumers	Service brokers	Application consumers	Service maintainers	Service administrators
Availability	X	X	X	X	X
Deployability				X	X
Discoverability	X	X			X
Maintainability				X	X
Performance	X		X	X	X
Reusability	X			X	
Robustness	X				
Scalability				X	X
Security	X				X

"mission[s that are] called for at an unknown time"), availability is very important and relevant to all stakeholders.

The OT&E of SOA availability should be measured throughout the OT&E test program, with the end users going about their normal course of work (e.g., application consumers using the application or service consumers using the acquired SOA system while they develop their own services or applications). One method of determining (at a very simple level) the availability of the service is to record the number of times a service is invoked successfully versus the number of times that it does not respond or returns an unexpected error. However, this metric is very simplistic, and there may be a need from a business-process perspective to quantify what an acceptable level of availability is. For example, a single business process that makes multiple calls to a service with a certain level of availability is more exposed to downtime than a business process that invokes the service only once. Additionally, some unavailability may be acceptable to end users. For instance, a system may be unavailable for 12 hours per day, but if the end users do not wish to access it during this period, then this level of availability may be acceptable. However, unanticipated users may alter this, as their usage patterns will most likely be unknown.

In the case of the service maintainers and service administrators, if the SOA system displays poor availability, this will increase their workload, as they will be expected to resolve any availability issues when the system is in production (or at the very least, they will have to deal with the resulting support correspondence from end users). It is important during the OT&E planning process that availability expectations from each group of end users be solicited, as each group may have different needs. For example, if the SOA system has been primarily developed to meet a nonurgent, non-mission-critical need, then it may have been designed for a different level of availability than a real-time safety-critical system. Additionally, service brokers may require a certain level of availability for a service to qualify for inclusion in the service registry.

Deployability. Deployability is the ease with which a system can be loaded into a specific environment (usually a production environment). Service administrators need easily deployable systems because part of their role is to stand up the SOA system both initially and in the case of hardware additions (due to scalability attributes), mirrored site locations, or recovery from critical hardware failure. Service maintainers may need to have an input into the deployability of the SOA, as they may need to set up the system for themselves as part of their through-life development cycle for development and testing of postacquisition changes.

The OT&E of the deployability of an SOA can be demonstrated by giving a service administrator (or maintainer) the installation material (software and documentation) and then asking that party to attempt to deploy the system to a set of hardware without further input or assistance. In terms of critical operational issues, the OT&E program should, at a minimum, address the question "Can a service administrator deploy the SOA system to a set of hardware that meets the minimum specifications?"

Discoverability. An SOA without discoverability (i.e., the ability of services to be discovered) is left to rely on word of mouth in order to gain use by the broader community. For this reason, discoverability is important both for the users that may wish to consume the provided services and for the service brokers that are responsible for maintaining the enterprise's service registry.

The OT&E of an SOA's discoverability should follow the typical use case for the publishing and discovery of SOA services. The service administrator, having deployed the SOA environment, should be able (through a documented process provided by the SOA developers) to submit the services to be made discoverable to the service broker, who then places these services in the service registry according to its own internal process. Once the services are in the registry, the service consumers should be able to discover these services through the use of the broker's service registry.

Maintainability. An SOA with a good level of maintainability can easily cope with new changes and has low maintenance requirements. If a system is not easily maintainable, then the service maintainers and service administrators will have a large burden placed upon them as a result of the acquisition of the SOA. Examples of poor maintainability are onerous scheduled maintenance that the service administrator is required to carry out (e.g., manual pruning of entries in a database so that it does not become full) and poorly written or poorly documented software source code that increases the complexity of changes that the service maintainers may wish to make in the future.

The OT&E of an SOA's maintainability can be assessed by asking the service maintainers and service administrators to perform their daily duties. This might involve getting the service administrator to perform daily, weekly, or monthly maintenance in accordance with provided documentation or asking the service maintainer to alter a service in a predetermined way; in both cases, record the time taken and the user-assessed degree of difficulty associated with these maintenance tasks. The critical operational issue from the point of view of the service administrator could be "Can the SOA system be maintained by one service administrator working a 38-hour week?"

Performance. The evaluation of the performance of an SOA requires close engagement with the end users. Some users may not be overly concerned with the performance of the deployed services (so long as their requests are serviced eventually), while other users may wish for near-immediate responses. Performance testing should be done by the test team under a representative operational load, which may be automatically generated (i.e., simulated). Care should be taken during the OT&E of performance to look only at big-picture end-to-end performance (the user-perceived delay between sending a request and receiving a response), as it is not the purpose of OT&E to identify specific performance bottlenecks (i.e., the cause of poor performance), but only to evaluate the suitability of the entire system to meet the business-process-related performance needs of its users.

Reusability. Services provided by the SOA should be as reusable as possible. The definition of reusability in this context differs depending on the end user in question. For service consumers, reusable services are services developed by the SOA software developers that can be reused in places and ways that were not necessarily originally intended. In the OT&E of an SOA's reusability, service consumers should be invited to make use of the available services in their own work (or in a canned scenario developed by the OT&E authority). It is important that the SOA development team not have any knowledge of the needs of these end users (or of any canned scenario), so as to establish an unbiased set of services for evaluation.

Reusability in the context of service maintainers pertains to the ability of the existing software code to be reused in order to create similar or complementary services for the SOA system. In an OT&E scenario, this may be evaluated by asking the service maintainer to create a new service that is similar to an existing one and recording the time taken for the task to be completed; a code-similarity analysis of the new service against the existing services can determine how much code the service maintainer was able to reuse. This test case is similar to the one outlined in the maintainability section of this article.

Robustness. The robustness of an SOA is its ability to handle errors both those brought about by malformed or erroneous input and those generated on the server side. Additionally, the erroneous completion of one call to a service should not adversely affect the completion of other current or future service requests. There may also be requirements for graceful degradation when a service is suffering difficulties. While the use of a service description may help to alleviate some of the problems brought about by users' not providing data in an expected format or in expected bounds, this will never alleviate all such problems. As part of the OT&E of an SOA's robustness, service consumers should not be provided with any documentation or guidance past the service description. If they then, during their use of the provided services, happen to pass erroneous input to the SOA, this action should not cause a degradation of the server environment; a helpful error message should be returned instead. The evaluation of what makes an error message helpful should be made by the end users, but it generally consists of the ability to help users recognize, diagnose, and recover from errors.

The other main sources of error are ones that are not caused by the user. In an SOA this might be due to an input service's being unavailable. When this happens, the system may negotiate to use a different service (e.g., through the service broker) or it may simply return an error message. In an OT&E scenario, one or more input services to the SOA may be disabled or have artificial response delays inserted by the test team; the end users in conjunction with the test team should then evaluate whether the error messages (if applicable) returned by the system were helpful and accurate.

Scalability. If an SOA exhibits high scalability, it is easy to grow the capacity of the system to meet an increasing workload. From a service-administration point of view, this could be something as simple as increasing the amount of hardware dedicated to the system and then following the normal deployment procedures. Service maintainers may need to be involved in the scalability of an SOA system, as tactics like server mirroring often depend on software support to allow service loads to be balanced across a set of hardware. This assumes that adding more hardware will actually increase the ability of the system to service more users. It could be the case that the system uses another service as an input that is out of the control of the service administrator, and this service is by far the slowest part of the system. If this is the case, then the system may be evaluated as exhibiting poor scalability. There may also need to be a consideration of the efficiency of the SOA scalability. In certain cases, balancing loads more effectively across hardware may not be a better solution (e.g., from a maintainability point of view) than simply adding more power to existing hardware.

In an OT&E context, the test team could apply a high load to the SOA system. The service administrator could then be asked to install, deploy, and configure additional hardware to increase the capacity of the system. When this activity has been completed, the load that was previously applied should now not place such a high load on the total available hardware.

Security. SOA security is a very broad topic but in the OT&E context there are two main factors that need evaluation by the typical end user: accessibility and confidentiality.

Accessibility pertains to the ability of an end user to use only the services he or she entitled to access. This may mean services that require a user name and password or it may mean services that are discoverable only by certain users (there are, of course, many other SOA security measures). A simple OT&E scenario could involve asking an end user to make use of a protected service and ensuring that the user cannot access it without the correct privileges (and then repeating for a user who should have access to the service).

Confidentiality within an SOA context pertains to the confidence of both parties that their conversation (i.e., the service request and response) is not being recorded in decrypted form by another party. Some end users may require confidentiality in their dealings with the SOA system, while others may be content for their conversations to remain open and available to anyone. For those users that require confidentiality, an OT&E scenario would involve those users communicating with the SOA system while the test team (or potentially another end user) monitors the traffic in order to establish that the messages are suitably encrypted.

Conclusion

There is a lack of existing literature in the area of OT&E for SOA. Key SOA characteristics that are well suited to OT&E need to be addressed. These include availability, deployability, discoverability, maintainability, performance, reusability, robustness, scalability, and security. There is benefit in introducing a more consistent and complete view of end users of the system who should be engaged during the OT&E process.

This article addresses these gaps by providing guidelines which will result in a more comprehensive OT&E program that addresses the needs of all relevant users. It establishes the end users and unique characteristics of SOA that need to be considered in the creation and implementation of an OT&E test program. It discusses the key SOA attributes relevant to OT&E and outlines some candidates for OT&E test cases. Further research and discussion could focus on specific technologies (e.g., load-simulation tools) and how they might assist the developers and operational evaluators of an SOA system. ❑

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Chapter News

ANTELOPE VALLEY CHAPTER

Antelope Valley ITEA luncheon brings Australia to the Mojave Desert

The March Antelope Valley ITEA luncheon was truly a treat for all attendees, with special guest speaker **Peter Nikoloff** from the Woomera Test Range in Australia. Nikoloff is an executive director, co-founder of Nova Systems, and a senior weapons system engineer. He is also the president of the Southern Cross chapter of ITEA, which allowed him to share some of his ITEA knowledge from the other side of the globe.

Nikoloff started his presentation by explaining the significance of the Woomera Test Range and how it came to acquire its name. Woomera is described as "the most efficient spear-throwing device ever," which provided the perfect platform for the development of a long-range weapons test range. The range was established in 1946 as a joint Australian/British project used for testing Unmanned aerial vehicles (UAV), including British nuclear tests from 1955 through 1963. Some of the missiles tested at Woomera were the Europa 1 and the HAE weapon. With respect to UAVs, the Jindivik was tested at this facility and over 500 were also built and placed in service by the Royal Australian Navy, the United Kingdom and the US Navy. Adding to this large array of capability, Woomera has additionally conducted UAV training.

*AV ITEA Chapter President **Doyle Janzen** proudly presents a 'runway coaster' as a token of appreciation to guest speaker **Peter Nikoloff** at the March AV ITEA luncheon.*

Over time, Woomera has evolved from two separate land areas to a smaller southern range, just north of Adelaide, totaling

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49,000 square miles. To put this into perspective, Woomera is still larger than Edwards Air Force Base, China Lake and White Sands Missile Ranges combined, but it does have limited airspace to the moon, is electromagnetically quiet and is supporting hypersonic research as a joint US/Australian program. Although the size of this range is vast, only 300 people live in the Woomera Village, primarily due to limited resources and service.

The Range Control Center is a newer building with older communications and microwave systems. However, it is functioning at full capacity with current weapons systems being tested. Some of these systems include: AMRAAM, ASRAAM, JASSM and JDAM. Because of the forward-thinking abilities of the testing world on Woomera, approval has been granted for a major upgrade to most of their systems–radars, optics, mobile range control, communications/timing/data infrastructure and their range control and safety systems.

If the testing and training capabilities are not enough to add excitement to the test and evaluation world, the American Institute of Aeronautics and Astronautics has acknowledged Woomera as a historic aerospace site–an integral part of the defense and aerospace efforts in Australia and around the world. Not only is Woomera successfully administering programs that will be beneficial to the future of space and aeronautics, but it is also doing its due diligence to preserve the historical value of its accomplishments.

Nikoloff concluded his presentation by answering a few questions from the audience, and the Antelope Valley ITEA President **Doyle Janzen** presented Nikoloff with a small token of appreciation–a commemorative coaster made from the old Edwards AFB runway.

(From Left to Right) ***Mr. Tony Vitale****, 1st* ***Lt Nathaniel Meier****,* ***Mr. Ben Brooks****,* ***Lt Col David Wright****.*

■ ■ ■

EMERALD COAST CHAPTER

The Emerald Coast Chapter is pleased to announce that the 4th quarter winner of "Tester of the Quarter" was the **F-15C V3 Test Team** of the OFP CTF, 46th Operations Group (46 OG). The Test Team expertly executed multiple tests involving the APG-63(V)3 active, electronically scanned array (AESA) radar. This extraordinary Team planned, briefed, integrated, and executed time-critical test missions while adhering to strict schedules and limited aircraft availability. The Team's combined efforts proved

(From Left to Right) MODERATOR ***Mr. Bob Arnold****, Emerald Coast Chapter;* ***Mr. Tom Gann****, Vice President, Government Relations, McAfee Corporation; and* ***Mr. Neil Gaudreau****, DoD Cyber IA Range Team.*

valuable with repeated successful missions resulting in zero program delays and in one instance even accelerated the schedule by an astonishing 50 percent.

In other news, the Emerald Coast Chapter and George Washington Chapter in partnership with the National Test and Simulation Association (NTSA) sponsored a Test and Training Crosstalk Forum during 21 – 22 Feb 2012 in Sandestin, FL. The theme of the event was "Maximizing Testing and Training Collaboration on Sharing of Range Resources and Events". Over 160 attendees assembled to discuss practical methods of accommodating Test and Training missions through streamlined operations and utilization of finite resources. The ground breaking forum created a means for better integration of testing and training on our nation's ranges. A plan is being discussed to have a subsequent Test and Training Forum in two years at a Navy or Army training range.

The Emerald Coast Chapter also completed its 2012 Scholarship Program and awarded five $1,000 scholarships to local high school graduates. Certificates were given to the winners at their school's awards recognition ceremonies. The following is a list of the five winners and their associated high school: Miriam Dennis (Collegiate High School), Jordin Finding (Collegiate High School), Harrison Freeman (Fort Walton Beach High School), Kathrine Stone (Fort Walton Beach High School), Gerrod Voight (Niceville High School).

The Emerald Coast Chapter also donated $600 to the 2012 Okaloosa-Walton Regional Science Fair. In addition to donating funds to the event, the Chapter also had member participation. Participation involved serving as a judge for middle school and high school contestants with the responsibility of analyzing each contestant's work.

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FRANCIS SCOTT KEY CHAPTER

During this past winter, the Francis Scott Key (FSK) Chapter stayed busy hosting monthly luncheons. In February, **COL(P) Dan Hughes** (Director, System of Systems Integration) briefed The Agile Process: Delivering Network Capability to the Soldier. In March, **Mr. Peter Christensen** (MITRE) briefed Cyber T&E to wet the whistle of the audience in preparation for FSK's Cyber T&E conference, November 27-30, 2012 in Baltimore. Keep your eyes and ears open as this will certainly be an event you will want to attend. Last month, **MG Genaro Dellarocco** (Commanding General, U.S. Army Test & Evaluation Command)) shared his thoughts on the current and future challenges and opportunities for ATEC. FSK thanks our keynote speakers and appreciates their support of our local chapter.

Additionally, the Francis Scott Key Chapter celebrated our professional award winners at the March luncheon. We would like to congratulate again our 2011 winners for their outstanding accomplishments.

The General Powers Award— recognizing a lifetime of outstanding achievements by government and industry professionals working in the field of T&E.

Mr. Harry Cunningham (ATC, retired)

In 1971, Mr. Cunningham was commissioned as a 2LT in the Signal Corps and was stationed at Ft. Gordon, Ft. Monmouth, Ft. Hood, and Camp Page, Korea. As a Captain, Mr. Cunningham was assigned to ATC and, after resignation from active duty, became a DA civilian for the Instrumentation Development Division. Mr. Cunningham held a variety of positions throughout his career at ATC, including Chief of the Ballistics Division, Director

Pictured from left to right: ***John Schab, Robert McCown, MG Dellarocco.***

Pictured from left to right: ***John Schab, Chris Voinier, MG Dellarocco.***

of the Technology Directorate, and Director of the C4 and Test Technology Directorate. He was also assigned as the Technical Director at the Electronic Proving Ground, Ft. Huachuca, AZ. As a part-time annuitant, Mr. Cunningham currently supports the Office of the Commander.

Mr. Cunningham's career has been punctuated with many noteworthy achievements—ADAPT program, VISION system, Superbox, and the first fiberoptically linked vulnerability test range. In addition, Mr. Cunningham has been instrumental in the development and mentoring of young T&E professionals within ATC and the APG community.

Mr. Cunningham graduated from Penn State with an undergraduate degree in electrical and electronics engineering. He received a master's degree in administration of research and development from George Washington University.

The T&E Professional of the Year Award—recognizing outstanding achievements by government and industry professionals working in the field of T&E.

Mr. Robert McCown (AEC) Mr. McCown served with the U.S. Navy as a sonar technician aboard the USS James Monroe. After leaving the Navy, Mr. McCown worked as a research analyst in industry, providing analytical support for contractor and developmental testing of extremely high frequency satellite communication systems. As a graduate research assistant, he supervised graduate research efforts for NASA's Mars program and the Office of Naval Research's submerged vehicle programs. He is currently the ATEC System Chair and Lead Evaluator for the Stryker Double-V Hull Family of Combat Vehicles at AEC.

Mr. McCown's efforts on behalf of the Stryker program have allowed the Program Manager to field a redesigned vehicle that affords increased protection to the warfighter. He led the ATEC System Team through multiple DT and OT events and provided capabilities and limitations of the Stryker Double-V Hull configuration to support a demanding fielding deadline. Working within a rapid, focused T&E program, he was able to provide the VCSA and DOT&E the necessary information to support fielding the Infantry Carrier Vehicle.

Mr. McCown received both a bachelor's and master's degree in electrical engineering from Florida State University.

The Young T&E Professional of the Year Award—recognizing the outstanding achievement by government and industry young professionals working in the field of T&E.

Mr. Chris Voinier (I2WD) Mr. Voinier began his career in T&E as a consultant, working in the EO/IR lab in I2WD, CERDEC. After he joined I2WD as an electronics engineer, he became the lab manager and then was assigned roles of increasing responsibility in support of CREW. He is currently the APM for Future CREW IPT.

Mr. Voinier was responsible for the development of load sets and techniques implemented into the state-of-the-art technology advancement to defeat remote-controlled IEDs. He interfaced with Army, Navy, and Joint organizations in efforts to test, evaluate, and field CREW systems and worked the day-to-day operations of supporting a fielded system in the face of changing threats.

Mr. Voinier received a bachelor's degree in physics from the College of New Jersey.

The success of the professional awards program comes down to those who volunteered their time to make it successful. FSK thanks **Chris Susman** (SURVICE) who chaired the awards committee this year along with **Cathy Pritts** (ATEC), **Jim Myers** (AEC), **Fred Merchant** (SURVICE), **and John Schab** (Georgia Tech Research

Institute) who sat on the evaluation board.

The Francis Scott Key Chapter continues its support and promotion of STEM education. Seniors (**Jackie Le**, **Hunter Bachman**, **Zachary Litsch**, and **Kamini Mallick**) from the Aberdeen Science and Math Academy briefed their senior capstone projects this past fall and are all invited back this spring to present their findings.

Through our great relationship with Harford Community College and the assistance of the ITEA Director of Professional Development, FSK continues to co-host courses this spring. Keep an eye open for them, and if you are in the Aberdeen area, please consider enrolling in one of them.

Finally, we can be found on the web at http://fskitea.org. 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

January Luncheon: At its luncheon on January 19th at the Army Navy Country Club in Arlington, the George Washington Chapter heard **Mr. David W. Duma**, Principal Deputy Director of Operational Test and Evaluation (DOT&E) discuss “The Future of Defense OT&E”.

Duma started by noting there will be continued pressure to reduce testing, not only because of budget constraints possibly including sequestration of funds, but also because of perceptions that testing costs too much and delays

Mr. David W. Duma, Principal Deputy Director of Operational Test and Evaluation (DOT&E).

program development. This is in spite of the fact that studies have shown OT&E is less than 1% of major systems’ costs and 84% of Nunn-McCurdy schedule breaches did not involve testing.

He predicted Congressional interest in T&E confirmation can be expected to continue, as they see program manager promises are often only “PowerPoint deep”. He pointed out that over the years during administrations of both parties; Congress has been a big supporter of testing. Examples are their creation of Defense staff offices for OT&E and DT&E, and establishment of the Test Resource Management Center, and the Defense Acquisition Workforce Initiative. A recent indication is a Congressional requirement that every program manager have a chief development test manager.

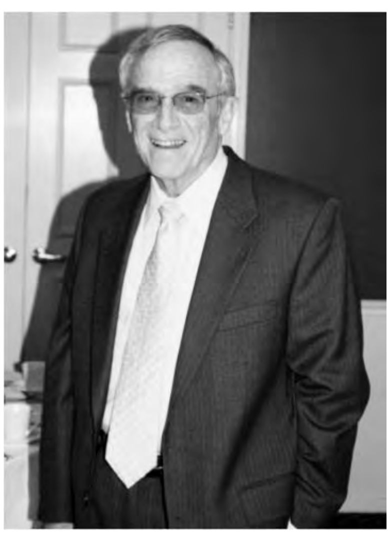
The office of the DOT&E, along with the rest of the Defense

David Duma receives a crystal ITEA paperweight as a memento of the occasion from chapter president Mike Wetzl.

Department and Congress, is on a continuing campaign to improve reliability, availability, and maintainability (RAM) of systems in development, because they drive sustainability costs over the life of a system. This is a problem because there is nothing formal to incentivize program managers to spend today to make savings for later managers. Congress tasked the services to collect RAM data and project sustainability costs. It is better to get this data early while fixes are feasible, rather than learn about problems in OT&E just before production. The Directors of OT&E and DT&E are working together on this goal, including developing a standard, a handbook, and an investment model empirically based on case studies.

(Left to Right) Mr. Bernard "Chip" Ferguson is presented with a crystal ITEA paperweight as a memento of the occasion by the chapter vice president ***Lou Husser****.*

In considering test infrastructure, Duma said he sees five "F's." Flora and fauna stand for mitigating test limitations necessary for protection of the both the natural and cultural environment. Folks refer to solving problems of urban sprawl encroaching on test facilities, which is best done by partnerships with local communities. Frequency is the issue of decreasing electronic spectrum for Defense. The president gave 500 government megahertz to civilian use, such as cell phones, that impacts important spectrum test needs such as telemetry, and Defense reduction can be expected to continue. This can be a big problem, as in the case of the B-2 bomber which had to develop a new radar in a different spectrum at a cost of 1.2 billion dollars. Fuel is his mnemonic for the testing interference caused by the need for energy conservation, such as wind farms and solar arrays near test facilities. The Defense Department agrees that energy independence is a national goal similar to strong defense forces.



Mr. Bernard "Chip" Ferguson*, Deputy Director for Interoperability of the Test Management Resources Agency.*

In a lively Q&A session Duma said that (1) a recent ITEA Journal opinion piece from three former Defense T&E Directors raises an issue worth debating about combining OT and DT; (2) the idea of testing to capabilities and limitations rather than requirements overlooks the fact that evaluation sometimes leads to favorable acquisition conclusions when requirements are not met, as in the case of the Predator drone which was found effective in for some missions without meeting all of its requirements; (3) the offer of testing at the Australian Woormera Range has been used for Navy F-18's and further opportunities may be possible depending on test infrastructure needs; and (4) that some progress is being made in protecting against a cyber threat, keeping in mind that the internet shouldn't be weighed down because it is also much used for Defense purposes. After the presentation, Duma received a crystal ITEA paperweight as a memento of the occasion from chapter president **Mike Wetzl**.

February Luncheon: At its monthly luncheon February 16th , the George Washington Chapter heard **Mr. Bernard "Chip" Ferguson**, Deputy Director for Interoperability of

Dr. Paul Alfieri *of the Defense Acquisition University (DAU) faculty.*

Agency discuss "Joint Mission Environment Test Capability (JMETC): Improving Distributed Test Capabilities."

Ferguson said JMETC enables distributed testing linking live, virtual, and constructive systems, which is especially useful when systems interoperability is a requirement. JMETC links 69 sites around the country, with more expected, For example: Edwards AFB, China Lake Naval Research Center, The Army's Cold Region Test Center in Alaska, and the Marines' Camp Pendleton. Different sites use different languages internally, and JMETC uses Test Enabling Architecture (TENA) as a common language to link them. TENA is more than a network; it provides tools for data collection and visualization, and has a repository for data and lesson learned. Linked systems are represented by hardware in the loop, for example: PATRIOT, JSTARS, AWACs and many others. When testers employ TENA for distributed interoperability testing, they plan and conduct the test, but do not have to worry about connectivity because JMETC takes care of that. Examples of successful distributed testing include interoperability of the F-16 and F/A-18, interoperability certification of the Joint Tactical Data Link, and Air to Ground Integrated Layer Exploration (AGILE).

(Left to Right) Mike Wetzl gave Paul Alfieri an ITEA embossed crystal paperweight as a memento of the occasion.

He went on to say that JMETC is improving its capability to support testing and training by upgrading equipment, working closely with the Joint IO Range for cyberspace testing, and holding quarterly meetings with users and potential users. Ferguson conducted the presentation informally with robust Q&A throughout and following the presentation. After the final question, chapter vice president **Lou Husser** presented Chip Ferguson a crystal ITEA paperweight as memento of the occasion.

March Luncheon: At its monthly luncheon March 22nd at the Army Navy Country Club in Arlington, the George Washington Chapter heard **Dr. Paul Alfieri** of the Defense Acquisition University (DAU) faculty discuss their T&E efforts. Alfieri said the DAU mission is to provide a learning environment for the Defense acquisition workforce, encompassing twelve career fields, including T&E which constitutes about 6% of its efforts. He said the school has five campuses across the country and sometimes offers courses in other location including overseas, as well as distance learning online. There are three T&E courses for the three levels of certification, the basic TST 102 which is all online, the one-week Level II certification TST 203, and the advanced one week seminar TST303 for Level III certification.

He went on to say that course content is governed by the Defense Director of Developmental Test and Evaluation, who chairs the annual Functional Integrated Product Team (FIPT) to verify the values of the instruction. Last year the FITP made no major changes in instruction, and this year's FIPT is about to begin.

Changes may be expected in such current hot topics as Reliability, Design of Experiments, Rapid Acquisition, and Integrated T&E. DAU provides training for the acquisition workforce certification while universities provide relevant education. In October of this year the educational standard for T&E will be upgraded to a bachelor's degree in a technical major such as engineering or equivalent. DAU has partnerships with many universities who give academic credit for DAU courses, including George Washington University, George Mason University and the University of Maryland. DAU also offers 13 Continuous Learning Modules important to acquisition, for example, in Modeling & Simulation for Test, Probability and Statistics, Telemetry, and Testing in a Joint Environment.

After a lively Q&A session, chapter president **Mike Wetzl** gave Paul Alfieri an ITEA embossed crystal paperweight as a memento of the occasion.

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Test and Training Crosstalk Forum

Jointly Hosted by the Emerald Coast and George Washington Chapters

The Emerald Coast Chapter in partnership with the George Washington Chapter, and in conjunction with the National Test and Simulation Association (NTSA), conducted a TEST AND TRAINING CROSSTALK FORUM February 21st and 22nd at the Sandestin Resort in Destin, FL, near Eglin AFB.

Mr. Bob Arnold of the Emerald Coast Chapter and **Mr. Skip Vibert** of the George Washington Chapter welcomed 160 attendees and explained that the purpose of the forum was crosstalk between the test community and the training community to improve the effectiveness and efficiency of both communities by increasing integration of operations. First day opening distinguished speakers were **Mr. David Duma**, Deputy Director for OT&E and **Col. Jeffrey Macloud** USAF, Director of Operations, Nevada Test & Training Range, Nellis AFB, UT. Both communicated current efforts and shortfalls and challenged the attendees to explore ways of improving integration. The 46th Test Wing Commander, **Col. Colin Miller** USAF described test and training activities at Eglin, which has included both communities and the Test Wing's efforts to bettercombine and deconflict testing and training.

On the second day of the forum **Mr. Edward Greer**, Deputy Under Secretary of Defense for DT&E and Director of the Defense Test Resources Management Center described his recently reorganized office, and named a few intiatives to improve acquisition outcomes.

The forum included eight panels which focused on the following topics: (1) T&T Infrastructure Outlook, (2) Distributed T&T Enabling Programs, (3) Information Assurance/Network Security for T&T Events, (4) Spectrum Challenges, Policy, and Outlook, (5) JFCOM Disestablishment, (6) Cyberwar T&T, (7) T&T Range Users, and (8) T&T Range Operators. A reception and breaks throughout the two days offered opportunities for informal discussion. The wrap-up and closing of the conference was conducted by **CAPT. Stan Bloyer**, USN (Ret) of the National Training and Simulation Association.

During the forum, the attendees submitted and posted several ideas to improve test and training integration. The event organizers will review and suggest these ideas to appropriate senior leaders for future implementation. The forum set the stage for building a constituency for better integration of testing and training on our nation's ranges. It is under consideration to conduct the next Test and Training Crosstalk Forum in two years, and ideally at a Navy or Army training range.

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ROCKET CITY CHAPTER

The Rocket City Chapter has elected new officers and would like to recognize Past President, **Leigh Christian**, for her dynamic leadership and years of service as the Rocket City Chapter president, which enhanced the Chapter and the entire ITEA organization.

The Chapter is pleased to announce **Major Cornelius Allen**, a U.S. Army Acquisition Officer currently serving in PEO Missiles and Space at Redstone Arsenal as the Joint Air to Ground Missile (JAGM) APM, as their new President.

With officers seated, the Rocket City Chapter is determined to continue and improve on past accomplishments. We have numerous speakers and facility visits in store to facilitate the critical cross talk/learning that is essential to the test community growth. Most recently, the Chapter hosted a Cybersecurity and Information Assurance short course in May. The instructor, **John Jorgensen**, CISSP, is a Principal Multi-Discipline

Systems Engineer with the MITRE Corporation.

The new slate of Chapter officers are:

- President - Maj. Cornelius Allen, U.S. Army PEO Missile and Space
- Past President/Publicity Committee - Leigh Christian, AMTEC Corporation
- Vice President - Tim Cotter, Enterprise Corporation
- Secretary - Stephen Jones, Scientific Research Corporation
- Treasurer - Gloria Power, MEI Technology
- Programs – Loren Traylor, Wyle
- Membership – Janice Isbell, Aviation Engineering Directorate USA RDECOM / AMRDEC
- Education - Wallace J. "Wally" Tubell Jr., Defense Acquisition University (DAU)
- Advisors & Past Chapter Presidents – Mike McFalls (ITEA Treasurer), Avion and Mark Brown, SRC

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SOUTHERN CROSS CHAPTER

The Southern Cross Chapter has been busy preparing for its major annual event, SETE 2012, to be held in Brisbane Australia, 30 Apr – 2 May 2012. The **S**ystems **E**ngineering/**T**est & **E**valuation (SETE) is a joint conference between ITEA (Southern Cross Chapter) and Systems Engineering community. We are pleased we are getting great support from our USA ITEA friends again this year. **Mr. Dave Duma**, Principal Deputy Director, OT&E will be supporting our T&E panel, **Ms. Eileen Bjorkman**, Technical Advisor, Air Force Flight Test Centre, providing a Key Note and **Mr. Gene Hudgins**, TENA Support Lead, US Government, will providing a tutorial.

The Southern Cross Chapter President visited the Antelope Valley Chapter at Edwards AFB in Mar 2012 and was please to be able to provide a lunch presentation to the local ITEA community titled "Woomera Test Range – T&E Aussie Style". There was a great turn out and I was well looked after by all, thanks for the hospitality. The highlight was being presented a piece of the Historic Edwards AFB runway 04/22.

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VALLEY OF THE SUN CHAPTER

The Valley of the Sun Chapter continues to chart the best way ahead. The leadership has continued to reach out to other organizations, and have attended AFCEA and NDIA Chapter meetings. By the time this is published, we hope to have heard the INCOSE Student Report and to have gotten the ITEA Design of Experiments course scheduled with commitments from students to attend. We have also identified four venues for holding Chapter meetings, which should make it easier for Chapter members to attend. We are still committed to hosting a Cyber Course in the Fall of this year as well. The Chapter is planning to become involved in the Arizona Sci-Tech activities starting in 2012. Finally we have started to identify the right places to offer scholarships and are looking for points of contact to work with all the major schools in the Phoenix Area.

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*ETTC -2011 - **Karen Lyons** (ITEA-EC) explaining the benefits of ITEA membership to a conference delegate*

WESTERN EUROPE CHAPTER

The European chapter of ITEA in collaboration with the European Society of Telemetering wishes to remind members that this year's European Test & Telemetry Conference (ETTC) will be held 12-14 June in Munich, Germany.

As well as an Industry exhibition, the 2012 ETTC programme includes eight technical workshops / short courses which may be of interest to ITEA members. This year's ETTC will be at a new venue - the **Auditorium and Business Centre BMW Welt - München**. Full details can be found at www.telemetry-europe.org. The ETTC is held annually and alternates between France and Germany. This three day conference attracts delegates from Europe, the USA and the Far East.

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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, CAE, ITEA Executive Director, by e-mail at jgaidry@itea.org, or at 703-631-6220, x204, for more information.

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.

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

Combinatorial Testing with Design of Experiments (CT-DOE)
June 4-8 ~ Fairfax, VA

Information Assurance and Cyber Security
June 21-22 ~ Colorado Springs, CO

Systems Engineering, T&E, and Project Management: Integrated Processes
July 17-18 ~ California, MD (Patuxent NAS)

Fundamentals of the Test & Evaluation Process
June 26-28 ~ California, MD (Patuxent NAS)

CALL FOR NOMINATIONS: ANNUAL TEST AND EVALUATION PROFESSIONAL AWARDS

An excellent opportunity to showcase your personnel for outstanding accomplishments in Test and Evaluation (T&E)

The International Test and Evaluation Association (ITEA) Board of Directors relies on ITEA members and T&E leaders to identify and submit nominations of individuals and teams worthy of recognition by the 2012 ITEA T&E Professional Awards Program. This recognition is a testament of their outstanding accomplishments in, or contributions to, T&E.

The 2012 competitive categories:

Allen R. Matthews Award was established in honor of ITEA's founder and is presented to an individual for a lasting, significant contribution to the field of T&E—such as the cumulative effect of a distinguished career. It is the highest award bestowed by ITEA. The recipient must be a member of ITEA.

Special Achievement Award recognizes a recent outstanding achievement in T&E engineering, technology, or management—such as the solution of a major problem or a notable project success for which there is evidence that tangible benefits have accrued. Period of performance for the Special Achievement Award is from June 1, 2011 to May 31, 2012.

Technical Achievement Award recognizes an individual or team for outstanding use of instrumentation, information technology, modeling and simulation, time-space-positioning information, electro-optics technology, or other T&E technologies to cause a program to be better, faster, and less expensive. Period of performance for the Technical Achievement Award is from June 1, 2011 to May 31, 2012.

Cross Award was established in honor of the late Major General Richard G. Cross, Jr., USAF (Ret), one of the most highly respected individuals in the field of T&E in the 20th century. ITEA presents this award to recognize outstanding achievements in the development or administration of T&E education.

Publication Award recognizes outstanding contributions to T&E literature. ITEA presents this award to honor individuals whose published books or technical papers have improved and increased the general body of knowledge relevant to better understanding and development of T&E technology. Period of performance for the Publication Award is from June 1, 2011 to May 31, 2012.

Junior Achievement Award recognizes a young professional who, during his/her first 5 years of practicing in the T&E field, has accomplished a significant achievement(s) which enhances and strengthens the T&E profession.

The nomination forms, the eligibility and evaluation criteria, and submission instructions are located under the ADVANCE tab on the ITEA website. Nominations are due by June 1, 2012 and the award recipient along with the nominator will be informed by e-mail in July. The recipients will be honored during the Annual Symposium, which will be held September 17 – 20, at the Hyatt Regency in Huntington Beach, California.

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.

There are three (3) ways that YOU can volunteer your time, talents, and expertise to assist ITEA in the development of this credential:

1. Participate in Subject Matter Expert (SME) roundtables to identify the key concepts, terms, and activities—the "Body of Knowledge (BOK)"—that define a competent T&E professional. If you would like to participate in the SME Roundtables, please make note of the upcoming date.

   Tuesday, June 26th, 8:30 a.m. to 4:30 p.m. – ITEA Executive Office in Fairfax, Virginia

2. Volunteer as a member of the Board of Examiners (BOE) – Description of this ITEA Board appointed Committee can be found on the ITEA Web site.

3. Contribute questions for use as part of the competency exam.

Also posted on the ITEA Web site is the draft of the BOK that will be used during the roundtables. Please note that this BOK is a "living" document that can and will be modified to ensure that all relevant areas of knowledge and skills that a T&E professional need to know to perform their job are included in the final "blueprint" for the competency exam. The key objectives in developing the BOK are:

Identify all of the "generally accepted" knowledge and skills that are applicable to most T&E professionals most of the time.

Represent a broad spectrum of knowledge and skills—including those used by T&E professionals in various types of organizations (e.g. commercial, government, DoD), various industries (e.g. consumer products, pharmaceuticals, transportation), and also in other countries.

Prioritize each knowledge and skill based on its:

- Applicability to the majority of T&E professionals across the broad spectrum (i.e. Do most T&E professional use this knowledge/skill).
- Criticality to performing the job as a T&E professional (i.e. Is it a "nice to know," "should know," or "must know" knowledge/skill); and,
- Relevance to the level of experience of the T&E professional (i.e. Is this knowledge/skill normally possessed by a novice, an experienced, or an expert T&E professional).

We appreciate your support of the Association, and your personal commitment to the professional excellence embodied in advancing the test and evaluation industry. Please contact James Gaidry, CAE, ITEA Executive Director, at jgaidry@itea.org, or 703-631-6220, x204, for the SME Roundtables or if you have any comments, questions, or suggestions.

CALL FOR NOMINATIONS: ITEA CHAPTERS OF EXCELLENCE AWARD

The ITEA chapters, through their local service to members, is the cornerstone of ITEA. Strong, active chapters provide the Association with volunteer personnel and subject matter for the Association's educational programs. Because of their close relationship with the membership, chapters frequently identify interest areas that are appropriate subjects for international educational events. At the same time, they may be the first to become aware of declining interest in a topic, discipline, or T&E-related technology. Strong chapters and open communication between chapters and the Board of Directors, the regional vice presidents, committee chairs, and the ITEA Executive Office are critical to the health and vitality of the Association.

ITEA Chapter nomination forms are due to Keith Sutton via email (ksutton@syzygy-tech.com) NO LATER THAN JUNE 15. Chapters should copy their Regional Vice President (RVP), as well as Bonnie Schendell (bschendell@itea.org) when sending the completed form. Verification of which chapters meet the requirements will be done and each chapter will be informed accordingly. A package containing those chapters who meet the criteria will then be sent to the RVPs. These chapters form the pool from which a single Chapter of the Year is selected. These Chapters will be honored during the Annual Symposium, which will be held September 17 – 20, at the Hyatt Regency in Huntington Beach, California.

If you have any questions regarding this Award or the completion of the attached required form, please contact either Keith Sutton or Bonnie Schendell.

ITEA Corporate Members

ACROAMATICS, Inc.
Advanced Systems Development, Inc. (ASD)
Advanced Test Equipment Rentals
Aegis Technologies Group, Inc.
Agency for Defense Development
Alion Science & Technology
AMPEX Data Systems Corporation
Arcata Associates, Inc.
Argon ST
ARINC
Avion Solutions, Inc.
BAE Systems, Aerospace Solutions
Battelle
Boeing Company, The
Booz Allen Hamilton, Inc.
CALCULEX, Inc.
CGI
Charles Stark Draper Laboratory
Command Post Technologies, Inc.
CSC, Applied Technology Group, (ATC)
Cubic Defense Applications
Curtiss-Wright Controls Avionics & Electronics
Department of Defence - RANTEAA
DigiFlight, Inc.
DRS Training and Control Systems, LLC
EMC Corporation
Energetic Materials Research and Testing Center (EMRTC), New Mexico Tech
ERC, Incorporated
EWA Government Systems, Inc.
GDP Space Systems
General Dynamics C4 Systems
Georgia Tech Research Institute
Glacier Technologies, LLC
Hurley Industries, Inc.
IDA Technology
InDyne, Inc.
InfoWhere Inc.
Integral Systems (a Kratos Company)
ITT Exelis
Jacobs Technology, Inc.
Jacobs/TYBRIN Corporation
JDA Systems
JT3 LLC
L-3 Telemetry-West
ManTech International Corporation
MEI Technologies, Inc.
NetAcquire Corporation
NewTec
New Mexico State University (NMSU)/ Physical Science Laboratory (PSL)
Power Ten, Inc.
Quadelta, Inc.
QinetiQ, Inc.
Rockwell Collins, Inc.
Rotating Precision Mechanisms, Inc.
RoundTable Defense LLC
Sabre Systems, Inc.
SAIC
Scientific Research Corporation (SRC)
SemQuest, Inc.
Sierra Lobo, Inc.
SPARTA, Inc.
Spectrum Sensors
Spiral Technology, Inc.
SURVICE Engineering Company
SYMVIONICS, Inc.
System Development Center (SDC), CSIST
System Testing Excellence Program at the FedEx Institute of Technology
Systems Engineering & Management Company (SEMCO)
Syzygy Technologies, Inc.
TAPE, LLC
TASC, Inc.
TRAX International Corporation
TRIDEUM Corporation
Weibel Scientific A/S
Westech International, Inc.
Wyle