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ENDANGERED SPECIES:
Data, Capabilities, Expertise

FEATURED CAPABILITY

The Georgia Tech Research Institute

TECHNICAL PAPER ABSTRACTS:

T&E Telemetry and Onboard Recording Data Projections

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Projecting growth is always a dangerous occupation. However, there are times when the exercise is worth the risk. Some members within the test and evaluation community think it is time to consider the quantities of data that will be collected in the future and actions that can be taken now to handle them. This article analyzes historical trends in several areas of data acquisition. The original motivation for this analysis related to the decreasing ability to meet telemetry needs with limited radio frequency spectrum. Specifically, the authors sought to determine the worst-case deficiency between what they would like to telemeter and what they can telemeter. The answer to the question, "How much would we telemeter if we had infinite spectrum?" is "Everything we record onboard." Thus, the following analysis includes telemetry data rates, as well as aggregate data acquisition rates. When confronted with the projections provided, the immediate question becomes "What do we do with all that data?" A brief response to this question is also provided.

Real-Time Data Warehousing and On Line Analytical Processing

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The Aberdeen Test Center is the U.S. Army's lead test center for land combat systems. Over the past two decades, land combat systems have grown exponentially in complexity through their evolution into internetworked, intelligent systems-of-systems. Tests of these modern weapon megasystems involve hundreds of measurement parameters and large volumes of human observations. The volume and complexity of data preclude quality control through human inspection and, instead, dictate that real-time automated processes be applied. In short, a flood of information has generated an urgent need for techniques and tools that can intelligently and automatically assist information users in transforming these data into useful knowledge.

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When Binomial Isn't Enough: Likely Value for Proportions in Bernoulli Trials

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When estimating the proportion of success in a system where the measure of success is a binary value, the most common estimator for the proportion p is s/n, the ratio of the number of successes divided by the number of trials, even though it is known to be inaccurate when no failures occur (or all failures) in a single small sample. The use of Laplace's rule of succession and its beta-distribution-based likely value estimator for p is explained and justified for use as a replacement estimator when indicated values for the proportion p are close to or equal to 1 or 0.

Personnel Policies Propagate Potential Test and Evaluation Expertise Crisis

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"The Department spends about $100 billion annually to research, develop, and acquire weapons systems and tens of billions of dollars more for services and information technology. At the same time, DoD, like other agencies, is facing growing public demands for better and more economical delivery of products and services. In addition, the ongoing technological revolution requires a workforce with new knowledge, skills, and abilities. DoD believed that these actual and projected reductions (1989-1999 downsizing) could be exacerbated by increased competition for technical talent due to a full-employment economy and a shrinking labor pool. As a result of the years of personnel reductions and the increasing competition for replacement talent, DoD concluded that its acquisition workforce was on the verge of a crisis—a retirement-driven talent drain." (GAO-02-630, 2002) This article examines the issues and some of the solutions addressed by the then-General Accounting Office (GAO) report as they relate to the test and evaluation profession.

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Supercomputing's Role in Data Problems and Its Contribution to Solutions

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High-performance computing (HPC) has proven to be a blessing that unfortunately generates a conundrum, the solution to which is of major importance: Will the resultant glut of data overwhelm the user to the point of destroying the benefit of the advances in computation? The Department of Defense can look forward with certainty to significant, steady increases in computer performance and may soon experience an even more expansive revolution in this area. This article sets forth actual experiences with several instantiations of HPC battlefield simulations, discussing the potential value contained in the flood of data that they generated. The impediments to the effective use of that data are identified and alternative methods of reducing these impediments are surveyed. A solution, which is now being implemented and tested, is presented. Further subjects such as data mining and data visualization, both needed to enhance insights, are described and discussed. The article ends with an outline of the future and an overarching vision for the appropriate response to the threat of data inundation.

AIM-9X Modeling and Simulation Support for Operational Testing: A Success Story

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For the past three decades, the U.S. Air Force has placed increased emphasis on using modeling and simulation (M&S) in the weapons system acquisition process. While M&S can make valuable contributions to an operational test program, test and M&S results are not combined to draw conclusions on how well the system will perform in an operational environment. The test team can use M&S to better understand test conditions, to help plan the test, and to augment the field test in areas in which testing was not able to be conducted. This article discusses the role M&S played in support of the AIM-9X Operational Test and Evaluation (OT&E) joint program.

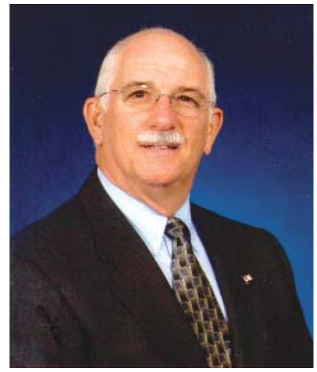
I hope that your summer was enjoyable and restful. Mine was great, but, who at my age can try to keep up with numerous grandchildren and claim that the experience was restful?!

The ITEA leadership and staff certainly have not been resting this summer either. Through the hard work of many people, great progress has been made in preparing for the Association's future. ITEA Executive Director Lori Tremmel Freeman, along with the Executive Committee and members of the Board of Directors, are completing a three-year Business Plan based on the existing Strategic Plan. The Business Plan provides specific guidance across all program areas. Key highlights from the Education, Events and Communications committees follow.

The **Education Committee** continues to provide top-quality courses and instructors for the test and evaluation (T&E) community. Three-day ITEA courses provide instruction that is directly applicable to government professional development programs. Although ITEA does not issue or track continuing education credits, the local training office should credit government attendees with 24 Continuous Learning Points (CLPs) or 2.4 Continuous Educational Units (CEUs) after successful completion of each course. ITEA continues to explore new course offerings to better serve the educational needs of the T&E community. Should you have a specific training need, feel free to contact **Peter Christensen**, the Educational Committee chairman, at *pchris@mitre.org*.

The **Events Committee** has taken a fresh look at the mission of ITEA events, including the nature, timing and location of each offering. Our vision is to ensure that ITEA provides meaningful content that serves the membership in a professional manner. The committee has adopted a strategic focus to work closely with programmatic and technical chairs to incorporate ITEA's goals into each event. We have constructed a five-year roadmap of events, combining recurring offerings with opportunities for ITEA to delve deeper into a variety of timely test topics. Our focus is to continue to facilitate T&E growth for defense applications, and also to reach into non-defense government and commercial applications as well.

Locations for ITEA Headquarters-sponsored events will be chosen to provide members with access to Association activities across the nation. This year, we successfully brought the ITEA Technology Review to New England; and next year, other new venues are being considered. We are building on the momentum of last year's successful Annual ITEA International Symposium by hosting this year's event in Lake Buena Vista, Florida, from October 30-November 2, 2006; and the 2007 Annual International Symposium will be held in Kauai, Hawaii.



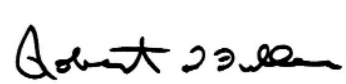
Robert T. Fuller

The Association's strong lineup of events across the globe provides ITEA's worldwide membership with unequaled access to the finest leaders, thinkers and ideas in the T&E field. Please contact Events Committee Chair **Richard Shelley**, at *rlshelley@earthlink.net*, anytime to discuss your ideas.

The **Communications Committee** has analyzed ITEA's web site and information technology capabilities and has surveyed our membership about ITEA's services. Efforts moving forward will focus on making the web site more user-friendly, which will include providing links to other technical web sites; establishing a new current events area; and providing electronic access to *ITEA Journal* archives.

Progress continues in forming alliances with the American Institute for Aeronautics and Astronautics and the International Council on Systems Engineering. The Communications Committee believes that leveraging relations with other professional organizations, coupled with technological advancement, is a great recipe to serve our membership. Be sure to let Communications Chair **Lawrence Camacho**, *larry.camacho@-1@nasa.gov*, hear your ideas for reaching out to the ITEA community.

On a final note, this is my last "President's Corner." My term of office ends November 2nd with the last day of this year's Annual International Symposium in Lake Buena Vista. I have truly enjoyed my time as your President, and I'm sincerely grateful for the strong, unwavering support that of all the individual and corporate members and the ITEA Headquarters staff have generously provided me. I will remain on the Board of Directors, and I look forward to serving our Association in a new capacity in the years ahead. ❑



Endangered Species: The Human Element of Data Analysis

Drexel L. Smith

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Demands on the test and evaluation community continue to grow, regardless of industry or product, due to increases in regulatory requirements, product assurance demands and buyer expectations. Critical decisions are based on the expectation that results from test organizations are accurate, dependable, repeatable and verifiable.

With accelerating advances in computing capabilities and capacity, the ability to generate enormous quantities of data has created a need for increasingly sophisticated data management systems. As a result, an entire generation of engineers now depend on computers for the calculations on which assessments are based. From a management perspective, the critical question becomes: "In the digital age, when so much 'brain work' is done by computer, are we doing enough to prepare our future workforce to apply the rigor, critical thinking and judgment that remain key to testing and evaluation?"

Drexel L. Smith

Historical perspective

Early in recorded history, the demand for accurate weights and measures was driven by commerce and construction. The "cubit" (length of the king's forearm) was the standard linear unit, and equally interesting standards were devised for weight. Once standards were established, measurements could be converted into "results" by means of counting boards (one of the earliest was the Greek Salamis Tablet, circa 300 B.C.). These devices led to the abacus, which was first used by the Romans more than 2000 years ago (in China, it was called a *suan-pan*).

In the 1600s, John Napier discovered the logarithm, which made it possible to multiply and divide by adding and subtracting, which led to the slide rule. What is important here is not the historical sequence, but the commonality: All the tools required the user to apply some degree of judgment. As most of us remember, the slide rule produced a numerical result, but we still needed to track the decimal point.

As recently as 60 years ago, hand calculations still outpaced the electronic tools of the day. In 1946, for example, a contest was held in Tokyo, Japan, pitting an abacus against a newfangled electrical calculating machine. As *Stars and Stripes* remarked:

"The machine age tool took a step backwards yesterday at the Ernie Pyle Theatre as the abacus, centuries old, dealt defeat to the most up-to-date electric machine now being used by the United States Government…The abacus victory was decisive."

Although technology has come a long way, it is interesting that the abacus is still in use. Early in my own career, mass flow was calculated by means of a slide rule using hand-logged pressure and temperature data. These data were manually compared to reams of output from pen-write recorders and *ocilographs*, where peak data points were hand-noted against calibration points. This was a painful process, especially when the test team had a good data set and wanted a "quick look" answer so the test system could be secured.

Pressure gages, thermometers, manometers, stopwatches, sight glass gages, hand data reduction and hand calculations have all gone the way of the slide rule. Unfortunately, what also is being lost is the rigorous review of raw data, often verified by several persons, as well as the calculation process that required judgment in answering the basic question: "Does this result make sense?"

Although errors sometimes occurred, the thinking process in developing the final data set was generally solid. The presentation of test results was supported by logs, data recordings and by independently verified, hand-calculated data.

Current era

During the past 20 years, collection of hand-noted data has been limited to academia, standard calibration laboratories and select experiments where fundamental measurements are demanded. Today, it is commonplace to collect high volumes of data using digital sensors (or analog-to-digital conversions) and to record them on digital data acquisition systems with real-time data reduction.

In a recent tour of a new cryogenic flow laboratory, I noted that the data acquisition system could handle 224 analog input channels (128 simultaneous), 64 digital inputs and 192 output channels with real-time architecture. This front-end system, combined with a sizable computer, allowed for nearly real-time computing of data, enabling the test engineer to monitor results as the experiment was underway. The final step was the use of customized software to translate the data into results. LabVIEW™, originally released for the Apple Macintosh in 1986, is used in many laboratories around the world, as are competing programs such as MATLAB™.

Amazing advances also have been made in acquiring flight data via telemetry systems. A modern flight test center is replete with simplified control consoles and flat-panel screens displaying calculated data from tens of thousands of channels. As a result, *our ability to acquire data has almost exceeded our ability to effectively manage and use the information.* To deal with such a reality, Wyle's Telemetry and Data Systems group has developed a data management system called Omega Data Environment, which uses Internet search engine technology to more effectively provide comparative analyses of the overwhelming volumes of data (already measured in terabytes).

In the old days, a test report answered the questions underlying a given project. Today, test results are often a means to verify or "calibrate" a design-based computer analysis. In this new world, data acquisition systems are no longer limited to acquiring data. They have become "management data systems" able to perform comparative analyses (with predictions from modeling and simulation computations), as well as comparisons across a range of experiments.

Diminishing human skills?

There have been many articles on the "aging" or "graying" workforce, forecasting the significant percentages of test and engineering personnel who are now—or soon will be—eligible for retirement.

This point struck home recently when Ron Chambers, a close friend and colleague, unexpectedly passed away. Ron was lead design engineer and technical director for Neff Instruments, a leader in data signal conditioning systems for more than 40 years (the company's front-end systems have been the standard for many test centers). Throughout his career, Ron understood the needs of testers and the importance of acquiring high-quality data. Thus, the products that he designed were user-friendly and reflected his commitment to quality.

As our associates leave the industry, we are left with the question raised at the beginning of this editorial: "Are we doing enough to bring along skilled and knowledgeable individuals to replace Ron and others like him?"

In many respects, those in today's workforce are better educated and more efficient in running an experiment using new digital tools. However, they have not experienced "all-nighters" sorting through data logs to hand-calculate information for use by the test team in the morning. With nearly real-time answers, the "gratification" for test engineers is instant. In fact, even at the technician level, powerful "plug-and-play" systems are diminishing the need to understand the real meaning of acquired data.

Case study

A few years ago, Wyle took over the operation of a precision measurement laboratory supporting the National Aeronautics and Space Administration (NASA), the Air Force and commercial calibration requirements. Technicians had been working in the highly disciplined Department of Defense (DoD) "plug-and-record" environment; however, as requirements and test technology advanced, the associated measuring equipment became more complex. This generated an interesting phenomenon: While increases in the complexity of measuring equipment produced corresponding increases in the complexity of calibration processes, they also produced the need for personnel to better understand the data and to do hand calculations on occasion.

We quickly discovered that our inherited workforce needed refresher training. The solution was a

10-week course developed with a local community college to reinforce computational skills required to perform new-generation calibration processes. Even with an "experienced" workforce (15 years average in this case), continuing education on the fundamentals is required because *basic skills are lost when engineers and technicians grow too dependent on instantaneous computer-generated data.*

The future

The concern for clear understanding of data sets is real. A recent independent review panel noted that many engineering packages submitted to formal control boards were not actually documents, but PowerPoint presentations. As the panel noted, "It appears that many young engineers do not understand the need for, or know how to prepare, formal engineering documents such as reports, white papers, or analyses."

As customers accelerate demand for ever-increasing quantities of instant test data, we must not lose sight of the absolute requirement for our engineers to be critical thinkers, applying experience-based judgment to the relevance of an answer before placing it into a presentation. It is up to us, the senior management team, to ensure that we are indeed doing enough, and that the critical human factor in data analysis is not lost forever.

Goodbye, Ron Chambers; you are missed. ❑

DREXEL L. SMITH is the senior vice president, Corporate Offices, for Wyle Laboratories Inc., El Segundo, California. He has more than 38 years of experience in the test and evaluation of weapons, munitions, propulsion systems, nuclear systems and components, in positions ranging from test engineer to corporate management. Most recently, he was senior vice president and general manager of Wyle's Technical Support Services Business Unit, which operates and maintains laboratories and research facilities for government and industry clients such as the Department of Defense (DoD), National Aeronautics and Space Administration (NASA) and major prime contractors. Programs include support of the General Electric Turbine Engine test facility; Propellant Systems, Non-Destructive Evaluation and Metrology Laboratories at Cape Canaveral/Kennedy Space Center; and research centers at Wright-Patterson Air Force Base. He also directed the Research Instrumentation and Metrology Services contract for NASA Langley. Smith is a long-time supporter and member of ITEA, having served on the Board of Directors (1996–1999) and was re-elected in 2005. He also served on the DoD Defense Science Board, UXO/Land Mine Task Force (1996–1998).

Architecture-Based Systems Engineering

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Test and evaluation (T&E) assets—instrumentation, hardware-in-the-loop facilities, processing software, simulations and more—have been developed over the years to meet a wide variety of needs and requirements. Generally, each of these assets has been developed by using standard systems engineering processes, in which requirements are analyzed, a design is created, hardware and software are manufactured and integrated, and the resulting asset is tested. Such a process results in superb, but limited, point solutions to recognized problems and does not usually result in a solution that might have applicability to more global T&E needs. The achievement of these higher-level goals requires a modification to the standard systems engineering process by creating an *architecture* as the central aspect of the requirements and design process.

An architecture is a *segmentation* of a system (or system-of-systems) such that the primary pieces are identified and their purpose, function, interfaces, interrelatedness and guidelines for their evolution over time are defined. Architectures put constraints on designers and developers. These constraints make possible the achievement of higher-level goals that would not automatically be achieved if developers worked independently. These higher-level goals are called the system's *driving requirements.* A system may have hundreds or thousands of individual requirements; however, the *driving requirements* are those overarching requirements upon which the purpose of the system depends. Once these requirements are identified, it is a relatively straightforward process to segment the system and address these requirements. The architecture is then used as a starting point for a design to fulfill all of the numerous detailed requirements.

An architecture is thus *a bridge from requirements to design,* in which the most important, critical or abstract requirements are used to determine a basic segmentation of the system. An architecture has costs (the constraints) and benefits (the achievement of the driving requirements and the facilitating of the system design). A good architecture is one that achieves the driving requirements using the minimum number of constraints (that is, at minimum cost). It is important to note that *all* systems have architectures, even if they are unstated. The issue is whether an explicit architecture is defined for a system to ensure that its driving requirements are met.

In addition to ensuring that a system can meet broad goals, an architecture also focuses attention on those areas of technological immaturity that prevent the full achievement of the driving requirements. Thus, the architecture can vividly identify the "long poles in the tent" that require science and technology investment. Current efforts to develop non-intrusive instrumentation have relied on architecture development as the core tool for identifying technology shortfalls. This has led to research into advanced "smart" sensors that will be self-calibrating and will not rely on the test article for power or communications. Such non-intrusive sensors will allow testing of advanced weapon systems without the need to heavily modify the test article to install instrumentation systems. Without an overall architecture, each new technology development would focus on a single "point solution" with little relationship to other assets or the broad Department of Defense (DoD) and range community goals and strategies. With an architecture, each new system can address a piece of the whole puzzle rather than simply addressing individual issues out of context.

While architecture-based development has gradually taken a more prominent role in DoD design practice, there is little agreement in the general engineering community over the actual definition of an architecture. The Institute of Electrical and Electronics Engineers gives general guidelines on what an architecture is, and in the software engineering field, the principals of Rational Software Corporation (now owned by IBM) have done a significant amount of work defining a "Rational Unified Process for Systems Engineering" in which to discuss software architectures. The Reference Model for Open Distributed Processing (RM-ODP) is another attempt at describing architectures in a systematic way. However, industry acceptance has been slow in coming.

In an effort to promote interoperability and cost-effective development of software systems, the Defense Science Board in the early 1990s suggested that DoD establish architectural guidance for all DoD military systems. This initiative has culminated in the creation of the DoD Architecture Framework (DoDAF), a guide for system architects to document an architecture in a standard way so that architectures can be compared and contrasted. The DoDAF lists a number of views, each one focusing on a particular aspect of the architecture *(see Figure 1)*.

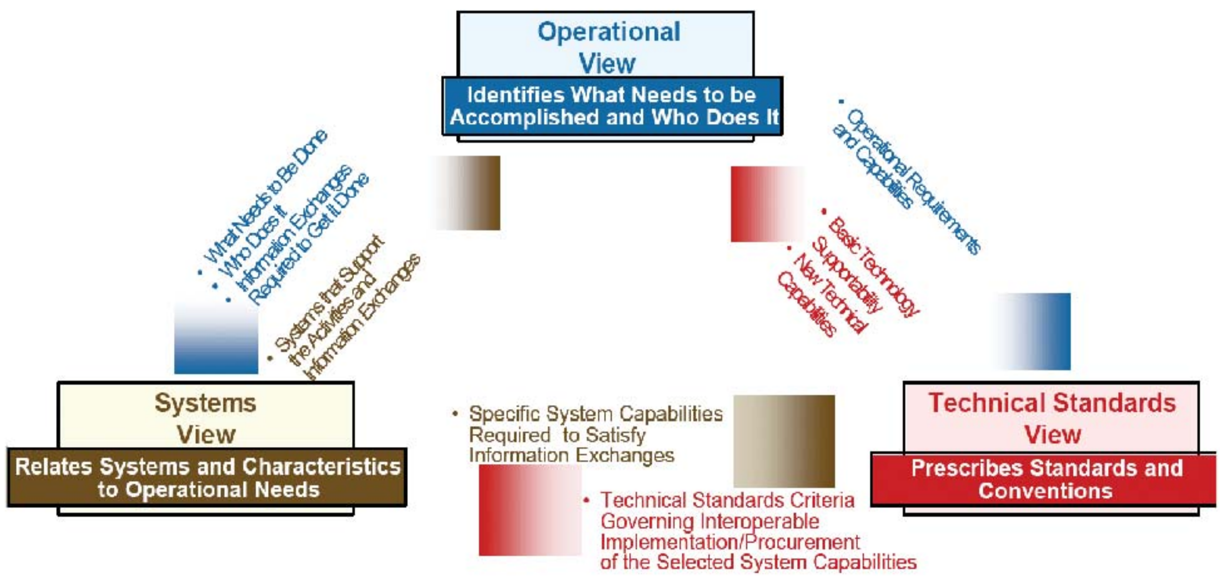

Figure 1. DoD Architecture Framework (DoDAF)

The Office of the Secretary of Defense (OSD) has taken the lead for creating an overall architecture for T&E assets. Each new T&E project is being asked not only to create an architecture for that specific project's deliverables, but also to address how those deliverables would fit into an overall T&E integrated architecture. Among the integrated architecture's driving requirements are interoperability among assets, reusability across ranges and services, spectrum efficiency and enablement of net-centric testing. The first step in T&E architecture-based development was the creation and widespread deployment of the Test and Training Enabling Architecture (TENA), which was designed to enable interoperability and reuse among range software systems. Additional architecture-based development is ongoing under the auspices of OSD, such as the Integrated Network-Enhanced Telemetry (iNET) project, the Data Management project, the T&E for Directed Energy project and others. The end goal of OSD's commitment to architecture-based development is the creation of new T&E assets that not only fulfill their narrow purposes but also fit into an interoperable, DoD-wide common range infrastructure for the next 30 years. ❑

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