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IACS: AN ESSENTIAL RESOURCE FOR ATTAINING BETTER BUYING POWER

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The Department of Defense's Information Analysis Centers (IACs) are undergoing the most sweeping change ever undertaken since their inception in 1947, in the wake of the Second World War. For over 65 years, the IACs have served as an essential resource to affordably access technical data and analysis in support of current operations. IACs operate under the leadership of the Assistant Secretary of Defense for Research and Engineering (ASD(R&E)), and are administered by the Defense Technical Information Center (DTIC); day-to-day work is conducted in partnership with all four military services along with joint organizations, such as the Combatant Commands. With their broad footprint across DoD, IACs allow the Department to reduce duplication, building on previous research, development, and operational experience.

The on-going effort to restructure the IACs will be completed by the summer of 2014. Driven by changes in government policy, while also incorporating best practices gleaned from decades of operational experience, the restructuring of the IACs is intended to accomplish these objectives:

- Realign focus to match the top priorities of the Secretary of Defense
- Increase synergy across related technology areas
- Increase opportunities for small businesses
- Lower cost and improve quality through enhanced competition
- Expand the industrial base accessible through the IACs

But will this change improve the IACs, or does it threaten to undermine the IACs long-standing success? To answer this question, DTIC commissioned a study by the Center for Strategic and International Studies (CSIS). After months of research, CSIS concluded that the restructuring the IACs is an "essential task" for the Department. In their final report, CSIS confirmed that the on-going changes will serve to enhance the IACs' value to the Department.

> *Under the new consolidated, restructured, and enhanced construct, [the IACs] will be positioned to create and sustain a focus on the Better Buying Power (BBP) Initiative to improve affordability, productivity, and standardization within defense acquisition programs.*

IAC Business Model: Building on a Solid Foundation

As the Department's focus has shifted to address asymmetric threats, DoD scientists and engineers simply do not have the time to sift through mountains of data to uncover essential information to address emerging requirements. This situation underscores the value of and necessity for organizations that provide analysis, synthesis, and dissemination of relevant, timely knowledge and information. The IACs are just such a resource. IACs provide tactical relevance through direct connection to the Warfighter, and strategic value through long term trend analysis and recommendations. They answer an immediate need, driven by the requirements of the Warfighter and acquisition community. Products such as State-of-the-Art reports provide a detailed analysis of immediate, critical challenges, while technical inquiry services offer a direct connection to a vast network of Subject Matter Experts (SMEs) from across government, industry, and academia. IACs maintain involvement in technical communities and work with senior executives to solve the challenges of the day, while anticipating and preparing for those of tomorrow.

In a time of shrinking budgets and increasing responsibility, IACs are a valuable resource for accessing evaluated Scientific and Technical Information (STI) culled from efforts to solve new and historic challenges. Through the IACs, research data is collected, reused to answer recurring challenges, and analyzed to identify long term trends and provide recommendations to the acquisition community.

The IAC model contains two key elements: Basic Centers of Operation (BCOs) and Technical Area Tasks (TATs). The IAC BCOs serve as the foundation for all IAC work. IAC BCOs are established in areas of strategic importance to DoD, to serve that technical community as a central knowledge resource. What does that mean? IAC BCOs are charged not only with hosting historic research data from their technical community, but also with maintaining information on the latest developments within that community – including work by government, industry, and academia. To facilitate this, they maintain databases, publish journals, provide web-based information resources (e.g., webinars), attend and host technical information exchanges, and much more. IACs also maintain an SME network, through which they reach out to key leaders and members of their technical community.

Building on the BCO foundation are TATs, which are individually-funded research and analysis efforts driven by emerging operational requirements. IAC BCOs help shape TATs, by ensuring new research and analysis builds on past experience, while maintaining alignment with both individual customer needs and broader DoD imperatives. For example, an IAC TAT focused on enhancing survivability of Remotely Piloted Aircraft (RPAs) builds on existing technology and historic lessons learned from years of manned aircraft operations. IAC BCOs collect and maintain aircraft shootdown data, documenting circumstances that resulted in the loss, analyzing trends, and recommending changes to decrease vulnerability. This data is used in executing an IAC TAT, to optimize new system design for RPAs, as well as inform tactics, techniques, and procedures to maximize system effectiveness.

A central feature of the IAC model is the establishment of a community of practice for each of the three focus areas of the IACs: Cyber Security and Information Systems, Defense Systems, and Homeland Defense and Security. Through these communities of practice, IACs engage in building and exchanging tacit knowledge, based on the diverse experiences of the individual SMEs within the community. This tacit knowledge goes beyond information contained in formal reports, and has been useful in answering the complex, multidimensional challenges our operational forces face in today's interconnected and dynamic environment.

Rather than simply provide access to raw data, IACs go a step further in creating tailored information products and analytical tools to make meaningful information available to influence operational decision-making. IAC governance is informed by an Executive Steering Committee, comprising senior executive and military members of each stakeholder organization. The Steering Committee identifies areas of future focus for the technical community, which the IAC analyzes to uncover gaps in the existing knowledge base. In order to fill these gaps, IACs undertake special studies to pull together information on existing technology and best business practices across government (DoD and other agencies), as well as the commercial sector; these studies are published and made available for broadest possible dissemination, to inform the technical community of potential capabilities that exist or are under development, that can be used to fill existing gaps as the Department anticipates and prepares for future challenges. Analytical tools make use of information technology to draw on vast amounts of technical data to answer specific questions, identify trends, and recommend courses of action.

Through all of these ways, the IACs maintain a focus on Better Buying Power. The IAC business model in particular directly supports the first two elements of the Department's Better Buying Power Initiative: achieving affordable programs and controlling cost throughout the product lifecycle. Both of these objectives depend on access to meaningful, relevant, and timely information and analysis. Such is the core focus of DoD's Information Analysis Centers.

Bringing the "Think Tank" to the Battlespace

A not uncommon criticism of research organizations is that they are disconnected from operational users. More than one lengthy study has regrettably concluded, after hundreds of pages of data, that "more research is needed on this topic."

The IACs recognize this potential pitfall; consequently, our focus is on bringing the "think tank" to the battlespace, focusing IAC information and analysis on real world, practical, and current operational challenges. IACs identify and collect the latest research, making it readily available for tactical operations; information products and analytical tools make the results of past research data accessible and relevant to the Warfighter. IACs occasionally forward deploy, sending research personnel into the field to better understand the challenges our men and women in uniform face in the field. This hands-on experience enables the IACs to better deliver relevant information and technological solutions to those who have an immediate need to put them to use. This also enables IACs to test and validate current research in today's operations environment. Additional data is gathered from the field to improve system design and implementation.

For example, the Reliability IAC (RIAC) evaluated systems failures from the fleet of Mine Resistant Ambush Protected (MRAP) vehicles; RIAC's research and analysis resulted in a series of recommendations to the MRAP Joint Program Office, as well as Original Equipment Manufacturers, to optimize reliability-centered maintenance. The result is an estimated cost avoidance of $8.542 billion over the life of the systems. This equates to a savings of $79.6

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million in reduced material cost and a reduction of 192.8 million man-hours. RIAC work has also improved Operational Availability of the MRAP fleet, with an increase of nearly 3,300 hours/year in mission availability, ensuring these critical systems are operational, functional, and available for the mission.

Embodying and Enabling a Focus on Affordability

While IAC operations support affordability in Defense programs, by building on existing technology and knowledge, internal restructuring also embodies a focus on affordability, aligning with top DoD priorities, enhancing synergy between related technology areas, enhancing competition and expanding opportunities for small business.

In a 2011 memo, the Secretary of Defense identified the following priorities for Science and Technology for the coming years (2013-2017):

› Data-to-Decisions
› Engineered Resilient Systems
› Cyber Sciences
› Electronic Warfare / Electronic Protection
› Counter Weapons of Mass Destruction
› Autonomy
› Human Systems

At a top level, the IAC model is focused on moving from data to decisions; that is, reducing the time and effort needed to extract actionable information from vast amounts of available data. Consequently, all IACs under the new model will be focused on achieving this top S&T priority. Remaining priorities are aligned to individual IACs, as depicted in Figure 1.

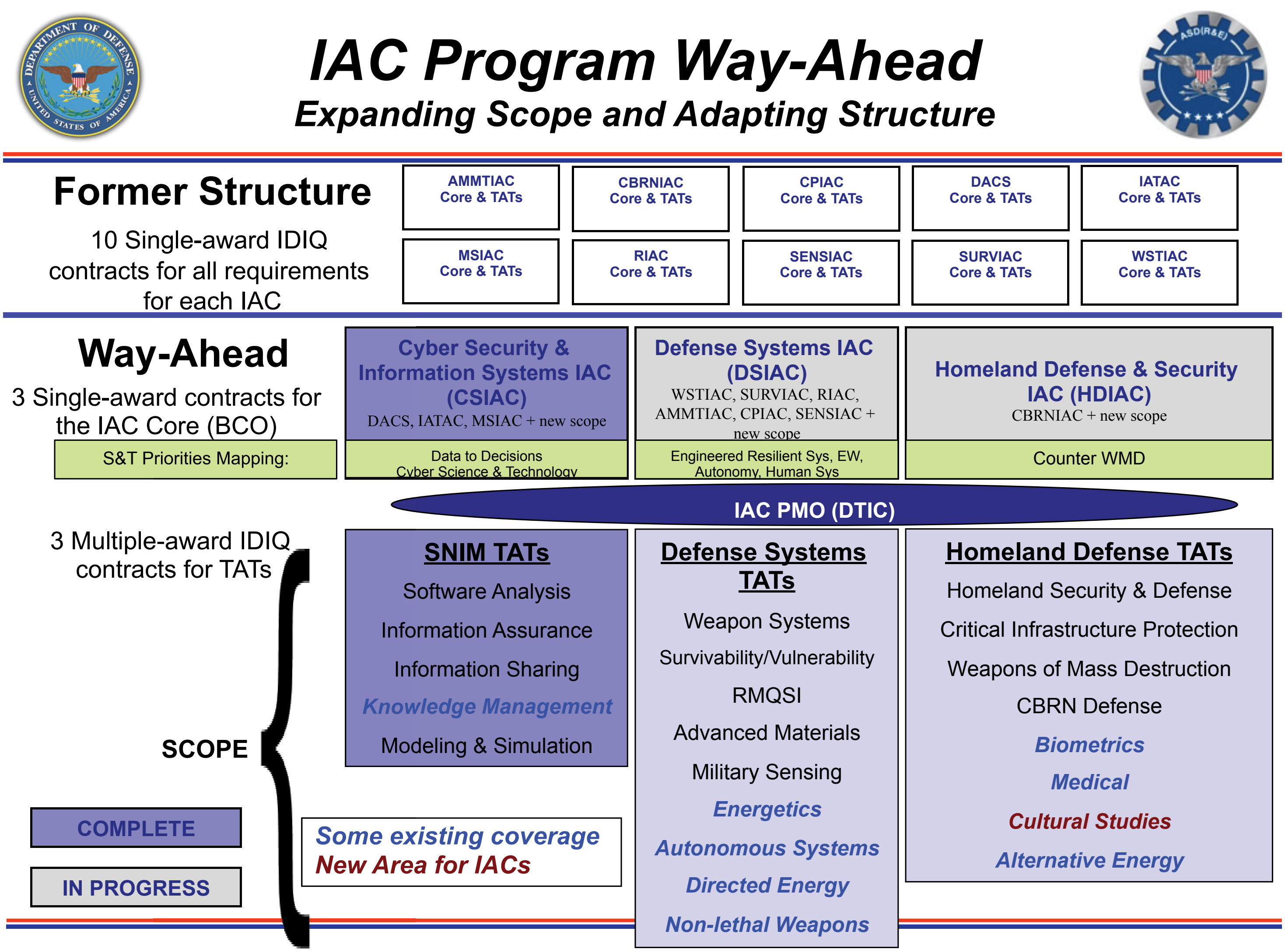

Figure 1: An Overview of the IAC Program Way-Ahead

IAC BCOs will focus on building a robust knowledge base for each of these areas, while TATs will focus operational research and analysis on identifying best-fit technological solutions. Existing knowledge and capability of the RIAC will be incorporated into the Defense Systems IAC (DSIAC), which will be in place by the summer of 2014.

While ensuring the restructured IACs are aligned to the Department's top priorities, the consolidated IACs will also bring together related technology areas, to further enhance synergy and information sharing between disparate communities. For example, advanced materials research will be merged with reliability engineering expertise under the Defense Systems IAC. While each of these technical areas is distinct, they are also mutually dependent, with advanced materials playing a key role in enhancing system reliability. Although the new IAC structure allows many common areas to be combined, the new structure is not an attempt to create three stove-piped organizations. Rather, the three consolidated IACs might be better represented as a Venn diagram, with each IAC sharing some common interests with the others; for example, Critical Infrastructure Protection (covered by the Homeland Defense and Security IAC) will certainly share information with the Cyber Security and Information Systems IAC, as many critical infrastructure systems depend on cyber security to protect operations in today's globally connected environment.

Under the new construct, IAC TATs will be issued through multiple award contracts (MACs). This approach satisfies congressional mandates for enhancing competition, while also expanding the industrial base accessible through the IACs. Under the MAC construct, customers throughout the Department will be able to select the best value solution to their complex technical challenges. In Fiscal Year 2012, the IACs' first MAC (a $2 billion contract focused on Software, Networks, Information Assurance, and Modeling & Simulation) demonstrated measured cost savings of 17%. The implementation of MACs for TAT work implements the Better Buying Power Initiative to promote competition by emphasizing "competition strategies and creating and maintaining competitive environments." (Implementation Directive for Better Buying Power 2.0, 24 Apr 2013: http://www.acq.osd.mil/)

The new IAC structure also significantly increases opportunities for small business. IAC BCOs will be set aside for small businesses, while TAT contracts will gradually increase small business performance, based on current market research into small business capabilities, in direct alignment with the Better Buying Power Initiative to "increase small business roles and opportunities." So far, two small business BCO awards have been issued; an assessment of their operations has identified several mission benefits, including increased access to sensitive industry information, which the Department depends on in order to achieve the Better Buying Power Initiative to control acquisition costs.

In the CSIS study on IAC alignment with Better Buying Power, the authors highlighted one particular initiative as an example of the significant steps the IACs have taken to address defense systems affordability. The Software & Systems Cost and Performance Analysis Toolkit (S2CPAT) exemplifies the IAC focus on acquisition affordability. Under S2CPAT, the Cyber Security and Information Systems IAC (CSIAC) collects cost and performance data from software-intensive defense systems, and provides both government and defense industry personnel access to trend data to enable more realistic cost estimates for future systems. These realistic cost estimates enable better planning and decision making in focusing diminishing resources on achieving the greatest positive impact – as such, they embody the essence of the overall Better Buying Power Initiative, strengthening the Department's buying power, improving industry productivity, and providing an affordable, value-added military capability to the Warfighter.

Conclusion: What About Sequestration?

In a recent Federal Times article, Pentagon spokeswoman Maureen Schumann said the IACs allow the Pentagon "to reduce duplication and build on previous research, development and other technical needs."

The Government Accountability Office (GAO) identified reduced duplication as an area where the federal government can achieve greater efficiency and effectiveness. In an April 2013 report, GAO asserts that "the government could potentially save tens of billions of dollars annually" by reducing fragmentation, duplication, and overlap. This assessment underscores the value of the IACs.

In a memo discussing IAC operations under sequestration, DTIC and IAC leadership affirmed that "the IACs will continue to operate, providing an efficient mechanism for the department to continue its mission under the severe constraints of sequestration." Ms. Schumann agreed, indicating that "in this time of budgetary uncertainty, the importance of DoD's IACs is actually enhanced." She concluded, "IACs serve as a proven resource for maximizing the value of each dollar the department spends."

With multiple avenues to support USD(AT&L), IACs represent an essential tool for cost-effectively fielding superior warfighting capabilities in today's ever-changing high-technological environment. Building on decades of experience, the IACs continue to adapt to the evolving needs of the DoD. As CSIS concluded in their case study on Better Buying Power, the restructured IACs serve as a "resource for organizations across DoD seeking to effectively achieve [Better Buying Power] objectives."

THE SCIENCE OF AFFORDABLE, RELIABLE WEAPON SYSTEMS

Dr. Catherine Warner, Science Advisor, Director, Operational Test and Evaluation (DOT&E)

The Importance of Reliability

Acquiring reliable Department of Defense (DoD) systems is of paramount importance. Reliable systems cost less overall, are more likely to be available when called upon, and enable longer system lifespan. In the current fiscal climate it is important that system reliability is emphasized early in the acquisition process. Reliability cannot be tested-in, it must be designed-in, from the beginning. While more up-front effort is required to build reliable systems in the near term, the future savings potential is too great to ignore.

A 2009 Cost Assessment and Program Evaluation (CAPE) study clearly illustrates the potential for future savings for reliable systems. The majority of life-cycle costs for DoD systems, including ground combat systems, rotary-wing aircraft, fighter aircraft, and surface ships, reside in the Operations and Sustainment (O&S) phase. Overall, operations and support consumes approximately two-thirds of total program costs. Unreliability is the greatest single driver of O&S costs accounting for approximately 50 percent of all O&S costs. The more reliable the system, the less it costs to operate and sustain in the field. With today's highly complex systems, a small decrease in reliability can mean additional, substantial cost, but a small investment in reliability growth can significantly decrease O&S costs.

Despite the importance of developing reliable systems, DoD systems do not have an excellent reliability track record. The Director, Operational Test and Evaluation (DOT&E) conducted a review of all Operational Test and Evaluation reports submitted to Congress from FY85 to 2QFY13; only 58 percent (102/175) of the systems met their reliability threshold during that time period. Additionally, the percentage of reliable systems has been flat over this period. Figure 1 shows the percentage of systems that were reliable by fiscal year; there is no significant trend, either upwards or downwards, in the reliability of DoD weapon systems over this time period.

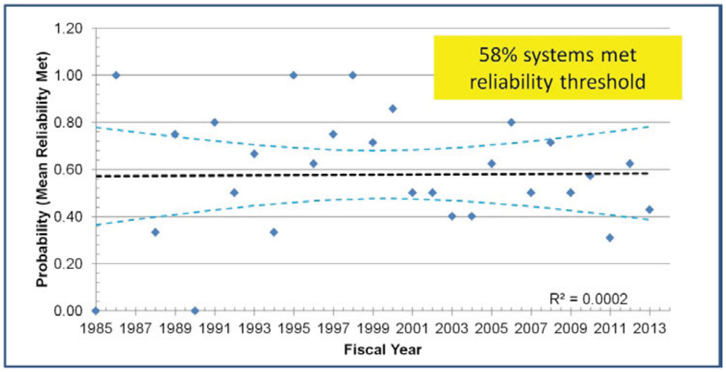

Figure 1: Probability Mean Reliability Met by Fiscal Year

Reliability is an important component in DOT&E's assessment of suitability. DOT&E's review of past reports showed that 98 percent of programs that achieved their reliability requirement were suitable, while only 22 percent of programs that failed their reliability requirement were suitable. Figure 2 shows the cumulative operational test reports that DOT&E has provided to the Congress along the black line. The green line shows the cumulative number of systems found effective, while the blue and red lines show the cumulative number of systems found suitable and reliable, respectively. Clearly, suitability and reliability lag behind effectiveness for our systems.

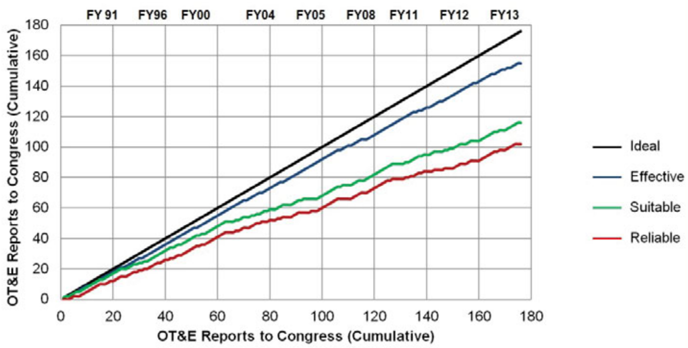

Figure 2: Cumulative Operational Test Reports

Efforts to Improve Reliability

In recent years, improving reliability has been a priority across the DoD and within DOT&E. In 2007, the Chairman of the Joint Chiefs of Staff (CJCS) Manual 3170.01C, Operation of the Joint Capabilities Integration and Development System, directed that materiel availability be included as a mandatory key performance parameter and materiel reliability as a Key System Attribute.

In 2008, the Defense Science Board Task Force on Developmental Test and Evaluation's primary findings included that, "the high suitability failure rates were caused by the lack of a disciplined systems engineering process, including a robust reliability growth program during system development." The Defense Science Board went on to recommend that "the single most important step necessary to correct high suitability failure rates is to ensure programs are formulated to execute a viable systems engineering strategy from the beginning, including a Reliability, Availability and Maintainability (RAM) growth program, as an integral part of design and development."

As a result of the Task Force's findings, DOT&E and the developmental test and evaluation office formed a reliability working group with three objectives:

- Ensuring programs are formulated with a RAM program
- Ensuring government organizations reconstitute a cadre of experienced test and evaluation and RAM personnel
- Implementing integrated testing

In July 2008, the Under Secretary of Defense for Acquisition, Technology and Logistics (USD(AT&L)) sent a memorandum to the Service Secretaries directing establishment of Service policy that all development contracts and acquisition plans must evaluate RAM during system design and evaluate the maturation of RAM through each phase of the acquisition lifecycle. DoD Instruction 5000.02 dated December 8, 2008, further says "PMs for all programs shall formulate a viable Reliability, Availability, and Maintainability (RAM) strategy that includes a reliability growth program as an integral part of design and development." On March 21, 2011, the USD(AT&L) issued Directive-Type Memorandum (DTM) 11-003, "Reliability Analysis, Planning, Tracking, and Reporting," to strengthen current acquisition policy by requiring RAM engineering activities throughout the system's lifecycle. It places early and continuing emphasis on reliability growth management that is fully integrated across systems engineering, lifecycle sustainment, and test and evaluation activities.

However, despite these policy changes, we have yet to see an improvement in the reliability of systems in operational testing as shown previously in Figures 1 and 2. Figure 3 shows the cumulative distribution functions (CDF) of the reliability thresholds programs met for three different sets of programs: those between FY07 – FY13 that have Reliability Growth Planning Curves (RGPC) in their Test and Evaluation Master Plan (TEMP); those between FY85 – FY98 that followed Military Standard (MIL-STD-785B); and those between FY99 – FY06 with no standards at all. This statistical test indicates that the set of programs governed under the current policy shown by the red curve (FY07 – 13) is resulting in improved reliability achievement when compared to previous policies characterized by the blue curve (prescriptive reliability standard, MIL-STD-785B) and the green curve (non-prescriptive, commercial best practices approach). Statistically, there is no significant evidence that any of these approaches are from a different distribution, meaning that none have produced better outcomes than the other. So, one may conclude that policy changes have not, in reality, changed the manner in which DoD systems are designed, developed, manufactured, and tested to improve reliability. However, the preceding data analysis does not include the potential impact of DTM 11-003 and the soon-to-be published DTM Implementation Guide. With a clear focus on understanding requirements, robust reliability design, and reliability growth demonstration and testing, it focuses on the important areas, but its activities will necessarily have to be contractual to ensure resources and time are committed to reliability.

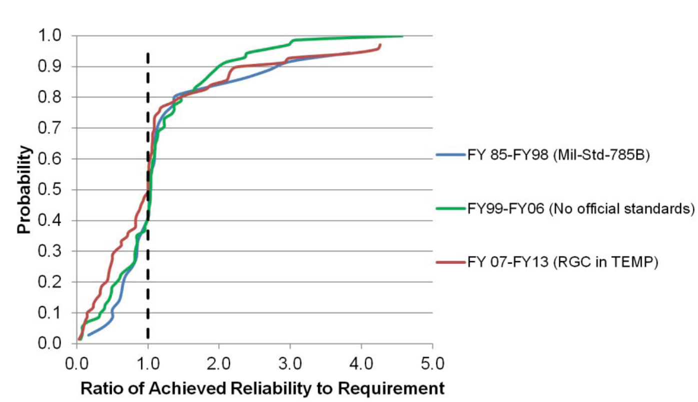

Figure 3: Comparison of Cumulative Distribution Functions for Three Groups of Programs

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To restore and enhance the ability of government contracting authorities to contract for reliability, DOT&E began sponsorship with the Services, industry, the Reliability Information Analysis Center (RIAC), and academia for the development of the American National Standard Institute/Government Electronics and Information Technology Association's (ANSI/GEIA)-STD-0009, Reliability Program Standard for Systems Design, Development, and Manufacturing. It was released on November 13, 2008, with its subsequent adoption for voluntary use by the DoD on August 20, 2009. The following discussion details the science of reliability in terms of the primary objectives of ANSI/GEIA-STD-0009.

The Science of Reliability

Reliability must be designed into a system from its initial conceptualization. Finding failure modes and fixing them after system specifications are determined can provide a marginal improvement in reliability, but the largest gains can be realized by designing the system with reliability as a key goal. A comprehensive reliability program focusing on reliability growth is essential for developing and acquiring reliable systems. From the start, programs should formulate and document a RAM program. The program should employ an appropriate reliability growth strategy to improve RAM performance until requirements are satisfied.

ANSI/GEIA-STD-0009 requires the developers and customer/users to work as a team to plan and implement a reliability program that provides systems/products that satisfy the user's requirements and expectations using a systems engineering approach. The ANSI/GEIA-STD-0009 has four simple objectives that are listed below.

- **Objective 1:** The team (developer, customer, and user) includes the activities necessary to ensure that the user's requirements and product needs are fully understood and defined, so that a comprehensive design specification and Reliability Program Plan is generated. *(Understand the user's requirements.)*
- **Objective 2:** The developer implements a set of engineering activities so that the resulting system/product satisfies the customer's documented requirements and needs. *(Design for reliability.)*
- **Objective 3:** The developer performs activities that assure the customer that the reliability requirements and product needs have been satisfied. *(Produce reliable systems.)*
- **Objective 4:** The team establishes a closed-loop feedback method to flow recommended improvements (corrective actions) and for continuous monitoring of reliability growth. *(Monitor and assess reliability.)*

ANSI/GEIA-STD-0009 and TechAmerica Handbook TA-HB-0009 define a systematic approach to engineering a system/product, incorporating best practices that have evolved considerably in recent years.

Five overarching areas to assess whether programs are completing activities necessary to acquire reliable systems and include the types of reliability information and activities requested by the Office of the Secretary of Defense (OSD) policy guidance include:

- System Engineering Plans (SEPs)
- Reliability test strategy
- Reliability growth strategy
- Reliability growth tracking
- Reliability in operational testing

Understand customer/user requirements and constraints

Clear and feasible requirements are essential for scoping the reliability program. Developers must be able to clearly understand the user's needs. This clear understanding is only possible if the requirement not only considers reliability for a given mission duration, but also the expected users of the system and the anticipated operational conditions. Additionally, the definition of failures should be defined up front in a Failure Definition Scoring Criteria (FDSC). However, these activities do not typically occur for defense systems. All too often requirements are specified without an operational context (user and environment) and the initial FDSC is not developed until much later in the program's lifecycle.

Requirements writers must also consider the costs of reliability. Long, et al (2007) investigated 17 systems and found a strong positive correlation between investment in the reliability program and the improvement in reliability. Reliability investments in the design phase resulted in reductions in the 20-year support costs; a twofold increase in reliability could result in as much as a 75 percent decrease in lifecycle support costs. The return on investment ranged from 5-100:1. Thus, while the upfront average procurement unit cost could increase by a factor of 2-10, the return on this investment over the lifecycle of the system greatly exceeds the investment.

Additionally, there are increased costs associated with testing systems with higher reliability. For example, consider a requirement for 99-percent reliability for completing a 6-hour mission. This is comparable to 600 hours between failures and would require at a minimum 1,800 hours of testing. If the requirement is lowered to 95-percent reliability, the associated mean time between failures is only 120 hours and testing could be accomplished in a minimum of 350 hours. This does not mean that users should lower their reliability requirements, but simply that they should consider these costs when determining if the requirement is adequate for their needs. DOT&E intends to require that Milestone B Test and Evaluation Master Plans (TEMPs) have an annex explaining the user's rationale for requirements in the Capability Development Document or the equivalent document. The requirements and rationale should be revisited as often as needed to permit discovery during the lifetime of the program.

Design and re-design for reliability

The most efficient and cost effective method for improving system reliability is to design reliability into the system during the design stage. Once the design is set, reliability improvements are more difficult and tend to focus on finding and fixing failure modes.

During the design and re-design stage, key engineering activities supporting the reliability growth program include:

› Reliability allocations to components and subsystems
› Development of reliability block diagrams (or system architectures for software intensive systems) and predictions for completing system configurations
› Updating the failure definitions and scoring criteria (FDSC)
› Failure mode, effects, and criticality analysis (FMECA)
› Refining system environmental loads and expected use profiles
› Dedicated test events for reliability such as accelerated life testing, and maintainability and built-in test demonstrations
› Reliability testing, including accelerated life testing (ALT) at the system and subsystem level

Design for reliability techniques, including robust product design and redundancies of critical systems, should be incorporated into the product design to improve reliability organically.

Produce reliable systems

Systems should be produced following industrial best practices. Quality control tools including control charts, design of experiments, and continuous process monitoring should be used to ensure that systems are produced in a controlled environment. This will minimize manufacturing related failure modes.

During early production of systems, reliability testing should shift from the subsystem level to the full system. It is essential to incorporate as much operational realism into the testing as early as possible to flesh out failure modes that will only be discovered in the operational environment. Once the system architecture is finalized, reliability improvements occur primarily by identifying failure modes and taking corrective action. The rate of growth depends on:

› Rate at which failure modes are surfaced
› Turnaround time for analyzing and implementing corrective actions
› Management Strategy (MS) – fraction of initial failure rate addressed by fixes
› Fix Effectiveness Factor (FEF) – fraction by which rate of occurrence of fixed modes is reduced

During the system production stage, programs should continue the activities of the design and re-design for the reliability stage. Additionally, the following reliability activities should be added to the reliability program:

› Determine initial estimates of system reliability
› Develop Reliability Growth Planning Curves (RGPCs) illustrating the reliability growth strategy and include justification for assumed model parameters (e.g., Fix Effectiveness Factors, Management Strategy)
› Determine adequate test time to surface failure modes and grow reliability
› Ensure that there is sufficient funding and opportunity to implement corrective actions and test events to confirm effectiveness of those actions
› Develop reliability growth tracking curves of failure data to support analysis of trends and changes to reliability metrics
› Develop entrance and exit criteria for each phase of testing

Monitor and assess user reliability

The initial operational test (IOT) is really only the first step in monitoring and assessing user reliability. The operational test should be scoped to provide reasonable levels of Consumer's and Producer's Risks. Operating characteristic (OC) curves are useful in determining sufficient test durations for demonstrating the reliability requirement. Figure 4 below shows a generic OC curve. It is important that the OC curve be based on the reliability growth goal.

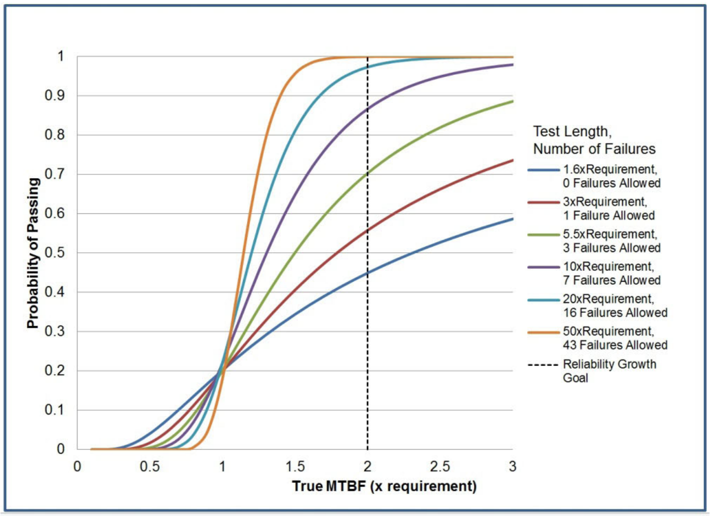

Figure 4: Operating Characteristic (OC) Curves

Consider for example in Figure 4, if the reliability growth goal was to achieve twice the requirement, then a test duration of 10 times the requirement would provide a high probability (87 percent) of the system successfully demonstrating the requirement in an operational test. However, if the system was only designed to achieve 1.5 times the requirement, a test duration of 20 times the requirement would provide a comparable level of risk. Resource requirements (including test articles and expendables) should reflect the required testing for conducting all reliability test and evaluation activities and are reflective of the allowable test risks.

Reliability monitoring is a lifetime process. The operational test is the first step in assessing and monitoring reliability. However, the

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process should continue for the duration of the system's usage. The reliability program should continue to be updated as new failure modes (including wear-out failure modes) surface; corrective actions need to be taken to ensure system reliability is maintained.

Conclusion

Reliability is a key enabler of suitability and robust reliability leads to reduced lifecycle cost by lowering O&S costs. However, reliability design and growth testing is expensive and requires careful planning, but the return on investment can also be high if properly executed. So, improving reliability has been a priority across DoD and within DOT&E and reflected in numerous policies. However, despite these efforts, we have yet to see an improvement in the reliability of systems in operational testing. Achieving reliability must involve contractually requiring sound reliability science as defined by the methodologies of the DTM and ANSI/GEIA-STD-0009.

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DTIC NEWS WIRE

Pentagon Asserts Increased Value of DoD Information Analysis Centers During Times of Budgetary Uncertainty

DTIC Communications Team
3 June 2013

Fort Belvoir, VA – For more than 65 years, the Defense Department's Information Analysis Centers (IACs) have provided an essential resource to affordably deliver data and analysis in support of the need for technical information supporting current operations. In a recent Federal Times article, Pentagon spokeswoman Maureen Schumann said the IACs allow the Pentagon "to reduce duplication and build on previous research, development and other technical needs."

The Government Accountability Office (GAO) identified reduced duplication as an area where the federal government can achieve greater efficiency and effectiveness. In an April 2013 report, GAO asserts that "the government could potentially save tens of billions of dollars annually" by reducing fragmentation, duplication, and overlap. This assessment underscores the value of the IACs.

The IACs operate as a part of the Defense Technical Information Center (DTIC), which supports their efforts, and provides additional technical data and research support for the Defense Department. In a recent memo discussing IAC operations under sequestration, DTIC and IAC leadership affirmed that "the IACs will continue to operate, providing an efficient mechanism for the department to continue its mission under the severe constraints of sequestration." Pentagon spokeswoman Maureen Schumann agreed, indicating that "in this time of budgetary uncertainty, the importance of DoD's IACs is actually enhanced." She concluded, "IACs serve as a proven resource for maximizing the value of each dollar the department spends."

Building on decades of experience, the IACs continue to adapt to the evolving needs of DoD. The Center for Strategic and International Studies (CSIS), in their case study on Better Buying Power, concluded that the on-going evolution of the IACs will only serve to enhance their value; according to the CSIS study, the IACs "will be positioned to create and sustain a focus on the Better Buying Power Initiative to improve affordability, productivity, and standardization within defense acquisition programs."

More information on the IACs can be found at http://iac.dtic.mil

BETTER BUYING POWER FOR SUSTAINMENT

James Farmer, ODASD (Materiel Readiness)

In April 2013, USD(AT&L) Frank Kendall issued Better Buying Power (BBP) 2.0, the second iteration of acquisition guidance aimed at improving how the DoD buys weapons systems, products and services. While the initiatives mostly apply to acquisition, improving how we sustain weapons systems will also yield an enduring benefit to the DoD. Operating and support (O&S) cost, after all, is two-thirds of the life cycle cost of a weapons system.

More and more, the department needs to know how much it can expect to pay to operate and maintain a weapons system before making the decision to develop and procure it. This leads to some practical how-to questions – but most fundamentally: How do programs establish requirements and structure business arrangements up front to deliver systems that will have higher readiness and lower life cycle cost, systems that get the most "bang for the buck" for the warfighter (and the taxpayer)?

The Modernization Trap

Simply modernizing our military systems has not been the answer to reign in cost. Modernization has provided unparalleled military capability, but invariably, newer and more modern systems have been more expensive to operate and maintain. There are few exceptions. For most systems fielded in the past 10-20 years, the annual O&S cost exceeds that of its predecessor (in constant dollars).

Former USD(AT&L) Jacque Gansler observed the trend of increasing O&S costs in the 1990's. He dubbed the situation a "death spiral" in which increasing O&S costs consumed more and more of the DoD's budget and prevented the investments in modernization that could reverse the trend. He attributed the trend to the age of our military equipment inventory. The older equipment is less reliable and requires herculean efforts to maintain readiness. He argued that modernizing our military assets would reverse the trend.

Unfortunately, while the observation is empirically true that operations and maintenance costs would eventually consume the entire DoD budget, buying newer systems has usually not helped. As an example, compare F-22 and F-35 O&S cost to F-16 or FA-18. Most of our newer systems are actually accelerating the "death spiral" rather than reversing the trend. In other words, the underlying cause of the "death spiral" might not be a lack of investment to replace aging systems. A major contributor to the trend is the *de facto* acceptance of higher sustainment cost for newer systems.

But this does not have to be the case. Experience on focused design for supportability efforts indicate that footprint, maintenance burden and overall cost can all be reduced at any stage of a program through proper design emphasis and prioritization of cost. The more modern system does not have to be more expensive to operate and maintain.

To that point, BBP 1.0 and 2.0 provide valuable guidance that actually can help reverse that trend. Table 1 summarizes a few BBP successes related to sustainment and some continuing challenges.

Table 1 – Sustainment Related BBP Initiatives

BBP Initiative	Success Areas	Challenges
Affordability Targets at Milestone A	• Controlling acquisition cost growth, equally emphasizing O&S cost • Integrating with JCIDS requirements process	• Controlling O&S cost between milestones as design matures • PM/PEO capability to control O&S cost
Should-Cost Management	• Acquisition cost management	• Developing defensible initiatives to reduce O&S cost
Increase Effective Use of PBL	• Implementing PBL with contractors and PPPs	• Incentivizing organic product support providers

Affordability Targets

Historically, the lack of an affordability requirement on programs has been a potentially crippling weakness to the department. The establishment of unaffordable requirement thresholds has led in some cases to program cancellation and in other cases to the fielding of unsupportable systems. There are two key elements to improving the cost-effectiveness of our acquisitions. The first is establishing an affordability target so that as system definition increases during development and cost estimates become more refined, cost growth can be mitigated by trading off system capabilities. The second key is having the discipline to make those trades as the program matures, that is, holding the line on cost during program execution.

BBP guidance requires "KPP-like" affordability caps at Milestone A, prior to conceptual design. The caps serve as a hard ceiling on acquisition and sustainment costs for a program. The immediate effect is to force the requirements community to consider the ability of the DoD to pay for the capability over the life cycle, before finalizing requirements and establishing an acquisition program baseline. The affordability cap includes acquisition and O&S cost.

Historical Challenges

Unfortunately, many decision makers in the past have sacrificed life cycle affordability for near-term acquisition "success." On one recent program, the requirement sponsor was seeking approval to reduce the program's reliability requirement so they could be approved for production with lower reliability. For that program, it would heavily affect sustainment cost and availability, with tangible operational impact in combat scenarios. The concerns over readiness were raised in a high-level meeting. The sponsor, a flag officer, replied, "We can always buy more availability." (Fortunately, the program received funding to grow reliability close to their original requirement and is on track to do so.)

The comment reveals several challenges in controlling life cycle cost in defense acquisitions. First, actual cost to operate and sustain a system is subject to outside forces such as changes in usage rates for training and other operations. Global threats change constantly. True O&S cost is always in flux. Historically the near-term cost has often outweighed sustainment consequences because the O&S cost estimates are deemed fuzzy at best.

As well, most programs transition to an in-service or sustainment program manager after procurement, dividing life cycle management responsibility between acquisition and sustainment. Funding for most operations and sustainment activities is completely separate from acquisition funding and is not programmed, budgeted or executed by the acquisition program manager. This stovepipe reinforces near-term decision focus within acquisition programs. It also reinforces the emphasis of capability over life cycle cost when setting requirements, because the requirement sponsor does not have to pay for sustainment.

Some aspects of statute have not helped either. Nunn-McCurdy reviews, which may result in program cancellation or milestone rescission, are triggered by critical acquisition cost breach and not by life cycle or sustainment cost breaches. Only recently has Congress required programs to report O&S Cost breaches for major programs.

Should-Cost Management

Should-cost management can put downward pressure on sustainment costs where such emphasis has been lacking in the past. Should-cost management is a tool to reduce program cost by seeking out and eliminating low-value-added cost contributors, through distinct actions. BBP should-cost management guidance provides defense programs with a structure that encourages and justifies program action to reduce sustainment costs as well as acquisition costs. When applied against a strong O&S cost baseline, should-cost techniques provide substantiated cost avoidance. The sustainment KPP/KSA requirements, and affordability targets at Milestone A, allow programs to establish a strong O&S will-cost baseline; this O&S cost baseline in turn enables should-cost management for sustainment.

The structure and guidance are straightforward, yet applying should-cost management to sustainment has been challenging in many respects. For one, it is difficult to estimate O&S costs early in the program, in a manner that ties O&S cost to design parameters and sustainment strategy. For example, at Milestone A, the requirement developer has determined the appropriate system capabilities and estimated life cycle cost. In many cases, the capability and technology are so new that the cost estimating relationships do not hold well.

This inability to demonstrate real O&S cost savings is a hindrance to applying should-cost management to sustainment. The expectation for should-cost management is that the program will begin with a baseline cost position (will-cost) and then develop concrete initia-

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tives to reduce cost to a should-cost level. Requiring a percentage improvement from a baseline is not should-cost management. The program should be able to demonstrate the cost savings resulting from concrete initiatives against a firm O&S cost baseline. One recent program just entering production estimated a 25% reduction in O&S cost for implementing performance based logistics (our next discussion), but could not provide a basis.

Another key issue has been the acquisition program manager does not control sustainment funding and may not feel empowered or responsible to impact sustainment cost. Operating and Maintenance (O&M) and Military Personnel (MILPERS) accounts are not under their control, and the cost associated with these appropriations is often driven by Service policy and high-level requirements decisions rather than controllable aspects of the system design or product support strategy. Intuitively, for example, we know that low reliability will drive maintenance labor and parts costs. However, it is the predetermined force structure and not system reliability that tends to drive the Unit Level Manpower cost.

One final point is that in many cases, higher O&S cost results from the necessary use of more expensive technologies and is driven by capabilities. (Here, acquisition cost and O&S cost both are higher than predecessor systems.) Many of these systems also take on new and expanded missions. For example, a new transport helicopter may be asked to fly higher and farther than the system it is replacing, inherently driving up its operating and support cost. Our new fighters, amphibious craft and ships will be expected to do things our old ones could not. Many transformational capabilities come with a high price tag.

The question is, how much of that additional cost is driven by the expanded mission and can trades be made? This is how should-cost management and the affordability cap work synergistically. Cost reductions from should-cost management can free up resources for added capability. However, the capability and mission scope of a system must ultimately be affordable. Affordability caps and should-cost management work together to achieve the best capability that remains affordable.

Should-Cost Management and RAM-C

Balancing Reliability, Availability, Maintainability and Cost (RAM-C) against other system requirements is essential. This is particularly difficult with military weapons systems. Additional capability features and interoperability requirements tend to increase system complexity. High performance thresholds for more basic requirements such as speed and armor protection add stress during normal system operation. And new weapons systems generally employ developmental technologies that redefine state-of-the-art. All of these factors work against RAM-C.

It is also important here to note that programs must consider the life cycle cost rather than only the acquisition cost, and the bulk of the life cycle cost is in sustainment. Focusing on acquisition cost alone can have an adverse effect on life cycle cost. For example, investment in design-for-reliability and reliability growth activities can increase acquisition cost, but generally will reduce life cycle cost by O&S cost avoidance. A more reliable system should be less expensive to maintain and has higher availability where it is most important, for the warfighter.

Figure 1 illustrates how strong reliability enables a program to achieve its sustainment performance goals, that is, adequate availability within the target O&S cost. Higher availability can be achieved after fielding with added resources. Higher reliability shifts the availability-cost curve, so that higher availability and lower O&S cost are achieved.

Often lost in the discussion, though, is that a system that is more reliable in its initial design is less expensive to develop in the long run, because the first prototypes are inherently reliable. These systems are less expensive to test because they have fewer failures and performance anomalies, and can more quickly accomplish integration and test events. Additionally, the design is more stable because reliability fixes are not constantly being introduced.

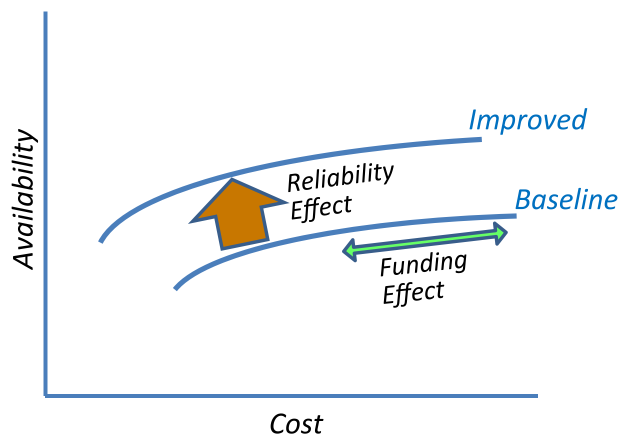

Figure 1 – Sustainment Impact of Reliability

In the past, the majority of programs did not emphasize sustainment performance during system development. In 2007, the DoD mandated that all major programs establish availability as a Key Performance Parameter (KPP) with reliability and operating and support (O&S) cost as supporting Key System Attributes (KSAs). These are also known as the sustainment metrics. They provide the overarching sustainment performance requirement for an acquisition program. Programs must also document the basis in the RAM-C Rationale Report.

This is not the way many engineers and program managers have been trained to think. Some years ago, on one program encountering early reliability issues on new-technology prototypes, one of the lead engineers had the stated approach, "Let's get it to work first, then let's get it to work more than once." This program was later cancelled after almost a billion dollar investment. Sadly, test data indicated that early focus on reliability and a willingness to trade some requirements could have saved the program.

The paradigm, while appearing logical, leads to high-risk, high-cost acquisition programs. Paradigms are hard to break and they take time to change. This is why even in the midst of acquisition reform, many programs still enter initial operational test with poor reliability, and several programs have been canceled over the past several years because of unacceptable reliability and unaffordable life cycle cost.

The earlier emphasis on O&S cost through affordability caps, RAM-C requirements analysis, sustainment planning and should-cost management, all beginning at Milestone A before requirements are finalized, is helping to break this pattern and ensure long-term affordability of military equipment.

Performance Based Logistics

There is one more key BBP initiative for sustainment: Increase the effective use of Performance Based Logistics. PBL is effective at achieving higher availability and reliability at reduced cost. But its proper implementation suffers because of problematic misconceptions.

According to the April 24, 2013, Better Buying Power 2.0 implementation memo, PBL "refers to a business arrangement that provides financial incentives to industry to deliver needed reliability and availability to DoD customers at reduced total cost by encouraging and rewarding innovative cost reduction initiatives." However, PBL is not a cure-all for an unaffordable system, and is not guaranteed to reduce cost wherever and however applied. PBL is an effective tool for achieving higher readiness at lower cost, by directly linking price to performance criteria that are in turn clearly linked to readiness.

PBL is an outcome-based product support strategy that plans and delivers an integrated, affordable performance solution designed to optimize system readiness for the warfighter. The Product Support Manager is tasked with implementing the support solution that accomplishes this with public (organic) and/or commercial product support providers.

When applied to contractor logistics support, PBL seeks to "align profitability more tightly with Department goals," which is another BBP initiative focused on contract structure. PBL extends well beyond contracting, however. The emphasis in the BBP implementation language is on business arrangements, of which contracting is one type. Other types include Public-Private Partnerships and formal agreements with organic support providers.

We must recognize that the program's relationship with each and every organization providing product support is in fact a business arrangement. The key is to structure the business arrangement in a manner that incentivizes better supply chain performance and lower overall cost and aligns with overall sustainment requirements, whether with organic, commercial or partnered provider organizations.

Government has been successfully implementing performance-based arrangements with industry for a long time. Purely organic PBLs on the other hand are scarce and have been difficult to accomplish for a variety of reasons. Because organic suppliers are not motivated by profit, it is difficult for product support managers to incentivize organic-to-organic business arrangements. Standard contract incentives do not apply.

It may also be that some Government organizations have been slow to measure their own performance with warfighter-focused metrics. A depot may be focused on workflow stability metrics or increasing labor hours, for example, rather than supply material availability and how depot turnaround time (TAT) impacts it. Organic suppliers must be willing to enter into a performance-based agreement that is focused on weapon system readiness and warfighter outcome. An organic wholesaler may track component reliability and order fulfillment for trend analysis, but can the organization formally commit to meeting performance thresholds?

Lastly, the government does not have the same range of options to incentivize its agencies or its workforce to meet business related or enterprise performance goals. Profit sharing and other cost related incentives are not available. Even though an organic provider may be limited in how much it can flow down customer focused organizational performance metrics to its workforce, a high-performing government organization should (and does) find ways to link individual compensation and performance evaluation to its organization's mission and goals. In fact, as an example, BBP 2.0 directs that government program manager evaluations will include should-cost management. The nature of the organic-to-organic business arrangement is fundamentally different, but nevertheless, it is a business arrangement.

BBP 2.0 implementation of PBL has at least two key enablers. First, we must expand the use of well-established contracting best practices. And second, a significant opportunity in the implementation of PBL strategies remains: to find creative ways to establish performance based agreements that incentivize organic product support organizations.

Conclusion

The implementation of Better Buying Power initiatives will have a lasting positive impact for the defense department. That positive impact will be greater as requirement developers, program managers and contractors continue to emphasize life cycle cost and RAM performance early in programs, and as Government organizations apply performance based business principles. These will increase our nation's ability to field more affordable and sustainable capabilities.

RECOMMENDATIONS FOR ACQUIRING MORE RELIABLE DOD WEAPONS SYSTEMS IN SUPPORT OF DOD BETTER BUYING POWER INITIATIVES

David Nicholls, Reliability Information Analysis Center (RIAC)
Paul Lein, Quanterion Solutions Incorporated

1 Introduction

Realigning and refocusing Information Analysis Center (IAC) capabilities and products on defense system affordability, in conjunction with current DoD initiatives, is an essential task for the DoD and Defense Technical Information Center (DTIC) leadership going forward. This article, reflecting the specific mission of the Reliability Information Analysis Center (RIAC), recommends approaches developed by Quanterion Solutions Incorporated[1] that directly support improvements to the DoD process for acquiring reliable systems based on:

- DoD Better Buying Power (BBP) and Data-to-Decisions (D2D) initiatives
- Directive-Type Memorandum 11-003 "Reliability Analysis, Planning, Tracking, and Reporting", 21 March 2011
- DoD "Reliability, Availability, Maintainability and Cost Rational Report Manual" (RAM-C), Department of Defense, 1 June 2009
- Compliance with Sustainment and Availability Key Process Parameters (KPPs)
- Compliance with Reliability and Ownership Cost Key System Attributes (KSAs)

1 Quanterion Solutions Incorporated is a private company, and the day-to-day operator of the Defense Technical Information Center (DTIC)-sponsored Reliability Information Analysis Center (RIAC) Core function.

The relationship of RMQSI investment costs to the Sustainment and Availability Key Performance Parameters (KPPs), the Reliability and Ownership Cost Key System Attributes (KSAs) and the "Reliability, Availability, Maintainability, and Cost Rationale Report Manual (RAM-C) processes are addressed in significantly more detail in the RIAC publication "The Influence of Reliability, Maintainability, Quality, Supportability and Interoperability on System Affordability" [Ref. 1], which comes with a MS Excel®-based tool called "Optimized Reliability Requirements and Cost Analysis" (OR^2CA) that automates the current RAM-C process and includes:

1. A more accurate translation of operational reliability needs into system inherent design reliability specifications based on statistical confidence and risk attributes

2. A cost-optimization approach that balances Design for Reliability (DFR) and formal Reliability Growth Test (RGT) investment decisions

3. A more effective Work Breakdown Structure (WBS) to capture actual reliability program costs as a function of quantified reliability improvement in order to provide better Return on Investment (ROI) analysis and interpretation.

The RIAC publication and OR^2 CA tool are available for free (by contacting the authors) to:

- DoD Acquisition personnel, including combat developers, Systems Engineers, logisticians, R&M engineers, etc.

(Must have a valid .mil email address; Description of the acquisition program and/or an active government contract number must be provided with the request)

› DoD Contractors working on active government contracts (Contract Number and description of role in the acquisition program must be provided with the request)

2 Background

It is known that the DoD has significant problems in acquiring weapons systems that comply with operational reliability needs. Figure 1 highlights a regression analysis performed by DOT&E based on reliability target thresholds over the FY97-2QFY13 time frame[2]. Each data point represents the percentage of systems that met their reliability thresholds during operational testing in each respective year. The graph highlights the general downward trend in the percentage of systems performing at or above their contractual operational reliability requirements. DoD systems that fail to meet their reliability goals during operational testing are becoming increasingly more problematic over time.

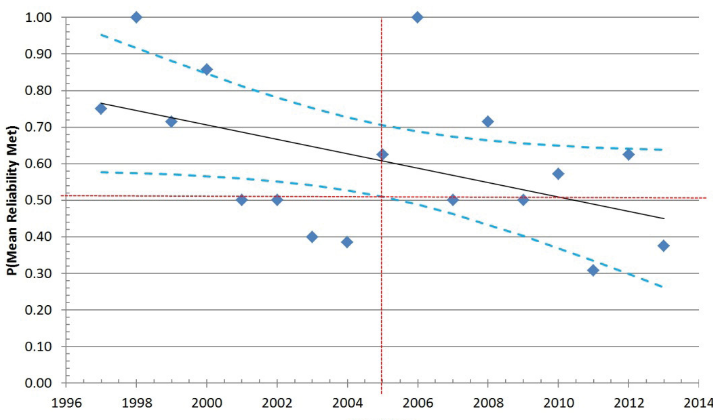

Figure 1: Negative Trend for DoD Systems Meeting Operational Reliability Requirements (1997-2Q FY13)

Figure 2 represents a real-world distribution of operational reliability root failure causes that ultimately impact the ability of a system to meet its reliability requirement. The Figure graphically illustrates the nominal percentage of operational failures attributable to eight failure cause categories based on historical failure data collected on DoD electronic systems by the RIAC[3]. They each contribute to the achieved operational reliability that the warfighter will observe. Each can potentially cause mission failure, even if they are not part of the contractual defined Failure Definition and Scoring Criteria (FD/SC).

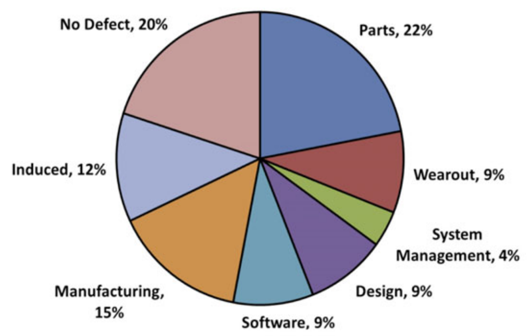

Figure 2: Nominal Failure Cause Distribution of Electronic Systems

The distribution shown in Figure 2 is conceptually reinforced by more recent summarized data provided by DOT&E, showing the root cause failure distribution of fifty-seven (57) DoD acquisition programs that failed to meet their reliability thresholds at IOT&E from FY97 through 2Q FY13 (Figure 3)[4].

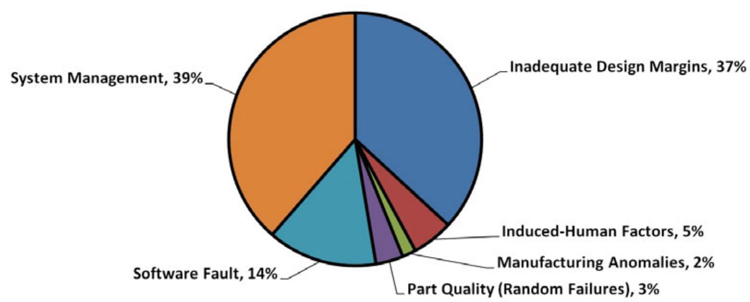

Figure 3: Root Failure Causes for 57 Programs Not Meeting Reliability Thresholds Between FY97 and 2Q FY13

3 A Major Potential Contributor to Operational Reliability Noncompliance to Reliability Requirements

References 2 through 5 suggest that the increasing disparity between observed operational reliability and specified reliability requirements may be more likely attributable to "bad" or misinterpreted requirements being specified that do not adequately consider all potential causes of operational mission failure.

As one hypothetical example, assume that a 100-hour operational MTBF goal is desired. Two potential scenarios for translating this goal into an inherent system design reliability requirement are:

2 This data was provided by, and is included with the permission of, Dr. J. Michael Gilmore, Director Operational Test and Evaluation (DOT&E) and Dr. Catherine Warner, Science Advisor, DOT&E.

3 The RIAC was called the Reliability Analysis Center (RAC) at the time this data was collected and analyzed and the distribution developed.

4 This distribution does not include the "Wearout" and "No Defect" categories of Figure 2. Since these are IOT&E results, wearout failure modes would not be expected. Also, since the root failure cause categories are at the aggregate system level (instead of a failure cause distribution within each system), the "No Defect" category would not be applicable.

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1. **Scenario 1:** The reliability requirement is written such that it quantifies the 100-hour operational reliability goal as the inherent hardware reliability design requirement MTBF. Based on Figure 2, the system operational MTBF experienced by the warfighter is 31 hours based on the inherent hardware design (Table 1).

Table 1: Achieved Operational System MTBF Based on Scenario 1

Failure Category		Original Specified MTBF	Contribution to Operational Reliability	Corresponding Operational MTBF
Parts	Inherent Hardware	100 hours	22%	100 hours
Wearout			9%	
System Mgmt	"All Other"	N/A	4%	45 hours
Design			9%	
Software			9%	
Manufacturing			15%	
Induced			12%	
No Defect			20%	
TOTAL System Operational MTBF			**100%**	**31 hours**

2. **Scenario 2:** The reliability requirement is written such that it downplays the hardware-centric focus of the inherent system design. It would include individual or integrated reliability requirements that explicitly address "All Other" failure categories, particularly software and human factors. The specified MTBF requirement would match the operational MTBF requirement of 100 hours, since all failure categories would have been accounted for in the system design requirement (Table 2).

Table 2: Achieved Operational System MTBF Based on Scenario 2

Failure Category		Original Specified MTBF	Contribution to Operational Reliability	Corresponding Operational MTBF
Parts	Inherent Hardware	100 hours	22%	323 hours
Wearout			9%	
System Mgmt	"All Other"		4%	145 hours
Design			9%	
Software			9%	
Manufacturing			15%	
Induced			12%	
No Defect			20%	
TOTAL System Operational MTBF			100%	100 hours

Scenario 2 is not "gold-plating" of the system design. The 323-hour requirement represents what the system needs to be designed to in order to meet the 100-hour operational MTBF goal because of the contribution of the root failure cause categories that are not part of the inherent design, but will be experienced by the warfighter.

If an operational FD/SC is based solely on the inherent hardware design, the 323-hour MTBF should serve as the basis for reliability growth planning and determination of an appropriate reliability demonstration test MTBF. This will not, however, account for the contribution of software, human and all other reliability issues associated with the system (145-hour MTBF). If the operational FD/SC includes these root failure cause categories, then reliability growth planning/tracking and reliability testing must be tailored to accommodate them. **If the limited FD/SC applies to reliability growth planning and demonstration testing, but the comprehensive FD/SC applies to operational testing and field deployment, then there is very little chance that the results of reliability growth tracking will comply with the reliability growth planning curve.**

It is obvious that there are significant impacts on the system Ownership Cost (OC) and Total Life Cycle Cost (TLCC) resulting from the different scenarios due to the disconnect between the stated operational reliability need and the specified system reliability requirement.

4 Proposing a Solution (Figure 4)

1 Understand End-User Operational Reliability Needs

Acquisition personnel must fully understand all of the root failure cause categories that contribute to the operational reliability of the system. If a decision is made to disregard any of these categories (as reflected in the operational FD/SC), then that also becomes part of the basic understanding of how the system inherent design reliability should be specified.

2 Define the Appropriate Contribution of the Eight Failure Categories

This step determines the percent contribution of each of the eight failure categories. The goal is to use a distribution that most closely corresponds to the environmental/operational profile of the system being acquired.

3 Apply the Previous Step Distribution to the End-User Operational Reliability Needs

This step allocates the operational reliability need initially defined to the eight weighted failure categories. At the end of this step, there is a quantified reliability requirement for each of the failure categories that can be used to determine the appropriate contractual reliability requirements (traceable to the operational reliability need) that should be considered. Their contribution is further tailored to the particular acquisition in the next two steps.

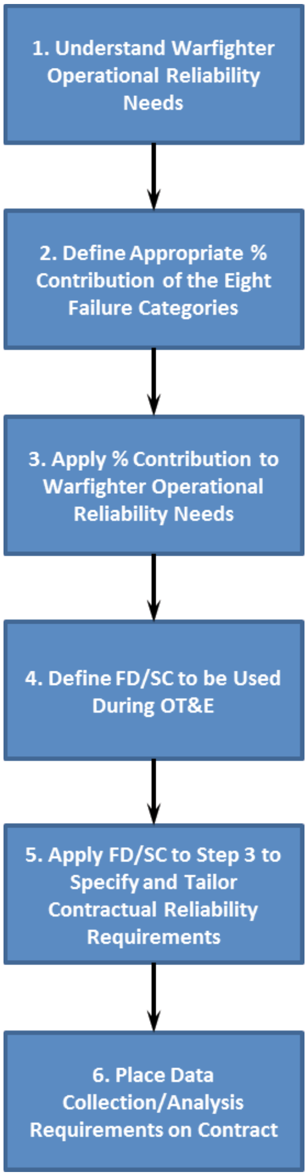

Figure 4: A Process for Specifying Compliant Operational Reliability Requirements

4 Define the FD/SC to be Used During Operational Testing and Field Deployment

The process of developing a FD/SC evolves over the course of system requirements generation, design/development, informal testing, system integration testing and operational use. In the development of specified reliability requirements, however, it is imperative that those requirements be based on a set of FD/SC that match how the end-user will ultimately judge the operational reliability of the system.

5 Apply the FD/SC to the Step 3 Results to Specify and Tailor Contractual Reliability Requirements

The combination of Steps 3 and 4 indicates what failure categories and corresponding design reliability should be contractually specified. If only inherent hardware reliability requirements are specified, then the quantified value of Step 3 for "Inherent Hardware Reliability" should be placed on contract. If both inherent hardware and software reliability requirements are specified (separately or combined), then the separate or combined values from Step 3 should be explicitly placed on contract.

6 Place Data Collection and Analysis Requirements on Contract

Requiring that system root failure cause data be collected, analyzed and categorized into the eight failure contribution areas provides (1) a means for verifying the accuracy of the allocation process used to determine the contractual reliability requirements under the current system acquisition (i.e., lessons learned) and (2) a database of root cause failure distributions to support the acquisition of future systems. It is critical, then, to include contractual language for the Government to retain rights to access/analyze the data. ANSI/GEIA-STD-0009, "Reliability Program Standard for System Design, Development and Manufacturing", explicitly includes this emphasis on Government data rights.

5 Implementing the Solution

There are three recommendations from Reference 1 that are directly related to the previous discussion. It is acknowledged that significant effort is required to fully implement these recommendations (and the OR^{2}CA tool has taken the first steps), but the authors consider the potential benefits to be significant for supporting the Better Buying Power initiative.

Recommendation 1: *A DoD data collection/analysis initiative is needed to develop accurate failure category distributions to support the translation of warfighter operational reliability needs into better system reliability requirement specifications.*

Recommendation 2: *A comprehensive Work Breakdown Structure (WBS) for reliability programs has been recommended in Reference 5 that would collect the cost elements needed to more accurately assess and quantify the OC and TLCC benefits of reliability investment decisions.*

Recommendation 3: *In order to develop specific DoD system cost profiles and models to support the RAM-C process and enhance the cost optimizing algorithms built into the OR^{2}CA methodology, the collection and analysis of system cost data is needed.*

Reference 6 presents two additional recommendations that complement the three basic recommendations above.

The first deals with decisions made by the DoD when evaluating competing Contractor proposals based on potential risks for meeting specified reliability requirements. The paper defines a new approach and metric called "Historical Observed Reliability Ratio" (HOR-R, pronounced "horror'), defined as the ratio of a Contractor's final pre-test reliability prediction or assessment value for a existing system and the most recent observed field reliability value for that system. The benefits of this metric are:

- It provides a quantitative measure for decision making based on the relative risks of proposed reliability program approaches offered by competing Contractors
- It is independent of the reliability prediction/assessment methodology used. Consequently, Contractors need not be constrained to a pre-defined approach.
- It can be applied to any reliability-based requirement (MTBF, MTTF, R(t), Ao, etc.)
- It supports the collection, analysis and assessment of field reliability data required by DoDI 5000.02 and ANSI/GEIA-STD-0009 to (1) determine root failure causes, modes and mechanisms, (2) validate in-house modeling, simulation and test results, and (3) assess reliability program impact on system TLCC

The second recommendation is based on the assumption that the Design for Reliability (DFR) process can actively promote reliability growth in the design/development phase of the system life cycle, prior to discovery of failures in manufacturing, testing or field deployment. A set of metrics is needed that quantifies the relative effectiveness of a Contractor's overall DFR process in identifying

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and mitigating failure modes in order to highlight opportunities for improvement. To that end, the paper proposed two new failure classifications to leverage lessons learned from discovered failures to improve the robustness and design impact of DFR activities, prior to those systems entering formal RGT or reliability demonstration testing.

The new failure mode classifications are:

- **Unanticipated Mode** – A failure mode that is discovered during manufacturing, testing or field use, but was not documented during DFR analyses and assessments
- **Unexpected Mode** – A failure mode that is accounted for, documented and thought to have been effectively mitigated by the DFR process, but occurs during item manufacturing, testing or field use anyway

Reference 7 introduced the detailed process and equations for quantifying and reacting to unanticipated and unexpected failure modes throughout the design, test, manufacturing and O&S life cycle phases.

As an example, consider a DFR process that is not "perfect" in identifying and mitigating all possible failure modes/mechanisms during system design/development:

For scenario 1, a failure occurs during manufacturing, integration testing, RGT, or field operation. Analysis using a Failure Reporting, Analysis and Corrective Action System (FRACAS) with comprehensive Root Cause Analysis (RCA) concludes that the discovered inherent design-related failure mode was not identified/documented during the DFR process. An opportunity to grow the system reliability during design was lost due to the discovery of this ***unanticipated*** failure mode.

For scenario 2, a failure occurs during manufacturing, integration testing, RGT, or field operation. Analysis of the failure using FRACAS with detailed RCA concludes that, while the failure mode/mechanism was identified and documented during the DFR process, the corrective action that was thought to have properly mitigated the inherent design failure mode was ineffective – the failure occurred anyway. An opportunity to grow the system reliability during design was lost due to the discovery of this ***unexpected*** failure mode.

Each of these scenarios is quantifiable, and can serve as a basis for improving the reliability growth process during system design.

A: For ***unanticipated*** failure modes:

$$\text{DFR Effectiveness Ratio}_{\text{Design Identification}} = \frac{\text{Number of Discovered Unanticipated Design FMs}}{\text{Total Number of Discovered FMs}}$$

where:

The "Number of Discovered Unanticipated Design FMs" is the total number of failure modes discovered in test, manufacturing and/or field operations whose root cause was traceable to a system design-related issue (hardware, software, or other), but those failure modes were not identified or documented as part of the DFR process (FMEA/FMECA, FTA, M&S, HALT, etc.).

The "Total Number of Discovered FMs" is the total number of all failure modes that occurred during test, manufacturing and/or field operations, regardless of root failure cause, and regardless of whether they were identified as part of DFR activities or not, or whether they are design-related or not.

The smaller the ratio, the more robust the DFR process is in identifying and documenting all design-related failure modes associated with the system. The appropriate corrective action for an unacceptably high value is to improve the DFR process to do a better job of proactively identifying and documenting inherent design failure modes.

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Since the implication of this metric is that it cannot be quantified until after testing has been done (or field data has been accumulated and analyzed), it should be emphasized that corrective action need not be delayed until all testing has been accomplished in order to be effective. Interim assessments that indicate an unacceptable ratio during ongoing tests may provide sufficient justification to stop testing and re-visit and improve the DFR process.

B: For ***unexpected*** failure modes:

$$\text{DFR Effectiveness Ratio}_{\text{Design Mitigation}} = \frac{\text{Number of Discovered Unexpected Design FMs}}{\text{Total Number of Discovered FMs}}$$

where:

> The "Number of Discovered Unexpected Design FMs" is the total number of failure modes discovered during test, manufacturing and/or field operations whose root cause is traceable to a system design-related issue (hardware, software, or other), and those failure modes were identified or documented as part of the DFR process (FMEA/FMECA, FTA, etc.), but the corrective actions taken were not sufficiently effective in mitigating the inherent design failure mode.
>
> The "Total Number of Discovered FMs" is as previously defined.

The smaller the ratio, the more robust the DFR process is in effectively mitigating identified system design-related failure modes according to expectations. The appropriate corrective action for an unacceptably high value is to improve the DFR process to identify and implement better, more effective corrective actions in the inherent system design.

6 Summary

The recommendations made in this article can only be successfully implemented through a dedicated commitment of resources to collect and analyze the data needed to support them. Government data rights have historically been restricted, to its great disadvantage. Documents such as DoDI 5000.02, Directive Type Memorandum 11-003, and joint Government/industry Standard ANSI/GEIA-STD-0009 "Reliability Program Standard for System Design, Development, and Manufacturing", contain the basic provisions needed to encourage and institutionalize Government access to this much-needed data. The result will be the acquisition of more reliable and affordable systems by the DoD that better meet the operational needs of the warfighter.

7 References

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4. Nicholls, David B., "A Recommendation for Specifying Better DoD System Reliability Requirements", NDIA 15th Annual Systems Engineering Conference, October 2012

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8. Nicholls, David B., Paul Lein and Tom McGibbon, "Achieving System Reliability Growth Through Robust Design and Test", Reliability Information Analysis Center, 30 June 2011

Correction ◁◁◁

In the Second Quarter, 2002 "Journal of the Reliability Analysis Center", an article was published entitled "The Facts About Predicting Software Defects and Reliability" and authored by Ann Marie Neufelder, Owner, SoftRel (www.softrel.com). In the transition of the Reliability Analysis Center (RAC) contract to the Reliability Information Analysis Center (RIAC) contract in June, 2005 and the subsequent conversion of old RAC Journal Articles to the new RIAC "Desk Reference" website, an error in a data table erroneously attributed authorship of this article to someone else. This error has since been corrected, and Ms. Neufelder correctly credited as the author. The corrected article can be viewed at http://www.theriac.org/DeskReference/viewDocument.php?id=126. We would like to take this opportunity to apologize for our error, and invite those interested to review the product, training and service offerings on her website.

FUTURE EVENTS in RMQSI

AUGUST

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AUGUST 2013

31st International System Safety Conference
Boston, MA
August 12, 2013 thru August 16 2013
Contact: http://issc2013.system-safety.org/

SEPTEMBER 2013

AReS 2013 : The Eighth International Conference on Availability, Reliability and Security
University of Regensburg, Germany
September 2, 2013 thru September 6, 2013
Contact: Prof. Dr. A Min Tjoa // P: +43-1-58801-18800 // F: +43-1-58801-18899 // office@ares-conference.eu

2013 Fall Simulation Interoperability Workshop
Orlando, FL
September 16, 2013 thru September 20, 2013
Contact: Simulation Interoperability Standards Organization // P: 407.882.1348 // F: 407.882.1304 // siso-help@sisostds.org

32nd International Conference on Computer Safety, Reliability and Security
Toulouse, France
September 24, 2013 thru September 27, 2013
Contact: Sonya De Sousa // P: +33 5 61336255 // F: +33 5 61336411 // safecomp2013@laas.fr

International Applied Reliability Symposium
Pune, India
September 25, 2013 thru September 27, 2013
Contact: ReliaSoft // P 888.886.0410 or 520.886.0410 // info@ARSymposium.org

OCTOBER 2013

International Applied Reliability Symposium
Singapore
October 2, 2013 thru October 4, 2013
Contact: ReliaSoft // P 888.886.0410 or 520.886.0410 // info@ARSymposium.org

2nd International Conference on Control and Fault-Tolerant Systems
Nice, France
October 9, 2013 thru October 11, 2013
Contact: systol-2013-committee@univ-lorraine.fr

International Integrated Reliability Workshop
South Lake Tahoe, CA
October 13, 2013 thru October 17, 2013
Contact: Jason Campbell // Jason.campbell@nist.gov

Annual Conference of the Prognostics and Health Management Society 2013
New Orleans, LA
October 14, 2013 thru October 17, 2013
Contact: http://www.phmsociety.org/events/conference/phm/13

NDIA 16th Annual Systems Engineering Conference
Arlington, VA
October 28, 2013 through October 31, 2013
Contact: Allison McCloskey // P 703.247.2570 // amccloskey@ndia.org

NOVEMBER 2013

ICSSEA 2013 25th International Conference on Software & Systems Engineering and their Applications
Paris, France
November 4, 2013 thru November 6, 2013
Contact: http://icssea.enst.fr/icssea13/

24th IEEE International Symposium on Software Reliability Engineering
Pasadena, CA
November 4, 2013 thru November 7, 2013
Contact: http://2013.issre.net/

Annual Systems Engineering Conference 2013 (ASEC2013)
Oxfordshire, United Kingdom
November 12, 2013 thru November 13, 2013
Contact: http://www.incoseonline.org.uk/EventBooking/ASEC_2013/General_Info.aspx?CatID=ASEC

DECEMBER 2013

Diminishing Manufacturing Sources and Material Shortages (DMSMS) 2013 Conference
Kissimmee, FL
December 2, 2013 thru December 5, 2013
Contact: Tracy Tapia // P: 937.426.2808 // F: 937.426.8755 // ttapia@utcdayton.com

Reliability-Centered SAP Plant Maintenance Forum
Bonita Springs, FL
December 9, 2013 thru December 10, 2013
Contact: http://maintenanceconference.com/sap13/

Reliability-Centered Maximo Forum
Bonita Springs, FL
December 9, 2013 thru December 10, 2013
Contact: http://maintenanceconference.com/maximo13/

RIAC Open Training Program
Celebration, FL
December 10, 2013 thru December 12, 2013
Contact: Pat Smalley, Reliability Information Analysis Center // P 877.363.7422 or 315.351.4200 // F 315.351.4209 // psmalley@theRIAC.org

JANUARY 2014

2014 Annual Reliability and Maintainability Symposium (RAMS)
Colorado Springs, CO
January 27, 2014 thru January 30, 2014
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