the newsletter of

RELIABILITY, MAINTAINABILITY, & SUPPORTABILITY

March 2015 • Volume 19 • Issue No. 1

William Pincham & David Cochran

The Case for Developing a Conceptual Framework for Engineering Complex System Designs with Humans in the Loop

This article presents the case for developing a top-down methodology for creating conceptual frameworks that integrate state-of-the art research in complex systems with humans-in-the-design loop during the concept development phase of the product Life Cycle. Currently advanced approaches for conceptualizing Systems of Systems (SoS) and Families of Systems (FoS) are focused on methods that use design libraries to minimize or eliminate humans from the design configuration decision-making process. Effective conceptual frameworks with humans-in-the-design loop will assure that outlier concepts and subsystems are synthesized with near term state-of-the art industrial research as boundary level concept possibilities. Typically design libraries do not include near-term research. Therefore, the potential functional payoff in new concepts is not considered. The conceptual framework approach will assure that performance risk trade studies of the most feasible and effective concept design solutions are translated from user scenarios into detailed design specification requirements. As a result, the most state-of-the-art concepts with the lowest risk of design performance variation will be selected as preferred concept designs for the detail design phase of the product Life Cycle (LC).

The Systems Engineering "V" model describes summary-level activities that engineers perform to translate user needs into specifications for detail design. However, Systems Engineering "V" activities are performed iteratively [1]. An effective conceptual framework will minimize the iterative actions associated with creating system designs and will improve detail design efficiency and design quality. The iterative nature of the Systems Engineering "V" model also describes activities associated with the management practices of industry and government organizations. It does not, however streamline the design processes itself. As it stands today, the iterative nature of the "V" model is not easily integrated into industry business development modeling and marketing operations because the iterative paradigm of build-test-fix is a defacto management practice. Conceptual frameworks are, "used in research to outline possible courses of action or to present a preferred approach to an idea or thought" [2], [3]. This article asserts that creating humans-in-the-design loop conceptual frameworks for modeling and evaluating set-based concurrent engineering approaches will create a more effective methodology for defining more effective design concept alternatives for down selection to a preferred concept [4]. As a result, specifications for the preferred concept created with this framework can more reliably meet procuring user scenarios

THIS EDITION

Published Quarterly

Russell A. Vacante, Ph.D.

Sustainability: A Technological and Budget Issue for the Defense Department

In the scheme of things, a system's total life cycle management planning for sustainment as a post-production to retirement activity is a normal part of the cradle to grave design and fielding package(s). It involves ensuring there is, for example, adequate depot maintenance, sufficient spare inventory, technical service supervision and, often, a sufficiency of private sector repair and overall facilities until a system's predicated retired. Unfortunately, technological and financial challenges surface within the DoD community when

continued on page 13

for handoff to detail design engineering teams than concepts created using design libraries in model based engineering methods [5].

It is generally accepted that 60% of Life Cycle (LC) costs are committed when the Preliminary Concept Design phase is completed and 80% of LC costs are committed at the handoff from the Design Development phase into the Production phase [6]. However, most innovative engineering process and technology research funding is targeted toward solving detail hardware and software design issues instead of improving solution-set or point-based design solutions [4]. Very little research is targeted toward examining top-down methodologies for creating and down selecting preferred system-level concepts that have the potential for integrating subsystem and component level research.

The authors contend that most engineering talent and research is focused on dealing with the iterative actions associated with revising detail designs to fix defects found during test operations, not eliminating the iteration itself. In addition, advances in detail manufacturing hardware and software design, tooling and process research improvements are not immediately available to small businesses. The overall effect of these observations is that technology offerings of innovative small businesses are not evaluated for integration and qualification as preferred concepts are synthesized.

As designers subsequently become knowledgeable of small business capabilities, integrating their functionality induces various degrees of time-consuming re-design effort. However, 50–70% of DoD programs consist of subsystems and components provided by small businesses. When system-level concepts are selected that reduce the need for iterative design action, life cycle costs for both large and small businesses would be reduced. In addition, further cost reduction opportunities may be identified by establishing a collaborative mathematical analysis that:

- discretely identifies key process improvement technologies for R&D investment, and
- measures the risk associated with entering the detail phase of the life cycle for preferred system-level concept alternatives .

The broader impact is that the output of a conceptual framework and methodology with humans-in-the-design loop will accelerate reductions in design cycle time and affordability that enterprises of any size can use to minimize design cycle time. As a result, small businesses that use the framework can accelerate organizational learning and generate more technology offerings in less time than their competitors. Design organizations will have the capability to focus research investments into known technology market needs that can be seamlessly integrated into existing (legacy) systems.

System Complexity

There are several connotations of "complexity" in industry and academia that depend on the context and purpose in which the word is used. For example, the Defense Advanced Research Projects Agency (DARPA) launched a major $60 million initiative known as the META program in late 2009 structured to reduce the complexity of designing defense systems [7]. The goal of the META program is to reduce complex system development by five times through Model Based Design methodologies. DARPA defined parts count plus Software Lines of Code (SLOC) as the initial measure of complexity and identified a research objective of defining more comprehensive measures as a program deliverable.

More specifically, the solicitation stated that, "... it aims to develop model-based design methods for cyber-physical systems far more complex and heterogeneous than those to which such methods are applied today; to combine these methods with a rigorous deployment of hierarchical abstractions throughout the system architecture; to optimize system

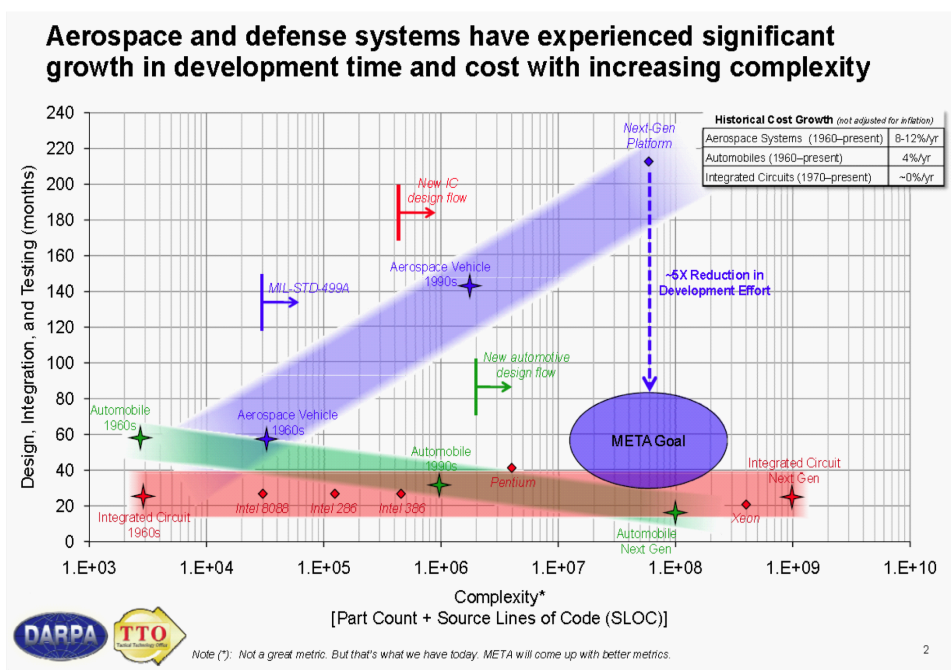


Figure 1 – DARPA Complexity Definition and Metric for META Program

design with respect to an observable, quantitative measure of complexity for the entire cyber-physical systems; and to apply probabilistic formal methods to the system verification problem, thereby dramatically reducing the need for expensive real-world testing and design iteration" [7].

Essentially, DARPA concludes that the detail design process in organizations works like stovepipes, which are based on application of the Systems Engineering "V". DARPA contends that the Systems Engineering approach causes, "un-modeled and undesired interactions (that) lead to emergent behaviors resulting in architectures (that) are fragile point designs," which take years to validate and verify through iterative integration and qualification testing [7].

Southern Methodist University's Systems Engineering Program (SMU SEP) states that complexity occurs at the interfaces and boundaries of subsystems and components. The observation is that with point-based design processes, the definition of system, subsystem, and component interfaces become the primary points where design-test-redesign iteration increases life cycle cost variation from planned cost projections and facilitates unnecessary activity loops.

Typically, when implementing the Systems Engineering "V" using point-based design processes, only a few system concepts are selected for detail design and verification testing [4]. When performance defects are discovered during testing, subsystems and components perceived to have caused the performance defect are re-designed and re-tested, one-by-one, until the specified functional capability can be verified.

However recent Model Based Design (MBD) engineering research is focused on developing processes to leverage data design knowledge libraries of standard subsystem architectures. The objective of current MBD research is to reduce product development time by limiting state-of-the-art alternatives using design libraries that limit the concept solution design space. One of the research hypotheses of the case we advocate for taking a, "Human-In-The-Loop Conceptual Framework Approach," will test whether the framework approach can form the basis for creating an interactive capability for generating concept architectures that treat selected system-level requirements one at a time as independent variables as a formal methodology. With this research case we advocate that not only does the framework approach of complexity apply to the design of hardware subsystem interfaces, it also applies to the definition and management of the systems engineering process itself. Therefore, there are broader implications to design independence. As noted by Dennis Buede, the Systems Engineering "V" activities are performed iteratively [1]. One of the META program's objectives is to decompose the activities of the system engineering process to reduce design, integration and testing time (see Figure 1) that is created by the iterative nature of SE activities to achieve significant improvements in design cycle time and cost.

There are other definitions of design complexity. They all appear to focus on combining the capabilities of subsystems and components in different ways to create new capabilities that could not otherwise be created [8]. Most are targeted toward understanding the source of iterative design effects. In addition a significant amount of bottom-up research currently is focused on studying the interactions of design engineering activities at the tools and process levels. However, complex systems from the perspective of the United States Department of Defense (DoD) can be described by the definitions of Systems of Systems (SoS), and Families of Systems (FoS) [9]. The opportunity is to develop a top-down methodology for creating a, "Human-In-The-Loop Conceptual Framework Approach," for integrating

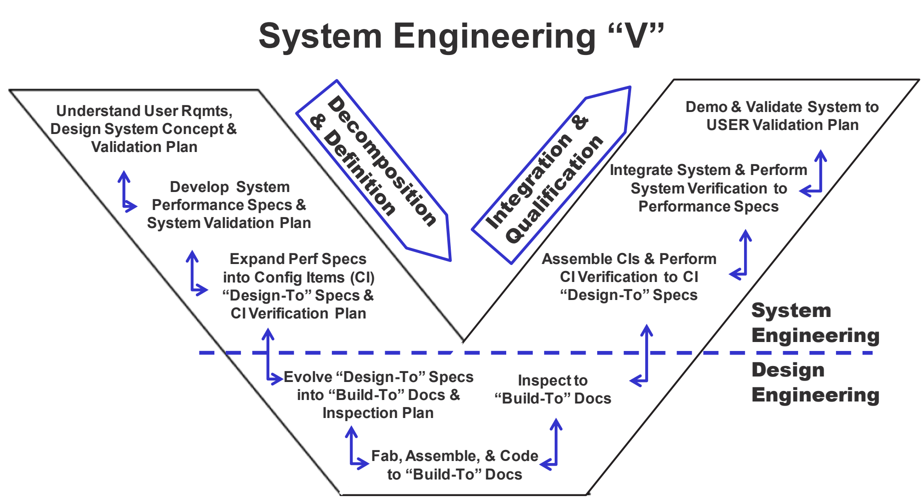


Figure 2 – The Systems Engineering "V"

state-of-the-art industrial research in complex systems with DoD definitions and perspectives about complex systems. The DoD SoS and FoS definitions are consistent with the complexity definition that says that complexity is related to the number and physical relationships that are coupled with the transfer or conversion of information describing physical phenomena at subsystem and component interfaces and boundaries.

Complex System Design Conceptual Frameworks

The Systems Engineering "V" model is a type of conceptual framework. However, the "V" model does not address the interactions of organizational domains external to the design process itself. Conceptual frameworks for developing complex systems would very likely be more successful if they were more comprehensive. Typically, conceptual frameworks are broadly defined and systematically organized to provide a focus, a rationale, and a tool for the integration and interpretation of information. Usually expressed abstractly through word models, a conceptual framework is the conceptual basis for many theories, such as communication theory and general systems theory [2]. Another definition says that a conceptual framework is a concise description (often accompanied by a graphic or visual depiction) of the major variables and their interaction. A framework, in fact, may either anticipate or directly present the basic design of a research plan [3].

A complex system design establishes a mutual understanding of user needs that can be decomposed and defined as a statement of the design problem (i.e., requirements) and architectures that model and represent the functional and operational attributes of the instantiated physical system to be delivered to the user. "An instantiated physical architecture is a generic physical architecture to which complete definitions of the performance characteristics of the resources have been added" [10]. To deliver an operational instantiated physical architecture, all six functions of the design process must be completed. The six functions of the design process defined by Buede [10] that must be addressed for each phase of the LC include: (1) Defining the system level design problem, (2) Developing the system functional architecture, (3) Developing the system physical architecture, (4) Developing the system operational architecture, (5) Developing the interface architecture, and (6) Defining the qualification system.

As Buede states [11], the design process is not a formal process that can be proved. However, Buede also states that formal processes have been developed by some researchers but primarily in the software engineering field. He further states that formal processes in the engineering of systems field are relatively rare but he also introduces a summary of Nam P. Suh's Axiomatic Design (AD) process [11] [12] as an example of a formal design process. Buede introduces the basic elements of Suh's AD process, but he discounts elements of AD to discuss attributes of system design embedded in various decomposition tools such as IDEF0 functional diagramming. Buede specifically states that, "While Suh introduces hierarchical decomposition in his axiomatic process, there is not sufficient richness of concepts in his process to handle complexity of the engineering issues associated with the development of a system" [11].

Suh states that, "axioms are general principles or self-evident truths that cannot be derived or proven to be true, but for which there are no counterexamples or exceptions. The axiomatic approach to design is powerful and will have many ramifications because of the generalizability of axioms, from which corollaries and theorems can be derived. These theorems and corollaries can be used as design rules that prescribe precisely the bounds of their validity" [6].

Embedded in the preceding statement is the dilemma that presents the greatest opportunity for understanding whether a conceptual framework methodology can be posited for defining complex system design models. Complex system design models should form the basis for a mathematical synthesis or simulation that facilitates evaluation of the payoff of integrating state-of-the-art research alternatives.

Suh suggests two main axioms and 30 corollaries but for this discussion on complex system design, we will only discuss the implication of the two axioms that are applied as design activities are decomposed and mapped for lower levels of decomposition from the customer's initial statements of operational needs and scenarios domain to the functional requirement domain and the solution space domain. Business management organizational structures and policies, procedures, processes, and detail engineering design and production tools are found in the solution space domain of the system design. The two axioms are:

- *Axiom 1: The Independence Axiom.* Maintain the independence of functional requirements (FRs)
- *Axiom 2: The Information Axiom.* Minimize the information content of the design

The two axioms may guide system engineering design decisions. Design intent is expressed as stand-alone, noun and verb phrase statements that are mapped from one domain to the other. As the design intent is decomposed from one domain to another (i.e., from customer needs to functional requirements to solution space), their linkage is evaluated to determine whether the resulting design decision relationships are redundant, path dependent, or uncoupled [13]. Although redundant systems may be desirable when designing hardware to achieve reliability objectives, redundant work management systems are cost inefficient because they cause unnecessary design iteration and iterative point-based design solutions. The investigative case postulated for this article embraces the use of axiomatic design to create a methodology for developing a conceptual framework for engineering complex system designs with humans-in-the-design loop.

In addition to iteration issues, the Southern Methodist University's Systems Engineering Program (SMU SEP) has identified an urgent need to create a quick response, complex system-level evaluation capability for interactively selecting design concepts and technologies based on the independent variables that impact detail design decisions one at a time [14] [15]. The reason for the urgency of this need is that during the 1960 - 1990 timeframe, DoD contractors had limited forms of this capability but lost it during industry consolidations imposed by defense budget cuts after the cold war. This capability (now unavailable) allowed contractors to quickly generate concepts for their platform specialties. Additional rationale for identifying the characteristics and measurable attributes of a complex system design conceptual framework are found in the December 2013 presentation made by The Office of the Deputy Assistant Secretary of Defense for Systems Engineering (ODASD SE) a new initiative to create "Engineered Resilient Systems (ERS)" [16]. With today's defense paradigm, the response requirement to counter-insurgency defense needs for system development has collapsed from years to months or even weeks. The issue that the human-in-the-design loop complex system design conceptual framework addresses is that conventional warfare system development "response loops" are now measured in decades, while the DoD need is on the order of weeks and months.

The intellectual merit of the case expressing the need for this research is that modeling the iterative actions of the Systems Engineering "V" as a tailorable conceptual framework would create enterprise work flow methodologies that are predictable, responsive to warfighter need and that significantly reduce cost. Therefore, innovative research focused on reducing design iteration with a, "Human-In-The-Loop Conceptual Framework Approach" for cognition of design relationships and interfaces within complex systems can be more effectively linked to designing new and sustaining existing FoS and SoS deployments. ●

References Cited

1) Dennis M. Buede, The Engineering Design of Systems, John Wiley & Sons, Inc., 2000, pages 5-11.
2) http://www.businessdictionary.com/definition/conceptual-framework.html.
3) http://education.astate.edu/dcline/guide/framework.html .
4) Michael N. Kennedy, Product Development for the Lean Enterprise, The Oaklea Press., 2003, page 122-143.
5) Dennis M. Buede, The Engineering Design of Systems, John Wiley & Sons, Inc., 2000, page xvi.
6) Dennis M. Buede, The Engineering Design of Systems, John Wiley & Sons, Inc., 2000, page 7-10.
7) META Solicitation Number: DARPA-BAA-10-21, Defense Advanced Research Projects Agency, 2009, Industry Day Presentation by Ermenko.
8) Yong-Suk Kim, David S. Cochran, Product Variety and manufacturing System Complexity, Proceedings of the Third World Congress on Intelligent Manufacturing Processes & Systems – June 28-30, 2000, Massachusetts Institute of Technology, Department of Mechanical Engineering.
9) Systems Engineering Guide for Systems of Systems Version 1.0, Director, Systems and Software Engineering Deputy Under Secretary of Defense (Acquisition and Technology) Office of the Under Secretary of Defense (Acquisition, Technology and Logistics), August 2008, Pages 3-5.
10) Dennis M. Buede, The Engineering Design of Systems, John Wiley & Sons, Inc., 2000, pages 215-222.
11) Ibid, pages 39-41.
12) Nam P. Suh, The Principles of Design, Oxford University Press, 1990.
13) Suh, N. P., Cochran, D. S., and Lima, P. C. (1998). "Manufacturing System Design," 48th General Assembly of CIRP, Annals of the CIRP, Vol. 47, No. 2, pp. 627-639.
14) "The Technology Transition Engineering and Management Guidebook," Southern Methodist University, Systems Engineering Research Program. Defense Acquisition University (DAU) with participation from Air Force, Army and Navy concept development specialists, August 2011.
15) "Technology Linkage, Selection and Transition Phase 1 Research Plan," Southern Methodist University, Systems Engineering Research Program, February 2010.
16) Engineered Resilient Systems (ERS) Overview December 2013, Jeffery P. Holland, PhD, PE, ERS Priority Steering Council Lead, Director, US Army Engineer Research and Development Center (ERDC) Director, Research and Development, US Army Corps of Engineers

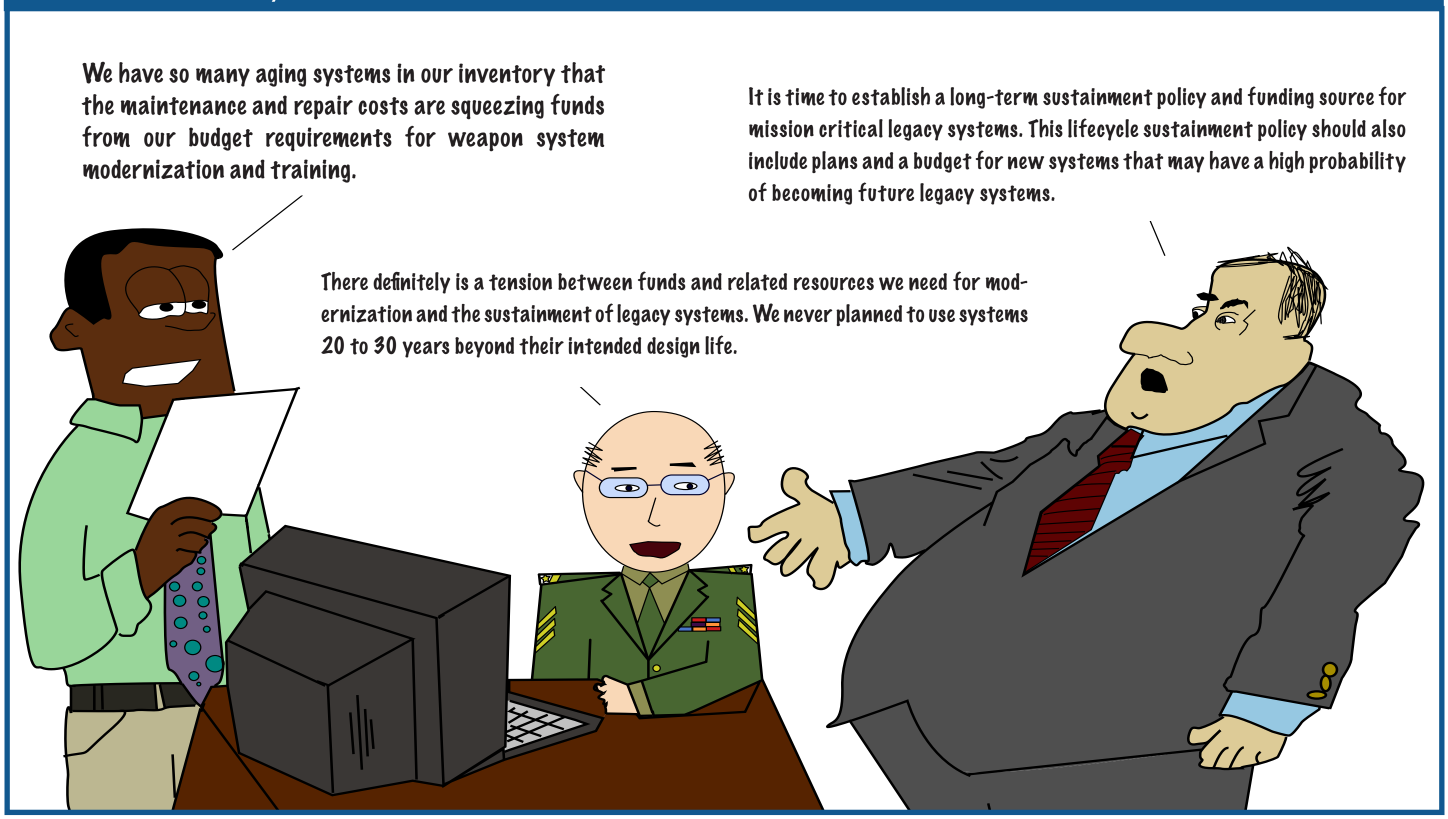
About the Authors

William Pincham *served as the 2008–2010 Operations Vice President of the RMS Partnership. He earned MSSE (2007) and MBA (1997) degrees from Southern Methodist and a BSIE (1972) from the University of Tennessee. In 2008, he retired from Lockheed Martin Missiles and Fire Control (LMMFC) as the Manager of Business Systems for Advanced Manufacturing Technologies. As a member of the SMU System Engineering Development Team, he was a key researcher and the author of research reports submitted to the U.S. DoD DAU entitled "Technology Linkage, Selection and Transition (TLST) to the U.S. Warfighter," March 2010 and "Science and Technology Systems Engineering Research Phase 0 Report," December 2008. In addition he was a key author of the Phase 1 report and the resulting "Technology Transition Engineering and Management" Guidebook, published July 2011.*

David Cochran *is an Associate Professor of Systems Engineering and is the Director of the Indiana University Purdue University (IPFW) Center of Excellence in Systems Engineering in Fort Wayne, IN. He serves on the Board of Directors of the IIE Lean Division, the Orthoworx Advanced Manufacturing Council, and the Purdue University Graduate School Council and is a member of the St. Francis Hospital Innovation Center. He earned a Ph.D. in Industrial and Systems Engineering from Auburn University and Masters of Industrial Engineering from the Pennsylvania State University. Prior to joining IPFW, Prof. Cochran established System Design, LLC and served as Adjunct Professor to Meijo University in the School of Business, Nagoya, Japan and the Southern Methodist University Systems Engineering program. He served as Assistant and Associate Professor of Mechanical Engineering at the Massachusetts Institute of Technology and led the Production System Design Laboratory to apply systems engineering methodology to large systems. He is a two-time recipient of the Shingo Prize for Manufacturing Excellence for his research to advance lean system design as an engineering discipline and was awarded the Norman Dudley Prize for Best Paper by the International Journal of Production Research in 2000.*

Another Day At The Office

by Russell A. Vacante, Ph.D.



International
Applied Reliability Symposium

Join the conversation!

June 2 - 4, 2015 in Tucson, Arizona

Reliability engineering has never been more important than in today's economic environment. Whether you are just beginning your reliability journey or you are a weathered veteran, the International Applied Reliability Symposium (ARS) has something for you. This reliability and maintainability conference provides a forum for expert presenters from industry and government to come together with reliability practitioners from all over the world to discuss the application of reliability principles to meet real-world challenges.

To register or for more information:
Website: http://www.ARSymposium.org
E-mail: Info@ARSymposium.org
Phone: 1.888.886.0410 or +1.520.886.0410

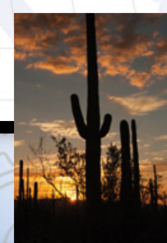
The Symposium will take place at:
Loews Ventana Canyon Resort
7000 N. Resort Dr., Tucson, AZ 85750 USA
Website: http://www.loewshotels.com/ventana-canyon/

Take the CRE exam: The CRE exam will be offered on June 1, 2015. The application deadline is April 17, 2015.

Presentations and tutorials cover a range of subjects, such as: Reliability programs • Design for Reliability (DFR) • Design for Six Sigma (DFSS) • Reliability specifications and metrics • Data collection, management and analysis • Experiment design and analysis • Accelerated testing • Failure Modes and Effects Analysis (FMEA) • Reliability growth analysis • Software reliability • System analysis • Asset management and maintenance planning • Risk and safety analysis • Warranty cost reduction

Additional training opportunity after the Symposium:
The ASQ – Reliability Division is also offering a choice of two one-day seminars on Friday June 5, 2015:
Course 1: http://www.asqrd.org/awards-2/course-new-product-development/
Course 2: http://www.asqrd.org/awards-2/course-halthass/

View PDF brochure: http://www.ARSymposium.org/2015/2015_ARS_NA.pdf



Sponsorship and Exhibitor opportunities are still available.

Organizers: ReliaSoft®, SRC System Reliability Center

Platinum Sponsor: ASQ Reliability Division (MAKE GOOD GREAT™)

Partner: TESLA

Global Issues, Local Perspectives!℠

Europe South America North America India Asia Pacific Middle East

Frank Straka

Mechanical Accelerated Life Testing

This paper describes a method for conducting quantitative accelerated mechanical life testing to enable one to make a useful life prediction. This concept can be applied to any part where testing to failure under different load stresses is done.

In conducting accelerated life testing, we need to identify the failure mode and the stress used to conduct the accelerated test since there may be multiple mechanical stresses and other failure modes. Some of these may not be relevant. Mechanical life failures are typically driven by 1) stresses and strains, 2) chemical reactions between the material and environment, and 3) by the combination of the two. The topic of this paper will cover mechanical reliability due to repeated stresses and strains or commonly called fatigue testing to predict the life of the product.

The paper will first describe the methodology that will be used and provide an example of a bracket pedal in an exercise equipment to illustrate it. This bracket pedal is used in exercise step equipment that supports a person's weight to simulate climbing stairs. The variables in modeling are the speed of operation, weight of user, and operational hours of use.

The product and the bracket product operational characteristics are as follows:

- Average user is approximately 200 pounds. with a 95% profile usage of 235 pounds, and worst case conditions of 350 pounds
- The bracket is subjected to an average 5,000 cycles per hour
- The bracket has an average yearly usage of 1500 hours of use
- The product operates indoors
- Durability requirement is five years or 38,750,000 cycles.

It should be noted that the life expectancy will depend on the user, speed of use, and the amount of hours the product is operated per year. As a result, the prediction from the accelerated testing will describe the durability at specific operational profiles of the product. In determining the base line, it is important to consider what the goal of the prediction is as each unit will be operated under different loads, speeds, and hours of usage. For it is not anticipated that a 350-pound user will use the equipment at the same level as a well-conditioned 200-pound user. For example, exercise equipment used at a health club for the population will have greatly different loading characteristics than if it was used for a professional sports team. The topic of establishing the goal and baseline for acceleration purposes has many facets and should be covered in a separate paper.

To illustrate the methodology, the goal that will be used in this paper will be a median life of five years with a 350-pound user.

Methodology

The bracket will be tested under higher than normal loads and increased cycle rate to duplicate and replicate the failure at accelerated test conditions. The test will be conducted with multiple forces and the time to failure recorded.

The time to failure data will be analyzed by the Weibull distribution to determine its probability of failure at a specific cycle time at each loading condition. Its horizontal scale will be used to plot cycles to failure and its vertical axis will provide the probability of expected failures at a various load. This will be done for each fatigue force.

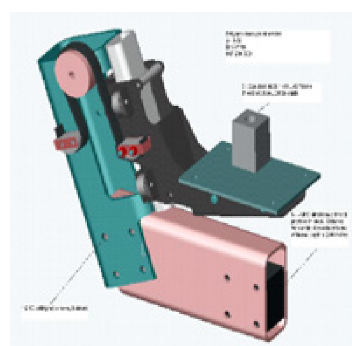
The slope of each load force should be similar to verify that the same failure mode is being accelerated.

The L50 results from the Weibull analysis for each load will be used to construct a stress versus number of cycle to failure curve for the new design and the original design. The curve developed at the accelerated loads will be extrapolated to 350 pounds to determine the number of cycles that would be applicable under normal usage.

Because of the highly accelerated testing and statistical limitations, I anticipate that accuracy of the prediction may decrease as the extrapolation is greatly extended beyond the actual test time. This approach can be expanded with using the statistical limits rather than the median rank curve.

Results

The figure below illustrates the failure mode of the bracket. The top photo shows the failure mechanism in the original design and the bottom photo shows the failure mechanism in the cost reduced design. The test was terminated at the signs of a crack rather than waiting until the sample broke.



CURRENT DESIGN		COST-REDUCED DESIGN	
Load Level (lbs)	*Time to Failure, (cycles)*	*Load Level (lbs)*	*Time to Failure, (cycles)*
1,250	162,000 279,000 342,000 396,000 396,000 801,000	1,100	103,000 113,000 233,000 132,000 142,000
1,175	333,000 441,000 540,000 550,000 756,000	900	484,000 651,000 396,000 552,000 688,000 461,000
1,100	496,000 784,000 1,270,000 1,320,000 1,810,000		
1,000	1,790,000 1,920,000 2,350,000 2,350,000 3,630,000		

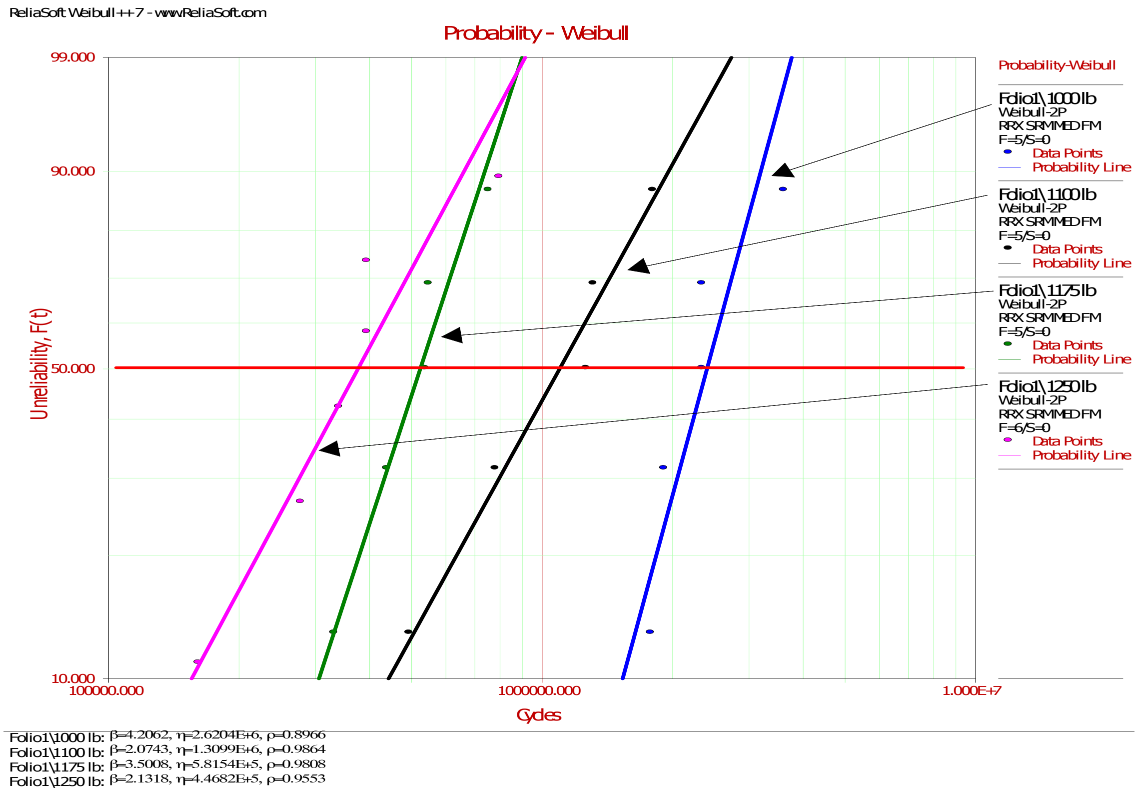
Test Results

Interested In Contributing?

If you are interested in sharing your knowledge in future editions, please contact Russ Vacante at

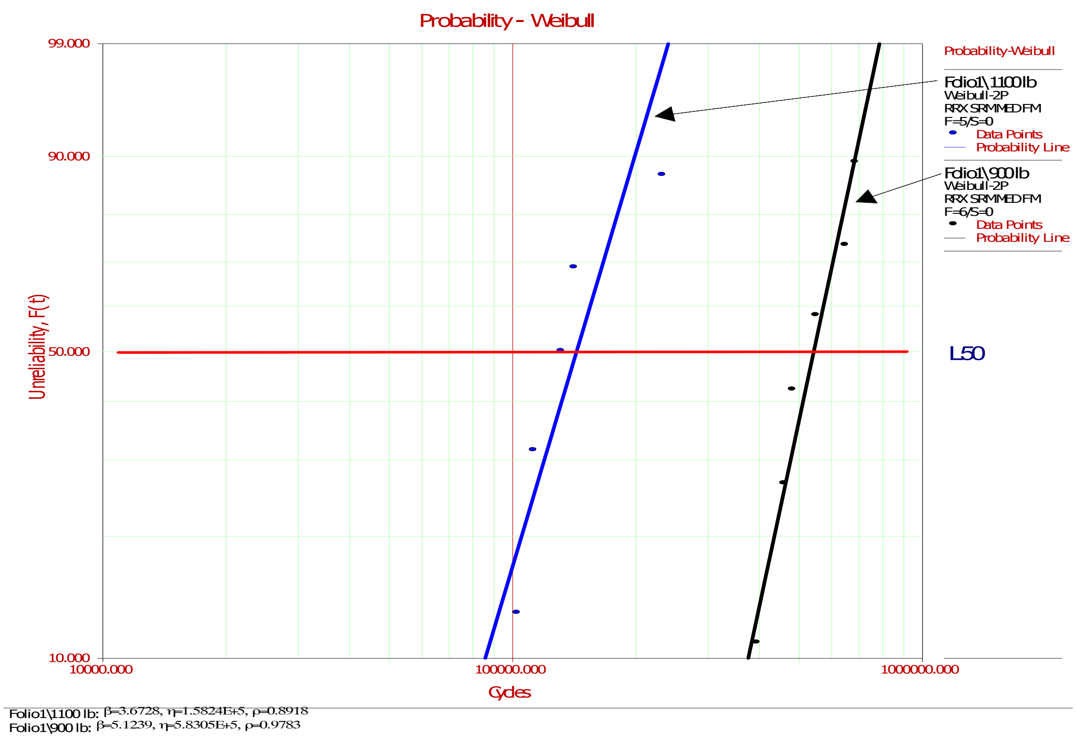
president@rmspartnership.org.

Articles can range from one page to five pages and should be of general interest to our members.



Weibull Plots for the Original Design

Note: the same failure mode should have the same shape. The 1175 pound force graph appears different, but it produced the same failure.

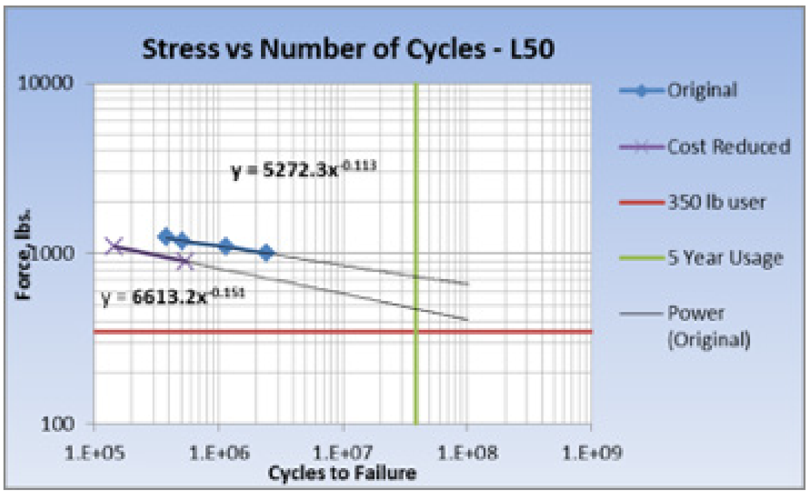


Weibull Plots for the Cost-Reduced Bracket

The next steps are to extract the L50 points from the graphs. These points are shown below.

	ORIGINAL DESIGN – L50		COST-REDUCED DESIGN – L50	
Pound Force at Failure	1,000	2,450,000	900	548,000
	1,100	1,150,000	1,100	145,000
	1,175	508,000		
	1,250	385,000		

From these points, the L50 S/N curve was plotted for the data and extrapolated to 350 pounds.



Summary

Although both designs achieve the goal of 38.75 million cycles since both designs were above the 350 pound force at 100,000,000 cycles, the original design has a better L50 life. In addition, the failure was classified as a crack rather than bracket breaking. Therefore, the cycles to failure are even greater.

This testing was done in a span of 30 days to cover a period of 5 years or it could have been extrapolated further.

Some other considerations:

1) The example used L50 for the decision basis. One might argue that L10 or less failures or R90 or greater be used instead of L50?
2) Statistical confidence should also be considered. Due to small sampling, it may be difficult to demonstrate high reliability with high confidence.
3) It is important to have a good knowledge of operational usage as this translates into the baseline for the acceleration model. These assumptions may vary depending if one is trying to understand what will be happen to the universe that have varying degree of operational speed, annual usage, and user weight. In this case, it would be wise to use an 85% profile or some other rationale. If one is making sure that there would be no safety issues, a worst-case profile might be used. ●

About the Author

Frank Straka *has been involved in the Quality and Reliability of products for over 25 years. His experience covers accelerated life test, design for reliability and production, reliability growth, statistical applications, six sigma, supplier quality, product safety, and manufacturing quality and includes electronic hardware, software, and mechanical products. His is background includes being a lead auditor for QS/ISO 9000 registrations covering software, hardware and mechanical products. Mr. Straka is Deputy Technical Advisor to U.S. Technical Advisory Group for Dependability (IEC TC 56), Deputy Co-convener to TC56 Working Group 2, and member of U.S. Technical Advisory Group on Quality (ISO TC 176). He also is a assistant secretary of IEC TC46 including /SC46A/and SC46F covering RF coaxial cable and components.*

RMS Reliability, Maintainability and Supportability PARTNERSHIP

Training Course Offerings
Wednesday – Friday
May 13, 14 & 15, 2015
George Mason University, Prince William County Campus
10900 University Boulevard
Occoquan Building, Rooms 110A & 1101
8:00 am to 4:00 pm

RMSP103: Implementing Performance Based Logistics (PBL). This fast-paced course integrates principles, policies and practices for implementing Performance Based Logistics (PBL) through enhanced Reliability, Maintainability and Supportability (RMS). It highlights key PBL concepts and the motivation for government and industry to improve sustainment strategies for defense weapon systems. The course summarizes Department of Defense directives and guidance concerning PBL implementation and describes examples from new systems and legacy sub-systems. It incorporates interactive team exercises to reinforce key activities like selecting a Product Support Integrator (PSI) and developing Performance-Based Agreements (PBA). The course also includes demonstration of additional PBL learning resources. **Instructor:** Dr. Lloyd Muller **Duration:** 3 days.

RMSP203: Reliability Engineering and Analysis. Reliability engineering and analysis includes the application of the advancing body of knowledge for mission reliability, maintainability and availability to achieve design requirements and life-cycle sustainability. Reliability analysis at the material or part design level provides methods that must be employed by engineers performing design, analysis and part selection (bill of materials) in specific disciplines [mechanical, structural, aerospace, electrical or chemical]. Reliability at the system design level provides methods to allocate requirements down to the assembly design configuration and subsequently achieve integration of design and reliability parameters into an assembly design configuration. **Instructor**: Dr Bill Wessels, PE CRE **Duration**: 3 Days

RMSP306: Diminishing Manufacturing Sources and Material Shortages (DMSMS). The purpose of this course is to understand and mitigate the loss of, or impending loss of, the last known supplier of an item or raw material. This course includes an overview of DMSMS acquisition policy and application of a proactive program and parts management for equipment and system. It includes elements of standardization, interoperability, counterfeit parts, and obsolescence. DMSMS cases may occur at any phase in the acquisition cycle, from design and development through post-production, and have the potential to severely impact commercial and weapon system supportability and life cycle costs. **Instructor:** Lincoln Hallen **Duration:** 3 Days.

Registration Fee until Monday, May 4, 2015 - $630.00; Late registration fee $695.

Group discount rates are available, contact Russ Vacante at president@rmspartnership.org or 703-967-3025.

On-line Registration at: www.rmspartnership.org; Checks accepted NLT May 8, 2015.
RMS Partnership, c/o R. Vacante, 9461 Shevlin Court, Nokesville, VA 20181-3369

Hotel Listing provided at the RMS Partnership web site.

Free Campus Parking.

the useful life of systems is extended far beyond their date of planned obsolesces. Further complicating the issue is the fact that legacy systems remain in needed use during an era when the technological change cycle, in many instances, is 12 months or less and when the battle space has taken on asymmetrical cyber warfare characteristics.

The issue of aging systems is a major challenge for a number of reasons. It is, in most cases, not in the financial interest of industry to maintain obsolete systems and related inventory of spares for a diminishing number of items with questionable longevity. For industry to do so would place them at a competitive disadvantage at a time when the evolution of technology is becoming increasingly sophisticated, of shorter duration and more complex with each iteration.

New system and component technology is often more reliable, smaller, lighter in design and operates more efficiently than systems and components they are to replace. Therefore from a financial perspective, manufacturers will invest their time and resources in designing and building systems with advanced technologies for expanding sales opportunities rather than on supporting legacy systems that can, at anytime, be eliminated with the swipe of a Congressional pen. In addition, legacy systems and components may not play nicely with advanced replacement technologies. For legacy systems that have not been designed for the insertion and use of advance technologies (i.e. not having a common backplane) often experience interface and interoperability issues and have proven to be a major readiness challenge for the DoD community.

There are other issues associated with the rapid turnover of technology that continue to challenge the DoD community. The public marketplace expectations for innovative technologies, especially in software, often means that by the time a product reaches the end of its initial production run it is obsolete. Therefore, since the lifecycle use of the product is relatively short, industry has little, if any, incentive to invest in long-term product reliability. The burning question: why design in systems with long-term reliability and availability when a systems' and/or equipments' useful life will only be one production run? In short, it is not in the competitive financial interest of corporate America.

Unlike the public sector that has the resources and flexibility to purchase products as they role off the production line, DoD strategic, economic, and mission requirements prevent investing in and purchasing advanced technology repeatedly on a short time schedule. The DoD acquisition process has a series of reviews and safeguards tied to Congressional mandates that usually cause the purchase of systems/equipment to be deliberately slow. Equally important is the fact that the DoD is much larger and more complex than any one single corporate entity within the private sector. It is responsible for the training and equipping hundreds, if not thousands of troops, deployed worldwide in the use of new technologies. Introducing new replacement equipment into the Services every year or two would create a logistics and training nightmare that would potentially leave very few funds available to DoD for other defense priorities.

Twenty first century battlespace complexity and variation requires a mixed use of systems containing innovative technologies along with legacy systems. Laser and acoustic weapon systems, for example, often are required to reside in the same space and time as the fifty-caliber machine gun. In addition, the battle space terrain keeps shifting. It can simply be confined to a remote village in Africa under terrorist occupation or can include nation-state and asymmetrical challenges from land to sea, to air, to space to cyber, from urban to desert environments, to a dense jungle environment or a combination of all.

As current worldwide urban conflicts have demonstrated, conventional urban warfare frequently requires "boots on the ground" in close combat situations. The use of conventional legacy systems tends to remain the weapon systems in use under this condition. Rifles, tanks, mortars, grenades can seldom be substituted with drones, tactical nuclear weapons, laser guided missions, computer-cyber programs and other similar advanced technologies for many regional conflicts that are challenging the national security of the U.S. Certainly advanced technologies can and do play a much needed support role within the conventional battle space however, it is conventional systems, many which are legacy, in the hands of seasoned troops that win and hold territory. This scenario creates a huge sustainment challenge for the DoD. Under such unpredictable circumstances the end cost(s) of the logistic complexity and sustainability of legacy systems is potentially damaging to our national defense and economy.

Many of the legacy systems, by definition, continue to be used far beyond their designed intended useful life. The older these systems, the less reliable they become (they break down often), parts become scarce, the more costly it becomes for maintenance facilities, equipment repair and maintenance personnel, and from a War fighter perspective, the less confidence they have that the legacy systems will keep them out of harms way. The sustainment of obsolete systems can be costly in many ways, to include using taxpayer resources that can be put to better use in defense of our county.

The time has come for DoD to develop and implement a comprehensive life cycle sustainment policy that addresses such matters as cost and part obsolesces for both legacy systems and newer systems that eventually will pass beyond their intended design life. Essential legacy systems and critical parts have to be identified and supported until there is an established, well-planned date for their replacement. Contracts for new systems need to include robust provisions for sustainment. DoD needs to do a better job in anticipating what legacy and new systems will be needed in the present and future battle space and firm, insightful cost sustainment metrics have to be developed so that provisions for a long-term, life cycle sustainment budget can be established. To do otherwise, makes the sustainment of legacy systems cost prohibitive, impedes their replacement and consumes DoD limited resources that are needed to be used in other ways to confront the global defense challenges of this century.

DDDDoD is a large enough proverbial dog to wag the tail of industry with respect to establishing educational priorities within the DoD community. When DoD leadership acknowledges the importance of and need for reliability engineers and related technical disciplines, industry will also make education and training a higher priority for its workforce. As a positive consequence, colleges and universities will have an incentive to grow their engineering programs and students will once again view engineering as an intellectually fulfilling and economically promising career. ●