START
Selected Topics in Assurance Related Technologies
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Simulation-Based Acquisition (SBA)

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Introduction

Simulation-Based Acquisition (SBA) is an acquisition process in which DoD and Industry are enabled by robust, collaborative use of simulation technology that is integrated across acquisition phases and programs. SBA enables large distributed work teams to operate in synthetic environments to produce higher quality systems at reduced cost over shorter periods of time.

SBA implies an interface and sharing of Modeling and Simulation (M&S) tools and technologies among the following domains:

- Research, Development, and Acquisition M&S
- Advanced Concepts Requirements
- Training and Military Operations

Consequently, the term "SMART" has been adopted in some organizations. SMART stands for Simulation and Modeling for Acquisition, Requirements, and Training. The term SBA/SMART is also used.

What is M&S?

Although definitions can vary, the following definitions of a model and simulation are commonly used.

Model: A model is a simplified representation of a system at some particular point in time or space intended to promote understanding of the real system.

Simulation: A simulation is the manipulation of a model so that it operates in a way that compresses time or space, thus enabling one to perceive interactions that would not otherwise be quickly readily apparent because of their separation in time or space.

Together, Modeling and Simulation (M&S) can be defined as a discipline for developing a level of understanding of how the parts of a system interact, and of the system as a whole. The broad level of understanding that is achievable via this discipline is seldom achievable any other way.

Computer simulation can be used as a tool to:

- Better understand and optimize performance of systems through trade-off analysis
- Verify the correctness of design
- Study day-to-day operations
- Develop "virtual environments" for training, war gaming, maintainability studies, etc.

Models are very familiar to the reliability and maintainability engineer. The reliability block diagram (RBD) is a model that describes how pieces of a product act and interact to determine the reliability of the product. It is characterized by blocks, representing parts, subassemblies, subsystems, etc., that are arranged in series or parallel configuration. Each block is defined by a probability of success, or a probability distribution function (pdf) and values of the associated parameters. Based on the pdf and its parameter values, the reliability of each block can be calculated for a given time. Then, by mathematically combining the reliabilities, the product reliability can be calculated and system strengths and weaknesses quickly become apparent.

RBDs can be incorporated in a simulation. RAPTOR, for example, is a simulation software package originally developed by the Air Force Operational Test and Evaluation Center. (RAPTOR can be downloaded free of charge from http://www.arinc.com/raptor/). RAPTOR stands for Rapid Prototyping for Testing Operational Readiness.

Using a Monte Carlo technique, RAPTOR can analyze an RBD over time and provide various measures of performance, depending on the type of input data that were used. Among the parameters calculated are:

- Uptime
- Mean Repair Time
- Availability (steady state, minimum, and maximum)

A publication of the DoD Reliability Analysis Center

- Spares costs
- Mean time between maintenance
- Number of system failures

Uses of M&S

Modeling and simulation can be used in system design trade offs and to support design and engineering decisions. Simulation early in the design cycle is important because correcting problems becomes dramatically more expensive as a design progresses from concept to final product. During design, simulation can be used to choose between design alternatives, verify a chosen design approach, evaluate accessibility and displays, and so forth. Later, simulation can be used to train operators and maintainers and mimic the performance of the product in "real life" operation. Training simulators for both operators and maintainers are used throughout a product's operational life. Failures or deficiencies found during simulation are less critical and more economically acceptable than those found during expensive testing.

Readily available simulation software has made it possible to model and analyze the operation of a real system by non-experts, who are managers but not programmers. Prior to the advent of computers and simulation software, extensive mathematical models were required, models that were created by experts. Modeling is, of course, still an important tool. In fact, a simulation is the execution of a model, represented by a computer program that gives information about the system being investigated.

Background and Concept of SBA

As defense budgets have shrunk, the DoD and military services have increased their efforts to acquire modern weapon systems at an affordable cost and in less time. Under Acquisition Reform, these efforts have resulted in standardization reform, consideration of non-developmental items (NDI) (includes commercial off-the-shelf, COTS, equipment), Integrated Product and Process Development (IPPD), the Single Process Initiative, cost as an independent variable (CAIV), and other initiatives.

Simulation-Based Acquisition (SBA) is the latest innovative approach to acquisition. SBA is a broad concept in which the capabilities of computers, M&S, and advanced information technology are brought together to:

- Substantially reduce the time, resources, and risk associated with the entire acquisition process
- Increase the quality, military worth and supportability of fielded systems while reducing total ownership costs throughout the total life cycle
- Enable IPPD across the entire acquisition life cycle
- Rapidly evaluate the effects of a wide range of inputs

SBA holds the promise of meeting these goals through three mechanisms: collaborative environment, information sharing, and sharing of mature advancements in information technology. This interdependent triumvirate is depicted in Figure 1.

As shown in Figure 1, these three enablers of SBA are interrelated and interdependent. For example, a key to effective collaborative effort is the efficient, automated and near-real-time sharing of relevant information among all personnel with a need to know. Team members must have an accurate and consistent understanding of the physical and functional characteristics of the system and its external environments. Information about the system is shared via a distributed product description (DPD). Information about its external environments is shared by similar mechanisms. A DPD is characterized by (see Figure 1.b):

- A single integrated data set
- Minimal data duplication
- Data set coherency
- Web-based access
- Security/access controls to protect classified, proprietary or private information
- Configuration management

What SBA is Not

SBA is not an approach in which simulations make the decisions. Simulation is simply a tool to help decision makers evaluate a complex set of interrelated factors. The results of simulations must be considered as carefully as the results of any analysis. Also, other more conventional sources of information, as well as experience in prior acquisitions, are still important inputs into the decision-making process.

SBA does not replace a sound systems engineering approach; rather, it provides a mechanism for effectively implementing a systems approach to design and development.

Similarly, SBA is not simply giving everyone all possible information and allowing everyone to see everything that others are doing. Collaborative effort goes beyond having total information and total visibility. It requires that members of a team have access to the information needed to perform their job, information that is accurate and timely. The information must be easily accessible and searchable. Controls must be in place to ensure that only authorized personnel can alter information.

Implementing SBA

SBA is not a replacement for good systems engineering. Indeed, an important simulation tool is Simulation Based Design (SBD), which is a system design approach based on the creation of virtual system prototypes and virtual environments within an integrated system design capture and simulation framework. Virtual prototypes of candidate system designs are constructed based upon design information captured in multiple domains.

Simulation allows virtual prototypes to be examined in operational scenarios. The cost and schedule associated with a specific design can be compared with the functionality and support costs of the design. In this way, systems can be designed and developed that meet the mission requirements at the minimum life cycle cost.

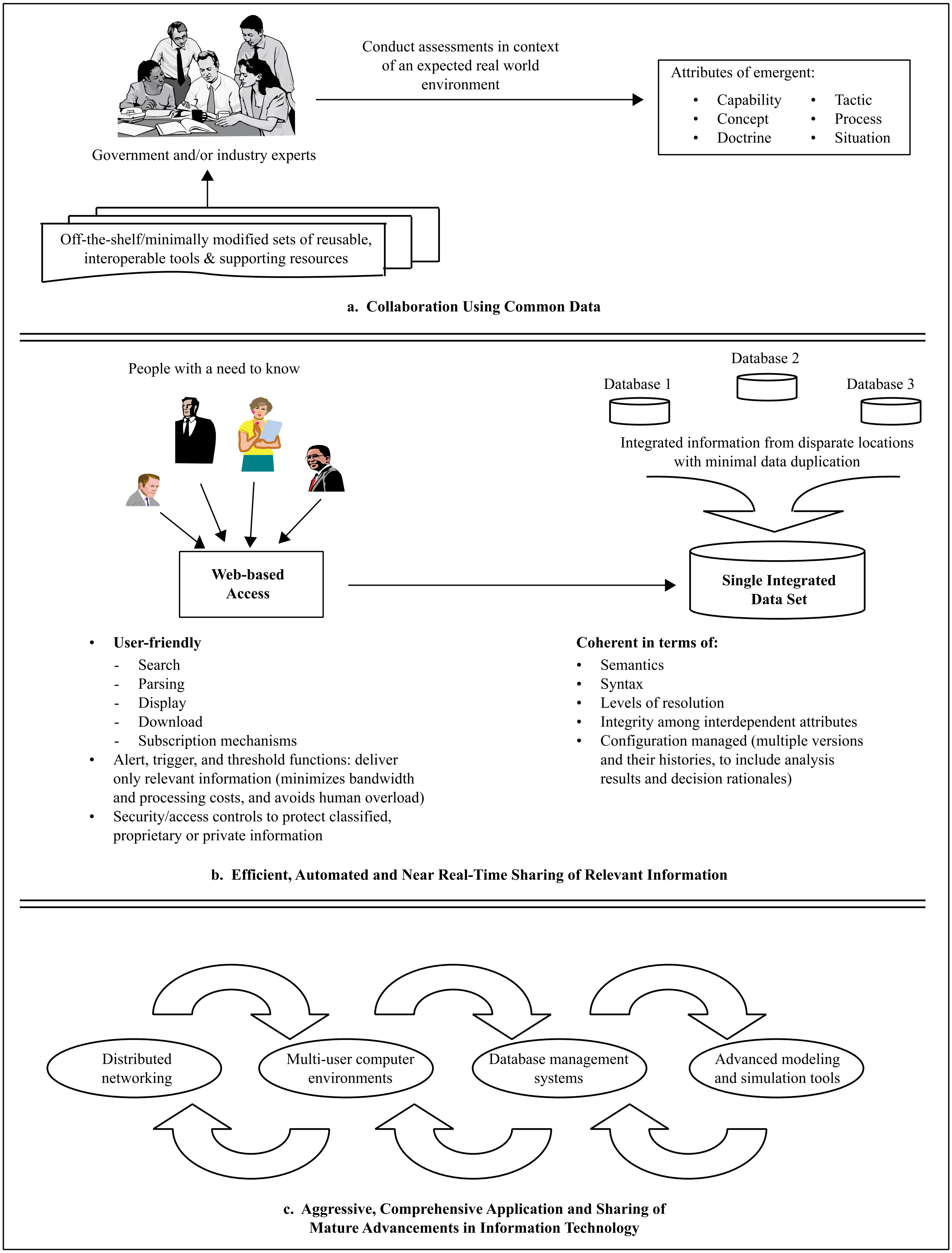

Figure 1. SBA involves collaboration, sharing of information, and the application and sharing of advances in information technology.

Advanced system engineering development methods and automation techniques allow the complexity inherent in the design of large complex systems to be managed efficiently and provide an effective means for evaluating multiple candidate design options at various levels of design abstraction. The US Advanced Research Projects Agency has pursued a simulation based design approach in the development of advanced ship design tools that address mechanical and hydrodynamic ship design factors.

Each military service is implementing SBA differently. The US Army has adopted the SMART, or Simulation and Modeling for Acquisition, Requirements, and Training, approach. Established by the Assistant Secretary of the Army for Acquisition, Logistics, and Technology, SMART brings together the requirements, training, and acquisition communities to address system development and life-cycle support. A centrally planned, decentrally executed strategy is being used to motivate Army program managers to incorporate SMART in their programs.

The US Navy was the earliest service proponent of SBA. Unlike the other services, however, the Navy has not established a high-level "champion" for the concept. The Navy plans to establish a work breakdown structure that supports the cost-effective implementation of SBA.

The US Air Force explored SBA roadmap concepts in 1998 using a Tiger Team under the leadership of the Air Force Materiel Command (AFMC). AFMC, with Air Staff assistance, has been given the leadership role for SBA within the Air Force. This team made recommendations concerning how SBA should be implemented within the Air Force. As a result of this Tiger Team and a subsequent General Officer SBA Conference, the Air Force established the SBA Infrastructure Program, scheduled to begin in October 2001.

Success Stories

SBA has already been used successfully on several major acquisitions. These include:

1. Advanced Amphibious Assault Vehicle (AAAV). A Model-Test-Model philosophy has been an integral part of the AAAV development process to date and is expected to continue throughout the vehicle's life.
2. Advanced Tomahawk Weapon Control System. This system consists of the Joint Precision Strike Demonstration (JPSD), Strike Warfare System Integration Lab, and Virtual Development Lab.
   a. The mission of JPSD is to demonstrate and deliver to US Forces Korea (USFK) a significantly enhanced capability to defeat North Korean 240 MM Multiple Rocket Launchers (MRLS).
   b. The Strike Warfare System Integration Lab is a certified system for testing Tomahawk Weapon Control Systems.
   c. The Virtual Development lab is an idea for the future that should allow new technology development, demonstration and integration.
3. Theater Air Defense (PEO-TAD). The philosophy of PEO-TAD is to phase the transition of Modeling & Simulation capabilities for current system to Next Generation Systems in support of SBA.
4. Joint Strike Fighter. Full-mission simulation demonstrations with full pilot-in-the-loop functionality used to validate design and reduce risks.
5. US Army GRIZZLY Breacher System. Integrated, Real Time, High Fidelity, Grizzly Virtual Prototype Simulation (GVPS) for development and test.

Reliability and SBA

In designing and producing a new weapon system, or any product for that matter, managers and engineers strive to meet a number of important, often conflicting requirements. These include cost, schedule, and performance. Performance itself has many different measures. These can include weight, stealth, speed, vulnerability, accuracy, range, and reliability.

The result of trying to meet many, sometimes conflicting requirements is a compromise. In fact, the systems approach can be viewed as an attempt to optimize the whole, not necessarily any and certainly not all of the parts. So the design process consists of a series of iterative tradeoffs, in which a given design alternative is evaluated for its merits against the performance criteria.

Reliability is a critical aspect of system performance because it helps determine the effectiveness of a system in performing its mission, system readiness, and the costs to support and operate the system over its operational life. So integrating reliability models and tools into an SBA approach is essential.

How might reliability be integrated into SBA? Figure 2 depicts one possible scenario. In this scenario, the designer has direct access to a computer-aided design system. The designer defines a certain design alternative for a structural part, for example.

After the designer defines the shape, connections, function, material, and other attributes of the part, he or she can use the computer system to access databases that include the environmental and operating stresses that will apply to the part. The designer also accesses an on-line Finite Element Analysis (FEA) tool, runs it and the computer records maximum stresses, critical areas, the deterministic safety factor, and so forth.

Next the designer uses the computer to access a program for analyzing the reliability of the part using the stress-strength interference method. Figure 3 shows the difference between deterministic method and the stress-strength interference method for estimating reliability.

The system also performs the same analysis using alternative materials, parts, and configurations. The designer is now given a comparison, showing how using different materials affects the weight, reliability, and cost of the part leading to informed quantitative design decisions.

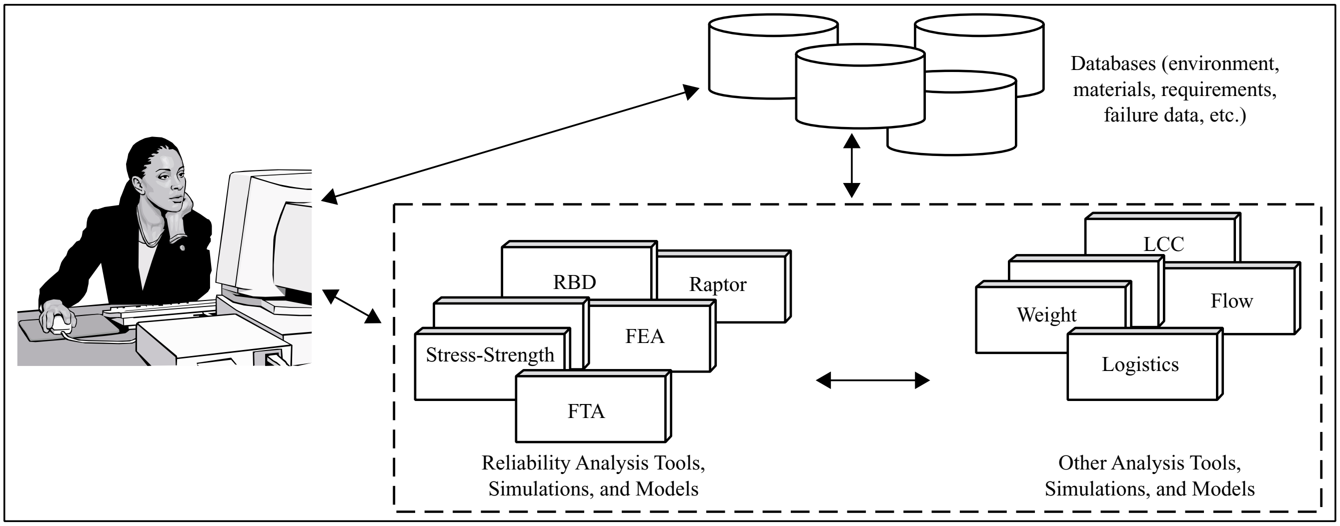

Figure 2. Integrating reliability tools, models, and simulations with other design tools, cost models, and databases make design trades and evaluations more efficient. Reliability can be addressed much more effectively and truly influence the design.

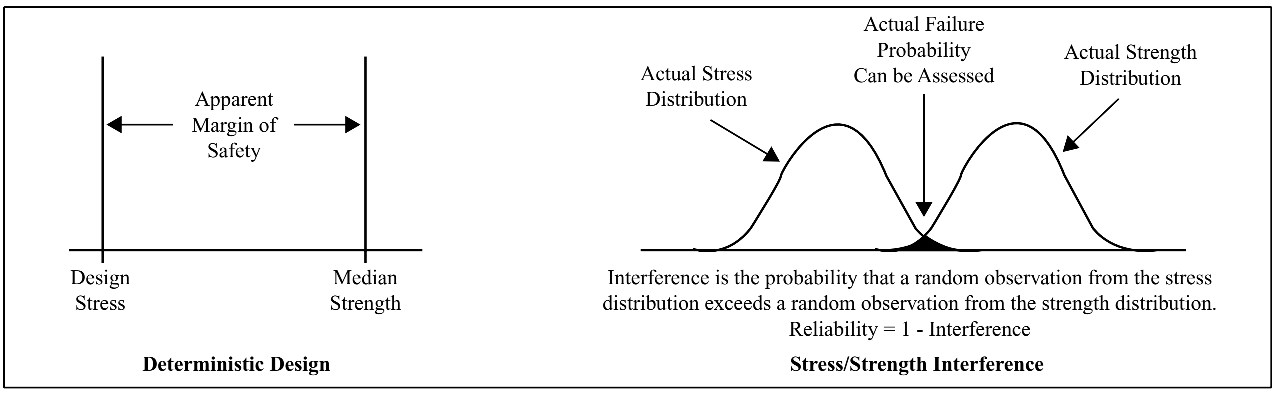

Figure 3. Deterministic design assumes point values (usually maximums and minimums). Probabilistic design accounts for uncertainty.

For Further Study

Additional information on SBA and on modeling and simulation can be obtained from the following web sites. In addition, many of the publications in the list that follows can be downloaded from these sites:

1. Web Sites:
   a. Air Force Agency for Modeling & Simulation, http://www.afams.af.mil/
   b. Center for Human Modeling and Simulation, http://www.cis.upenn.edu/~hms/
   c. DARPA SBD tools, http://classic.deskbook.osd.mil/valhtml/2/29/291/291W02.htm
   d. Defense Modeling & Simulation Office, http://www.dmso.mil/
   e. Modeling & Simulation Information Analysis Center, Special Interest Area - SBA, http://www.msosa.dmso.mil/sba/default.asp
   f. Navy Modeling and Simulation Management Office, http://navmsmo.hq.navy.mil/
   g. Simulation and Modeling for Acquisition, Requirements and Training (SMART) Conference 2001 (download presentations), http://www.amso.army.mil/smart/conference/2001/agenda-pres.htm
   h. The Society For Modeling and Simulation International, http://www.scs.org/
   i. STRICOM Simulation Based Acquisition, http://www.stricom.army.mil/PRODUCTS/SBA/

2. Publications:
   a. "A Roadmap for Simulation Based Acquisition," Report of the Joint Simulation Based Acquisition Task Force, Coordinating Draft, 8 December 1998.
   b. DSMC Press Publications, "Simulation Based Acquisition: A New Approach," (1997-1998). Free download from: http://www.dsmc.dsm.mil/pubs/mfrpts/mfrfr_1998.htm.
   c. DoD 5000.59, "DoD Modeling and Simulation (M&S) Management," 4 January 1994.

d. DoD 5000.59-P, “DoD Modeling and Simulation Master Plan,” October 1995.
e. DoD 5000.61, “DoD Modeling and Simulation Verification, Validation and Accreditation (VV&A),” 29 April 1996.
f. Hollenbach, J., “Department of the Navy Approaches to Simulation Based Acquisition,” Proceedings of the Fall 2000 Simulation Interoperability Workshop, September 2000.
g. Law, Averill M. and David M. Kelton, “Simulation Modeling and Analysis,” McGraw-Hill Higher Education, Columbus, OH, October 1999.
h. “Modeling and Simulation Support to Simulation,” Air Force Instruction 16-1002, 1 June 2000.
i. Severance, Frank, “Systems Modeling & Simulation: An Introduction,” John Wiley & Sons, Incorporated, New York, September 2001 (not yet published).
j. “Simulation Support Plan Guidelines,” Office of the Assistant Secretary of the Army for Research, Development, and Acquisition, May 1997.
k. Zeigler, Bernard P., Tag Gon Kim, and Herbert Praehofer, “Theory of Modeling and Simulation,” Academic Press, Incorporated, January 2000.

About the Author

Ned H. Criscimagna is a Science Advisor with IIT Research Institute (IITRI) and Deputy Director of the Reliability Analysis Center. He has been involved in a wide variety of projects related to Defense Acquisition Reform, reliability, acquisition, logistics, reliability and maintainability (R&M), and availability. He led the development of MIL-HDBK-470 and the update to MIL-HDBK-338. He has over 36 years experience in project management, acquisition, logistics, R&M, and availability.

Mr. Criscimagna earned his B.S. in Mechanical Engineering from the University of Nebraska-Lincoln in 1965 and his M.S. in Systems Engineering from the USAF Institute of Technology in 1971. He is a member of the American Society of Quality and a Senior Member of the Society of Logistics Engineers. He is a certified Professional Logistician, a Certified Reliability Engineer, chairs the ASQ/ANSI Z-1 Dependability Subcommittee, is the Deputy Technical Advisor of the US TAG to IEC TC56, and Operations Chair for the SAE G-11 Division.

Future Issues

RAC’s Selected Topics in Assurance Related Technologies (START) are intended to get you started in knowledge of a particular subject of immediate interest in reliability, maintainability, supportability and quality. Future START sheets will cover Testing Confidence Levels, Experimental Design, OC Curves, Reliability Growth Projections, and Repairable Systems.

Please let us know if there are subjects you would like covered in future issues of START.

Other START Sheets Available

Many Selected Topics in Assurance Related Technologies (START) sheets have been published on subjects of interest in reliability, maintainability, quality, and supportability. START sheets are available on-line in their entirety at http://rac.iitri.org/DATA/START.

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