The Journal of
Reliability, Maintainability & Supportability *in* Systems Engineering

Spring 2015

Reliability, Maintainability and Supportability Partnership

Table *of* Contents

Introduction

James Rodenkirch

I continue to focus on thematic "Systems Engineering, across the Enterprise" topics. Much of this focus comes from the RMSP President, Russ Vacante who, in a recent e-mail to me, passed his ideas on regarding "new themes" to introduce—one being the need to seek a balance between liberal arts, i.e., the humanities, and technological education with an eye towards fostering well-rounded professionals. Given the huge importance placed on STEM-centric education these days—emphasizing Science, Technology, Engineering and Mathematics—this is, certainly, a contemporary area for discussion.

There are a variety of influencers regarding a STEM education with or without a humanities emphasis; three that come to mind are political, the actual requirements and fairly current data/research. An article/essay in the October, 2013 edition of The Chronicle of Higher Education, *The Wedge Driving Academe's Two Families Apart: Can STEM and the Humanities Get Along?*, really gets to the political reasons for why two disciplines, "the humanities" and "the sciences," won't be meshing anytime soon. Suffice it to say, I am reluctant to delve into the politics associated with it all as that conversation will lead us all down a warren we'll never escape. However, this article is well written and highlights the political disengagement between the two disciplines. You can peruse it and the comments here: *http://chronicle.com/article/Why-Cant-the-Sciencesthe/142239/* Note: many of the reader comments highlight or embellish the disengagement discussion and are worth a look.

A little "digging" uncovered some interesting data or group-oriented focus that supports, or not, the notion a well-rounded education is the requirement. First off, groups such as the STEM Education Coalition (go here: *http://www.stemedcoalition.org/*) have a posted goal, "to inform federal and state policymakers

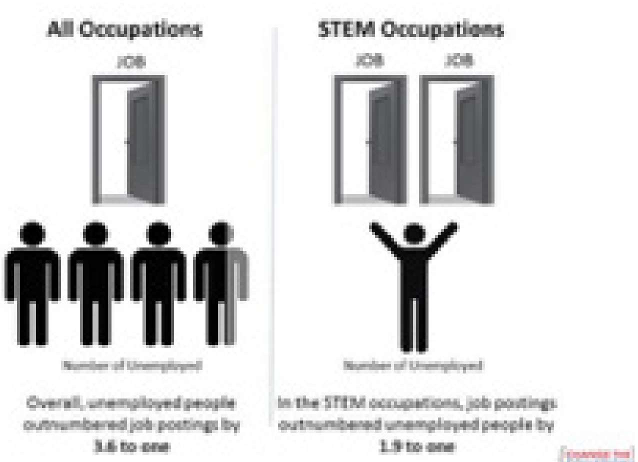

FIGURE 1

on the critical role that science, technology, engineering, and mathematics (STEM) education plays in U.S. competitiveness and future economic prosperity." That's "ok"—keeping elected officials in the know" is important. However, figures such as the one below (see Figure 1) found at the website, when juxtaposed alongside articles from credible groups like IEEE (I'll get to them shortly) start to look a tad difficult to justify.

In an August, 2013 article in IEEE's Spectrum, *The STEM Crisis Is a Myth: Forget the Dire Predictions of a Looming Shortfall of Scientists, Technologists, Engineers, and Mathematicians*, the author, Robert Charette, makes the case there are simultaneous claims of both a shortage and a surplus of STEM workers. Mr. Charette goes onto suggest, "There is indeed a STEM crisis—just not the one everyone's been talking about. The real STEM crisis is one of literacy: the fact that today's students are not receiving a solid grounding in science, math, and engineering." (go here: *http://spectrum.ieee.org/at-work/education/the-stem-crisis-is-a-myth*)

Mr. Charette's emphasis on a STEM crisis, but not the one imagined, comes from the data he's collected off a ton of research he has completed over the years. For example:

The National Science Foundation (NSF) and the Department of Commerce track the number of STEM jobs, using different metrics. According to Commerce, 7.6 million individuals worked in STEM jobs in 2010, or about 5.5 percent of the U.S. workforce. That number includes professional and technical support occupations in the fields of computer science and mathematics, engineering, and life and physical sciences as well as management. The NSF, by contrast, counts 12.4 million science and engineering jobs in the United States, including a number of areas that the Commerce Department excludes, such as health-care workers (4.3 million) and psychologists and social scientists (518,000).

His comment to the above, "Such inconsistencies don't just create confusion for numbers junkies like me; they also make rational policy discussions difficult. Depending on your point of view, you can easily cherry-pick data to bolster your argument." Mr. Charette mentions that 20% of graduates, "within 2 years of graduating with a B.S. or M.S. in a STEM-related field, are working in a non-STEM field" and, "10 years after receiving a STEM degree, 58% of STEM graduates had left the field, according to a 2011 study from Georgetown University."

Mr. Charette cites more examples where data clearly counters the plethora of handwringing articles—call it anxiety—over STEM shortfalls, wage discrepancies and the like. He refers to Michael S. Teitelbaum, a Wertheim Fellow at Harvard Law School, who has studied the phenomenon, and says that in the United States this "anxiety dates back to World War II. Ever since then it has tended to run in cycles he calls "alarm, boom, and bust." Mr. Teitelbaum says the cycle usually starts when "someone or some group sounds the alarm that there is a critical crisis of insufficient numbers of scientists, engineers, and mathematicians" and as a result the country "is in jeopardy of either a national security risk or of falling behind economically." Examples include Americans, in the 1950s, "worried that the Soviet Union was producing 95,000 scientists and engineers a year while the United States was producing only about 57,000. In the 1980s, it was the perceived Japanese economic juggernaut that was the threat, and now it is China and India."

Finally, Mr. Charette focuses on what perpetuates this "anxiety" with these observations:

- The bottom line. Companies would rather not pay STEM professionals high salaries with lavish benefits, offer them training on the job, or guarantee them decades of stable employment. So having an oversupply of workers, whether domestically educated or imported, is to their benefit. It gives employers a larger pool from which they can pick the "best and the brightest," and it helps keep wages in check.
- Governments also push the STEM myth because an abundance of scientists and engineers is widely viewed as an important engine for innovation and also for national defense. And the perception of a STEM crisis benefits higher education because the "taxpayer subsidizes more STEM education works in the interest of the universities" by allowing them to expand their enrollments.

Mr. Charette sums it all up with these missives:

- A broader view, I and many others would argue, is that everyone needs a solid grounding in science, engineering, and math. In that sense, there is indeed a shortage—a STEM knowledge shortage. To fill that shortage, you don't necessarily need a college or university degree in a STEM discipline, but you do need to learn those subjects, and learn them well, from childhood until you head off to college or get a job.
- Many children born today are likely to live to be 100 and to have not just one distinct career but two or three by the time they retire at 80. Rather than spending our scarce resources on ending a mythical STEM shortage, we should figure out how to make all children literate in the sciences, technology, and the arts to give them the best foundation to pursue a career and then transition to new ones. Instead of continuing our current global obsession with STEM shortages, industry and government should focus on creating more STEM jobs that are enduring and satisfying as well.

Finally, I juxtaposed Mr. Charette's articulation of the "problem" with the earlier mentioned figure and what is posted at the Stem Education Coalition website and, I infer, are their "priorities":

- STEM education must be elevated as a national priority.
- Our nation's future economic prosperity is closely linked with student success in the STEM fields.
- The U.S. must expand the capacity and diversity of the STEM workforce pipeline.
- Policymakers at every level must be informed about policy issues related to STEM education.
- Effective policies to promote STEM education should be bipartisan and evidence-based.

There are enough inconsistencies in what some groups state are absolute "educational needs," related to "a crisis or major problem" and what research indicates, to cause me to cast a somewhat jaundiced eye on all that is touted as being "wrong" with our country's approach to technological education; i.e., a STEM-focused curriculum is "the answer/need."

A January, 2015 article in U.S. News and World Report, Thinking Outside the Box, Our Tech-driven Future Needs the Skills of Liberal Arts Graduates, provides a grounded, liberal arts treatment I found interesting.(read here: http://www.edweek.org/tm/articles/2014/11/18/ctq-jolly-stem-vs-steam.html) The author, Dr. Tuajuanda C. Jordan, is the president of St. Mary's College of Maryland. Albeit a liberal arts college, its focus is on cultivating students through/via a culture:

- Where people respect the natural environment and the tradition of tolerance which is the heritage of the University.
- Where people cultivate a life-long quest for disciplined learning and creativity.
- Where people take individual responsibility for their work and actions.
- Where people foster relationships based upon mutual respect, honesty, integrity, and trust.

There's more but you catch "its drift" and you'll appreciate that cultural emphasis in concert with where Dr. Jordan is headed by samplings below from her article:

- As more and more college students set their sights on jobs in the science, technology, engineering and mathematics fields, we tend to forget about figures across history who achieved great things in science but who had no formal training as "scientists"—for example, Benjamin Banneker, Benjamin Franklin, Leonardo da Vinci and George Washington Carver. It was the culmination of their experiences, curiosity and critical thinking that led them to the height of science, discovery and thought.
- When most people hear "liberal arts" their thoughts turn entirely to the humanities. A rigid barrier in the popular mind separates disciplines like chemistry and physics from English literature and art. I'm a biochemist by training, but today I lead one of the nation's most unique liberal arts colleges.

- In a difficult economy, the "employability" of an education is always given significant weight. Parents have understandably gone from encouraging "learning for the sake of learning" to emphasizing the course of study that they believe will set their child up for a rewarding career. There has even been discussion as to whether we really need the liberal arts at all—STEM-centric education is portrayed as the only option for our children's economic futures. But when you ask the employers at huge corporations and technology companies what they need in their new employees, they want people who can communicate and learn quickly outside of their comfort zone, both traits fostered better by a liberal arts education than a solely technical degree. Fast Company noted back in August that many tech CEOs actually prefer employees with liberal arts degrees, as "the liberal arts train students to thrive in subjectivity and ambiguity, a necessary skill in the tech world where few things are black and white."

Note: the Fast Company article can be found here: *http://www.fastcompany.com/3034947/the-future-of-work/why-top-tech-ceos-want-employees-with-liberal-arts-degrees*

Juxtaposing Dr. Jordan's main points with those of Mr. Charette's one feels there are educators and researchers out there who understand the importance of marrying some of the humanities courses with the STEM curriculum. One curriculum doesn't trump the other but a complementary approach could help in delivering college graduates who can "fill the need."

My juxtaposing effort wouldn't be complete without a third approach—moving from a STEM focus to a Science, Technology, Engineering, Arts and Mathematics (STEAM) curriculum. An article in the Education Week Teacher magazine by Anne Jolley, *STEM vs. STEAM: Do the Arts Belong?*, discusses what the author refers to as a "tug of war" between advocates of both curricula.

From the STEM camp: STEM lessons naturally involve art (for example, product design), language arts (communication), and social studies and history (setting the context for engineering challenges). STEM projects do not deliberately exclude the arts or any other subject; rather, these subjects are included incidentally as needed for engineering challenges.The focus of STEM is developing rigorous math and science skills through engineering. How can you focus on other subjects (such as art) without losing the mission of STEM or watering down its primary purpose?

And, from the STEAM camp (the promoters of the "A"rt component - Ed.): Engineering and technology can certainly serve the artist and help create art. But if we're talking about how one can use art in engineering…as an artist, it seems we're missing the point and devaluing, or not realizing, art's purpose and importance. We have it backwards.

Referring to the above two camp positions, if one didn't know better, one might think we'd wandered in to an "out take" from the Chronicle of Higher Education article mentioned earlier on! It appears as if the two "camps," STEM and Arts, are at loggerheads—what a shame. It seems to me the requirement for a STEM-based curriculum with the "right mix" of humanities component is the answer. What does "right mix" mean? I don't have a clue but, given Mr. Charette's cautionary note, "children born today are likely to live to be 100 and to have not just one distinct career but two or three by the time they retire at 80," and his data reflecting 20% of STEM graduates, 2 years after graduating, work in a non-STEM field and 58% are after 10 years, I'm betting the education community, prompted by the companies needing the STEAM-like engineers, needs to gather around a unifying plan and get that plan implemented.

Finally, one always looks for a "poster child" that exemplifies what one espouses or promotes and I found a likely candidate. While reviewing a flyer on a technology talk at Southern Methodist University titled, "Choreographic Abstractions for Embodied Design of Heterogeneous Robotic Behavior" by Professor Amy LaViers of the Department of Systems and Information Engineering, University of Virginia, I espied Ms. LaViers bio (STEM + humanities emphasis in bold):

Amy LaViers is an Assistant Professor in Systems and Information Engineering at the University of Virginia (UVA) and director of the Robotics, Automation, and Dance (RAD) Lab where she develops algorithms for automation inspired by movement and dance theory. At UVA she is spearheading **research in advanced manufacturing through an industry-university consortium**, the Commonwealth Center for Advanced Manufacturing (CCAM), and **forging interdisciplinary ties with the UVA Dance Program and the Laban/Bartenieff Institute for Movement Studies**, where she is pursuing a Certification in Movement Analysis (CMA). She completed her Ph.D. in Electrical and Computer Engineering at Georgia Tech where she was the recipient of the ECE Graduate Teaching Excellence Award and a finalist for the CETL/BP Outstanding Graduate Teaching Award. Her **dissertation included a live performance exploring the concepts of style she developed there.** Her research began at Princeton University **where she earned a certificate in Dance and a degree in Mechanical and Aerospace Engineering. Her senior thesis, which compared two styles of dance,** earned top honors in the MAE department, the School of Engineering and Applied Science, and the Lewis Center for the Arts.

If Ms. LaViers can combine STEM and liberal arts studies into a successful Ph.D. in a decidedly technologically complicated engineering discipline, so can others, particularly if the two disciplines/curriculums come together and "work nice." The notion of introducing an "A"rt component to the STEM push—promoting a STEAM approach/focus—would seem, on the surface, to offer a way to vector off the "STEM is it" approach that is prevalent these days. If we could shrug off the pesky politics and data manipulation efforts…things could look brighter for those espousing a truly well-rounded engineering/science education.

Moving away from theme selections for the Journal we want to introduce to what remains the focus of this Journal—articles that address our interests—the articles selected for this spring, 2015 edition continue to span the breadth of "the Enterprise." Up first is the article, *Impact of Weight on Reliability of Army Ground Vehicles* by Geetha Chary and Michael Pohland. All of the "up-armoring" efforts for the ground force troop vehicles in Iraq and Afghanistan certainly add(s) a "ton of weight" to those vehicles so how does that affect vehicular reliability? Ms. Chary and Mr. Pohland put together an excellent article that "presents the lessons learned and recommendations regarding approaches to assess the impact of an increase in weight on vehicle reliability."

John Leavitt and Miklós Szidarovszky provide us insight into Monte Carlo flowchart simulations with their article, *Reliability Through Customizable Computerized Monte Carlo Simulation*. They explain how a new program, RENO, can be utilized to quickly estimate the reliability of a given system through the design of user friendly, visually appealing and logically programmed flowcharts. Anytime a user friendly a visually appealing approach comes along, we should be "all ears."

The third piece is my expanded article on measurements, *Are Your Measurements "Stacking Up"*? It was a "fun effort" on my part as it merely carries over the effort I invest, during my time teaching a Systems Architecting course at Southern Methodist University, enjoining the students to truly focus on a process to measure and report accurately and effectively on what they measured. The original article appeared in a recent RMSP Newsletter; I expanded it to add an example and "flesh out" the measurement process.

The fourth article, *Developing Reliability Requirements for Potable Water Solutions in Politically Discontinuous Areas—Part 3 of 3, Hydro-Political*, by Katherine Pratt, is part three of her investigation into the problems associated with ensuring the delivery of reliable water to the Middle East. Katherine provided, in parts one and two, reliability and management/stewardship considerations. Her final offering takes us through some of the political issues associated with a dynamic area of our world—an area "in the news" daily and one the world needs to pay attention to. Katherine's original submittal is in the neighborhood of 90 pages, too long for Journal length requirements. However, I coerced her into authoring an overview piece which is what you'll find. We will post the entire article on the RMSP web site, in the near future, as her research certainly has opened our eyes to the complexities associated with one aspect of the infrastructure in the dynamic region of our world.

Enjoy these Journal offerings—if an idea for an article comes to you contact me as we're soliciting articles for our Winter 2015 edition; my e-mail address can be found on the last page of the Journal.

Impact of Weight on Reliability of Army Ground Vehicles

Geetha Chary & Michael Pohland

Abstract

Increasing demand for modernized armor kits has resulted in a dramatic rise in the weight of the Army ground vehicles, impacting acquisition and sustainment costs adversely. Recent combat operations and testing of up-armored vehicles have shown reliability degraders of collapsed springs, cracked frames, broken upper control arms, crushed air conditioning condensers, broken lower control arms, cracked radiators, failed suspension bushings and failed gear drive hubs. While working to achieve the best capabilities, the Army is struggling to keep the well-known reliability characteristics of the legacy systems. This paper presents the lessons learned and recommendations regarding approaches to assess the impact of an increase in weight on vehicle reliability.

Acronyms

AMSAA	Army Materiel Systems Analysis Activity
DfR	Design for Reliability
FD/SC	Failure Definition Scoring Criteria
FEM	Finite Element Model
MMBU	Mean Miles Between Unscheduled
M&S	Modeling and Simulation
MTBOMF	Mean Time Between Operational Mission Failure
OMS/MP	Operational Mode Summary / Mission Profile
PoF	Physics of Failure

Introduction

Over the years, the Army has evolved in technology and armor protection significantly to provide soldiers with sophisticated capabilities. To meet the threat on today's battlefields, it has become essential for the Army vehicles to be more mobile, effective, safe and affordable. Unfortunately, these requirements brought many technical challenges along with the drastic increase in weight and cost of the vehicles. Figure 1 provides a graphical comparison of growth in the cost and weight of the combat vehicles.

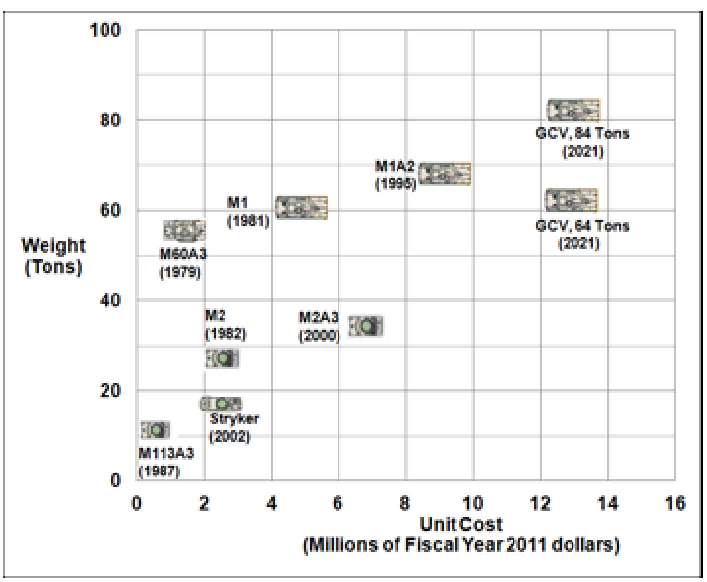

Figure 1. Evolution of Armored Vehicles in the U. S. Army [1].

Weight Impact on Fatigue Life

While the weight (payload) increase directly impacts the vehicle speed, performance, and its fuel economy, it can inherently contribute to limiting the life of the individual sub-systems and therefore affect the reliability of the full system. In one study, the impact of added weight on the fatigue life of suspension components for a tactical wheeled vehicle was investigated by comparing the baseline weight configuration with an increased weight configuration. In this study, the Army Materiel Systems Analysis Activity (AMSAA) partnered with the Aberdeen Test Center to evaluate suspension reliability as a function of weight growth using Modeling and Simulation (M&S), both computer and hardware-based and limited field testing. AMSAA developed a computer-based, Finite Element Model (FEM) for a quarter of a vehicle suspension using Abaqus/CAE (commercially-available, finite element analysis software); only one quarter was required due to symmetry of design. The suspension of an actual vehicle was instrumented with strain gauges, accelerometers, string pots, and a wheel force transducer. A stress analysis provided a roadmap for actual strain gage placement. The vehicle (under different weight configurations) was then driven over a Reliability, Availability, and Maintainability (RAM) course profile, developed to simulate the Operational Mode Summary / Mission Profile (OMS/MP). The collected data was used to drive and validate the computer-based models. A dynamics model of the quarter-suspension with flexible bodies generated from the FEM was developed in Virtual.Lab Motion (commercially-available, multi-body modeling software) to simulate and record the dynamic response of the suspension to terrain loading. The terrain loading, recorded by the wheel force transducers, was applied at the model's wheel location. The modal time histories of the main suspension components were output and used along with the FEM to determine the fatigue life of the suspension components. An example analysis flow is shown in Figure 2.

Additionally, an actual quarter-suspension was placed on a hardware simulator known as the Vehicle Durability Simulator and run using a time-compressed mission profile. Both the test and analysis showed component degradation with weight growth; however both indicated that sufficient time to failure based on operational usage may still exist.

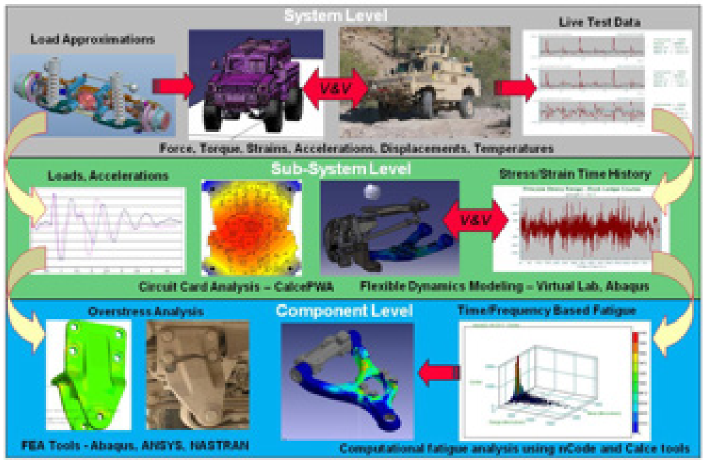

FIGURE 2. AN EXAMPLE ANALYSIS FLOW TO CALCULATE COMPONENT LIFE.

Field Data Studies

In another set of studies, a number of wheeled and tracked vehicles were looked at to determine if a relationship between weight and system reliability exists. In one study, albeit counter-intuitive, some heavy vehicles were found to be reliable; yet, some light vehicles were actually found to be unreliable. The vehicle system weight vs. reliability data is plotted in Figure 3.

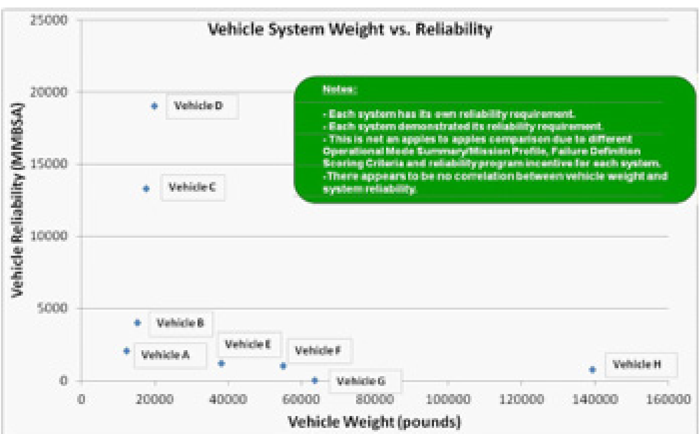

FIGURE 3. VEHICLE SYSTEM WEIGHT VS. RELIABILITY PLOTTED.

Mean Miles between Unscheduled (MMBU) Visits and Actions of various light and heavy vehicles showed no consistent trends when comparing regular loads (Light) with up-armor loads (Heavy). Vehicle Data from Field Data Collection are plotted in Figure 4.

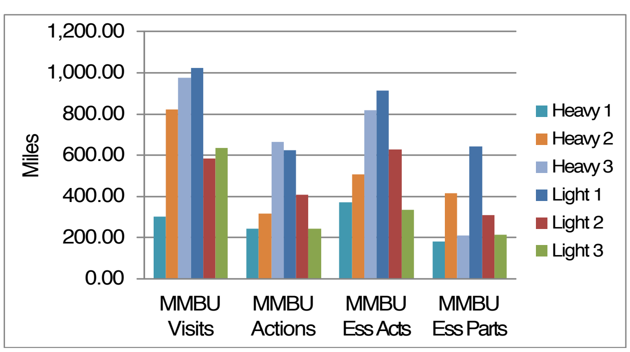

FIGURE 4. MEAN MILES BETWEEN UNSCHEDULED (MMBU) VISITS AND ACTIONS PLOTTED FOR LIGHT AND HEAVY VEHICLES.

Failure Modeling and Simulation

In one set of studies, AMSAA looked at actual field and test data of a ground vehicle to determine what suspension components were failing and their rate of failure occurrence and then simulated weight growth to analyze its effect on the high failure rate components. A multi-body dynamics model of the vehicle was developed to assess localized response load changes at the component locations due to the weight increases; individual component finite element models were created to translate the loads into stresses and strains; and finally, various failure models were used to estimate life at the most likely failure sites for the mechanism analyzed. With a 30% increase in vehicle weight, component replacements were expected to increase by 20% to 60%. It was also noticed that vehicle reliability was seen to be decreasing but not at a constant rate. Figure 5 and Table 1 show the impact of weight on estimated number of fleet replacements over 20 years.

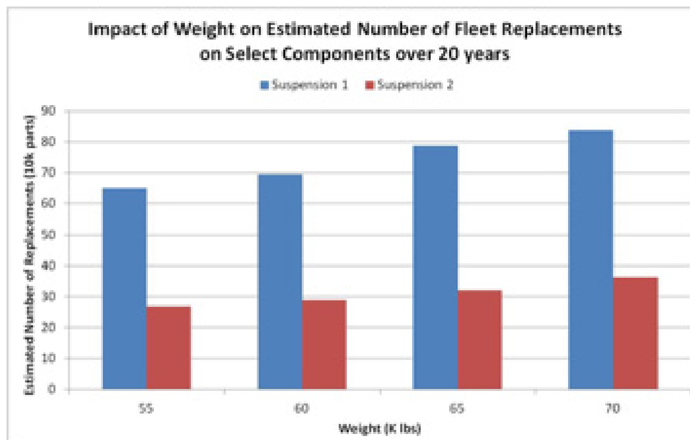

FIGURE 5. WEIGHT VS. FLEET REPLACEMENTS PLOTTED.

	Percent Increase in Replacements	
Weight Increase	Suspension 1	Suspension 2
55–60	7%	7%
60–65	13%	11%
65–70	6%	13%

TABLE 1. PERCENT INCREASE IN REPLACEMENTS DUE TO ADDED WEIGHT.

Design Change Impact on Reliability

In another study, four concept vehicles were evaluated for reliability improvements over a baseline vehicle under higher input loads (more rigorous mission profile) increasing the input loading has a similar effect on the suspension to increasing the vehicle weight. The four concept vehicles started as the baseline vehicle and then were modified to a varying extent that ranged from minimal changes such as upgrading only a few suspension and engine components to maximum changes such as completely changing the suspension, power train, electrical system, and frame/chassis. The vehicles were then run over a course profile representing the

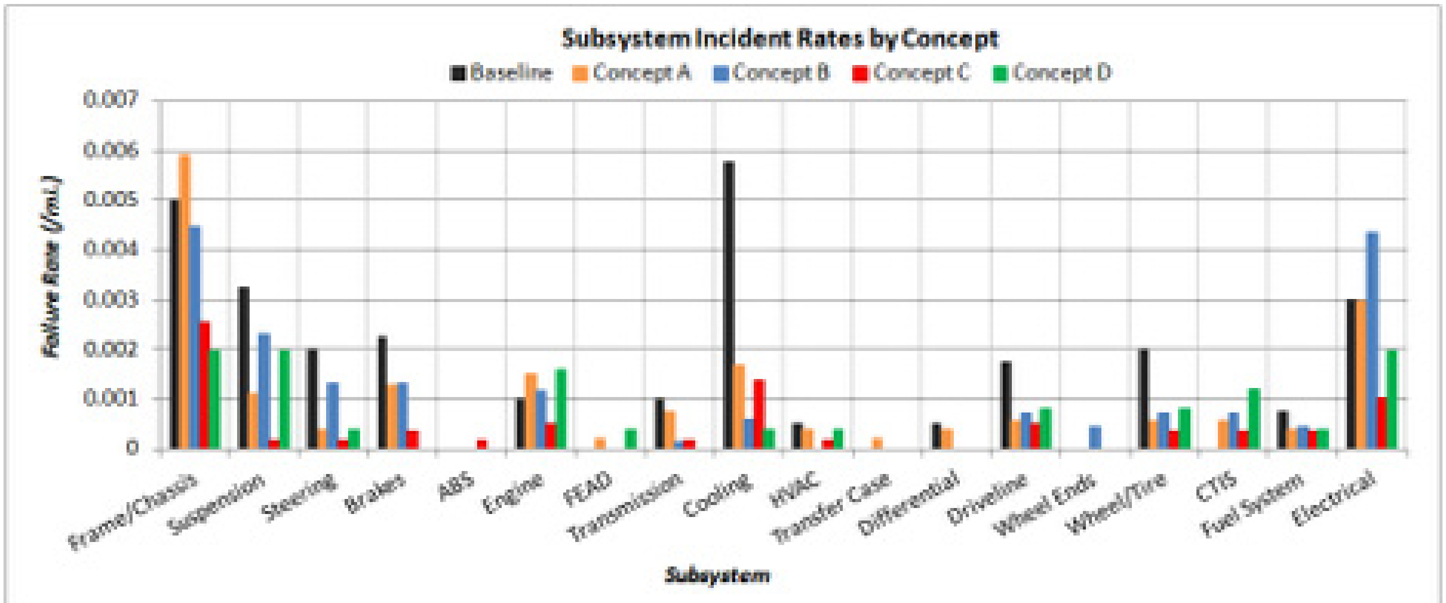

FIGURE 6. CONCEPT SUBSYSTEM OPERATIONAL MISSION FAILURE RATES COMPARED TO BASELINE (BLACK).

mission profile. Failures were captured in Test Incident Reports (TIRs). As can be seen in Figure 6, design changes to the system can produce good results (improved overall system reliability); however some subsystems can actually become less reliable depending on the changes.

Targeted physics-based analysis (AKA Physics of Failure (PoF) analyses) can help aid in the design changes and allow for a better understanding of how the changes affect the system response, and consequently, the system reliability.

Reliability Improvement Enablers

Assessing reliability requires detailed knowledge of the system and how it is used. In general, it is challenging to find an approach that can estimate the reliability of an entire vehicle system based on weight. Since the reliability is design specific, the system can be, potentially, broken down into sub-systems and investigated. It is critical that the design of new systems allow for sufficient weight growth potential. In general, developers and contractors should consider the historical data and plan for weight growth increases of 25% over the life of their system [2]. In the case of a new vehicle design, one potential approach is as follows:

- Investigate sub-systems (driveline, engine, suspension, etc.).
- Determine the weight rating for each sub-system. Most components will have a weight rating: the maximum allowable weight for a component without failing over the course of the product's life.
- Use the weight rating as a "Go/No Go Criteria" for the component.
- Determine the weight of overall vehicle. Include weight growth margin (e.g., 20% weight growth potential for vehicle).
- Compare overall weight of vehicle to sub-system weight rating.
- If the sub-system weight rating is between ±10% of the overall rating, sub-system has potential and should be investigated further using failure analysis techniques.
- If sub-system weight rating is outside ±10% of the overall weight– sub-system may not be a good candidate.

For example, when assessing a potential suspension, the following chart (Figure 7) could be used.

By leveraging historical U.S. Army reliability test data and Sample Data Collection and Analysis (SDC&A) data, it can be ensured that lessons learned from past programs are applied to current and future acquisition programs. It is also recommended to conduct early Design for Reliability (DfR) activities such as developing Reliability Growth Planning Curve (RGPC) with a realistic initial reliability (Mi) estimate based on Physics of Failure (PoF) analysis techniques / failure modeling to further reduce program risk (Figure 8).

When developing and accepting redesigns, keeping a balanced system design with respect to reliability, weight, and cost is essential. The DFR efforts should be resourced early and adequately in order

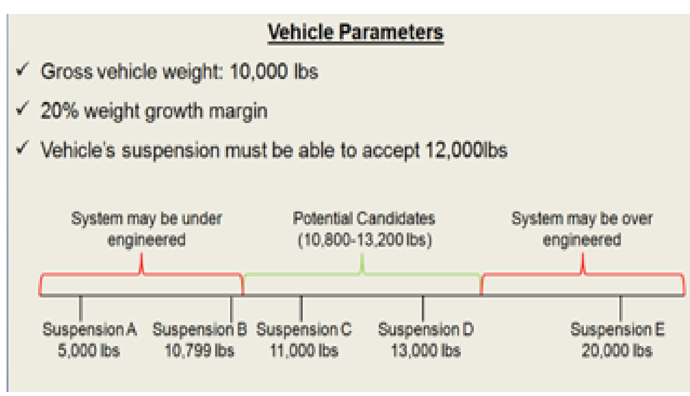

FIGURE 7. VEHICLE PARAMETERS TO CONSIDER DURING ASSESSMENT.

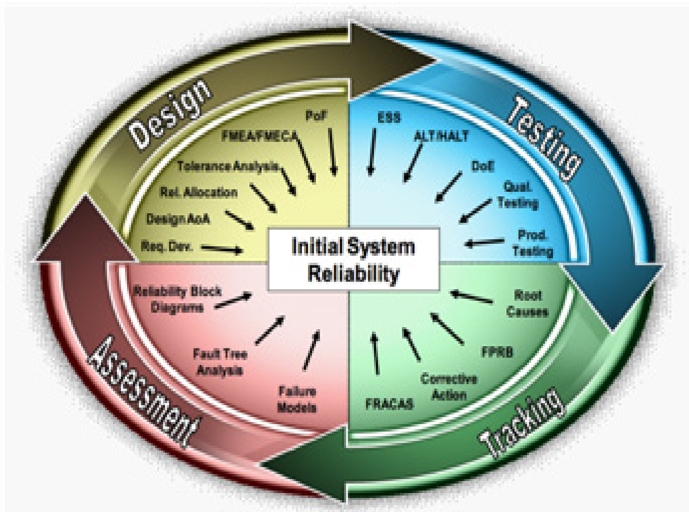

FIGURE 8. DESIGN FOR RELIABILITY APPROACH.

to develop a more reliable design solution. In one study, AMSAA supported United States Marine Corps in planning and implementing a successful reliability growth program for a redesigned vehicle [3]. In this study, initially, a fault tree analysis was performed by breaking out the mission essential functions (MEFs) of the vehicle. The fault tree was further broken down into component levels, identifying mission essential components (MECs). For each of the MECs, A Mean Time between Operation Mission Failure (MTBOMF) was allocated. This allocation was compared to the MEC's normalized, demonstrated, MTBOMF that was determined using previous reliability test data. For MECs that demonstrated reliability significantly lower than their allocation, the decision was made to address these MECs through a subsystem or component level redesign. Reliability growth testing (RGT) was performed on the system to surface failure modes. A Failure Prevention and Review Board (FPRB) assisted in developing corrective actions for failure modes and prioritizing them appropriately for the Corrective Actions Periods (CAPs). Failure mode trends and reliability from the various test sites were compared and the test data was reconciled in order to assess the system reliability with the reliability growth tracking and projection models as illustrated in Figure 9. The planned reliability growth program provides

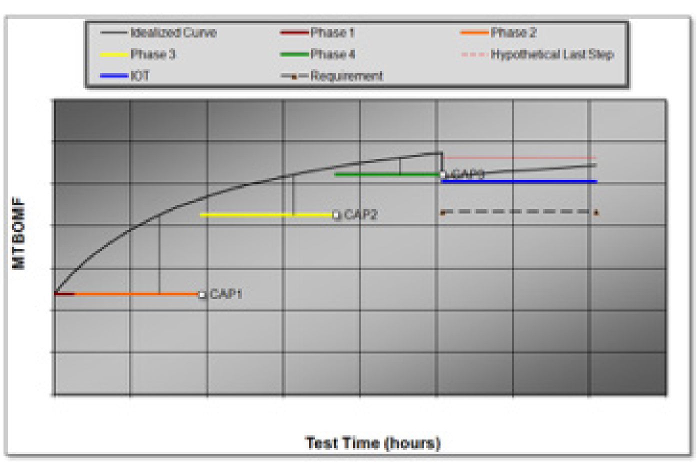

FIGURE 9. RELIABILITY GROWTH PLANNING MODEL BASED ON PROJECTION METHODOLOGY (PM2).

opportunities to make significant jumps in reliability as well as opportunities to periodically measure reliability.

Conclusion

This paper presents study findings on vehicle weight and its relationship to reliability. In addition, it provides some strategies to quantify and minimize the weight impact on reliability. No consistent relationship (linear or non-linear) has been established to help assess how a weight increase will impact reliability. This is understandable. With different Operational Mode Summary / Mission Profile (OMS/MP), Failure Definition Scoring Criteria (FD/SC) and reliability program incentive for each system, each vehicle is designed to be unique. Based on the specific designs, competing failure mechanisms are at work. The dominant failure mechanism will drive failure and, ultimately, system reliability. Further investigation on a case-by-case basis is needed to make a significant conclusion.

Vehicle weight will continue to grow as changing threat environment and advances in technologies continue to drive the need for increased survivability, lethality and improved communications and automotive performance. It is essential to fully understand the impacts of the weight changes. A detailed understanding of the failure modes and mechanisms is critical. Judicious use of computer-based Modeling and Simulation (M&S) tools and limited testing can enhance this understanding and provide a good estimate of reliability impact. A better understanding of the failures and their mechanisms will help identify reliability improvements. Addressing these will reduce the risk to the soldiers operating the vehicles and also potentially save the Army millions of dollars of acquisition and/or sustainment costs.

—

References

1. Kempinski, Bernard and Murphy, Christopher. "Technical Challenges of the U.S. Army's Ground Combat Vehicle Program." November 2012. Congressional Budget Office website.
2. Clapp, LTC Timothy P. and Cassidy, Joseph F. "Historic Weight Growth of U.S. Army Combat Vehicle Systems." *Military Traffic Management Command, Transportation Engineering Agency* (27 August 2002): 13.
3. Morningstar, Matthew and Herbert, Nate. "Successful Implementation of Design for Reliability and Execution of Reliability Growth Testing on the Expeditionary Fighting Vehicle." in *International Applied Reliability Symposium*. New Orleans, Louisiana. June 13-15, 2012.

Reliability Through Customizable Computerized Monte Carlo Simulation

John Leavitt & Miklós Szidarovszky

Introduction

A customizable and computerized Monte Carlo analysis uses thousands of simulations to estimate the reliability of a given system within an abbreviated period of time. This technology allows a user to perform a user-friendly flowchart simulation, which may be used for reliability calculations, failure analysis, optimization analysis, financial analysis, and event tree analysis, just to name a few functions.

Before computational numerical analysis advances, Monte Carlo experiments or simulations needed to be performed manually in real time to observe the frequency of each occurrence. In 1946, Stanislaw Ulam recognized the potential for computerized simulations while trying to determine the probability of winning a game of solitaire [2]. Today, software can be used to design the systems,run simulations, record data, and then perform analysis on that data within minutes or even seconds.

In this article, we will use ReliaSoft's RENO software to perform a simple reliability and risk analysis for an anesthesia machine and its safety sensors. This software is used to build complex models for simulations [4]. ReliaSoft's Weibull++ software, a life data analysis software tool [5], will also be used to generate a failure model that can be used with RENO.

An anesthesia machine is frequently used during dental and medical procedures. The machine mixes oxygen (O2), nitrous oxide (N2O), and sterilized air into a vapor that is then used to sedate the patient. Component reliability, especially in safety sensors, is crucial for anesthesia machines, as failures have the potential to result in damage to the machine and, in extreme cases, death of the patient. To avoid and prepare for potential failures, the design and operation of the machine requires preventive engineering, detection controls and a trained anesthetist who is capable of responding to failures.

In this example, we will demonstrate how to perform a failure analysis with the help of Weibull++, and how to estimate the probability of failure and perform a simple sensitivity analysis given thousands of Monte Carlo simulations using RENO. Such a sensitivity analysis may be used by reliability engineers to simulate the reliability of detection controls, given the simulated reliability of specific components. In the end, RENO will be used to calculate the total ending cost.

Process

Suppose an anesthetic machine follows the process diagrammed in Figure 1. *N.B., that this diagram and the machine operations are for example purposes only and may not represent an actual anesthetic machine. [1]*

A gas cylinder containing oxygen-enriched breathable air supplies high pressurized gas through a pressure relief device (PRD) to a vaporizer. The PRD regulates air pressure to prevent high pressure damage to the vaporizer. An electronic pressure detection sensor is located on the other side of the PRD to inform the anesthesiologist if the PRD fails. The oxygen-enriched air is then mixed with nitrous oxide within the vaporizer until the mix is safe for sedation. An electronic oxygen detection device ensures that the vaporizer mix maintains safe oxygen-to-nitrous-oxide ratios. If oxygen levels don't appear to normalize, the sensor alerts the anesthesiologist. Next, the air mix travels through a one-way valve to the patient. Before reaching the patient, a final sensor checks incoming air pressure to be sure that the air is getting to the patient. If there is a perceived loss of air pressure, an alert is sent to the anesthesiologist.Finally, the patient exhales waste air that is sent through a one-way valve and dispersed to an outside environment.

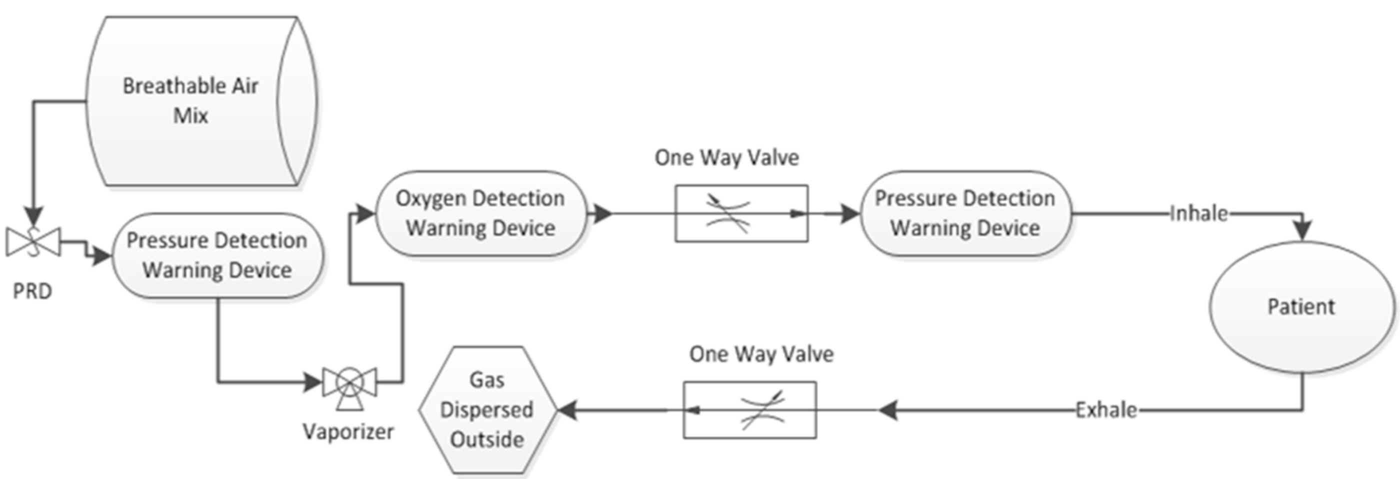

FIGURE 1

In operating an anesthetic machine, it's important to avoid Type II errors, where we think the system is reliable even though it's not, because they may lead to damage of the machine or harm of the patient. Detecting effects that are not present, a Type I error, is frustrating but it is preferred when compared to the alternative.It is for this reason that safety warning sensors are placed after essential components.

Assumptions

The following assumptions are for example purposes only and may not reflect an actual failure distribution for an anesthetic machine.

1. The pressure relief device follows a 2-parameter Weibull distribution with a beta of 1.5 and an eta of 1,400 hours. A failure would be a leak that allows over-pressurized air to reach and potentially damage the vaporizer.
2. The vaporizer reliability follows a 2-parameter Weibull distribution with a beta of 2 and an eta of 600 hours. A failure would occur if the vaporizer did not produce the correct air to nitrous oxide mixture ratio.
3. The inhalation valve distribution is unknown, but 2000 points of failure were provided for failure analysis. A failure could be an air leak on the way to the patient or a valve that allows exhaled air from the patient. We will use Weibull++ to perform the failure analysis on the data set.
4. The PRD high pressure sensor will detect dangerous pressures 99% of the time, given that the PRD is not working correctly.
5. The low oxygen detector, located after the vaporizer, will detect low oxygen levels 94% of the time, given an incorrect vaporization mixture.
6. The inhalation valve pressure sensor will detect losses in air pressure 97% of the time.
7. Machine components are inspected and refurbished like new after every 400 hours of use. If a failure is detected, the machine is repaired before its next operation.

Objective

A failure of the failure detection systems for the PRD, vaporizer, or unidirectional valve is not acceptable. While human error, such as improper monitoring of the patient by the anesthesiologist may occur, this example will only estimate the probability that the failure detection systems fail to recognize a malfunctioning component. Failed components may cause a lower or higher anesthetic dose than desired, or may prevent the patient from receiving breathable air. This example will demonstrate how to find the expected percent of times safety controls fail given a component failure within the machine.

Failure Analysis

In this example, the assumptions state the distribution, beta and eta values for two out of three components. In reality, these values often need to be analyzed and then calculated using failure data that can be obtained either from reliability life data analysis, or actual operation of the machine. Weibull++ may be used to perform such an analysis [3]. This section will demonstrate a basic computerized analysis of the inhalation valve's failure data.

After importing the inhalation valve failure data into Weibull++, and then analyzing the data, Weibull++'s Distribution Wizard is used to determine the best distribution for the data set. In this case (Figure 2), the 2-parameter Weibull distribution is the suggested distribution for the data set.

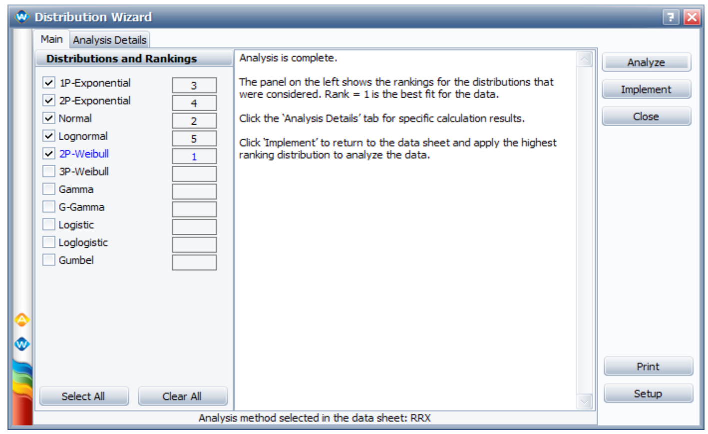

FIGURE 2

After implementing the suggested distribution, the results show a beta value close to 1.5 and an eta value near 2000 (Figure 3). These parameters can be saved as a model and then used in the RENO based Monte Carlo solution.A life data failure analysis may be performed for each component, so long as failure data exist for that component.

Analysis Summary	
Parameters	
Beta	1.567484
Eta (Hr)	1985.667389
Other	
Rho	0.983708
LK Value	-829.137384

FIGURE 3

Solution

RENO can be used to simulate the process of a flowchart with assumptions imbedded into it as resources. Resources are called upon by the flowchart during a simulation. In this solution we will use three different types of resources:models, static functions and variables.

The solution in RENO must include reliability models for the pressure relief devices, the vaporizer and the valve. We defined RENO static functions to generate a random failure time from each model that remains constant throughout each simulation analysis. Lastly, we defined two variables to keep track of the number of preventive maintenance cycles and reliability improvements for the components. A summary of all resources is shown in Figure 4.

Type	Name	Equation/Value	Category	Parameter1	Parameter2
Model	PRD	2P-Weibull	Reliability	1.5	1400
Model	Vaporizer	2P-Weibull	Reliability	2	600
Model	Valve	2P-Weibull	Reliability	1.5	2000
Static	StaticPRD	rvm(PRD)			
Static	StaticVaporizer	rvm(Vaporizer)			
Static	StaticValve	RVM(Valve)			
Variable	PM_Cycle_Time	400			
Variable	Improvement	1			

FIGURE 4

After inputting the assumptions into the software, a reliability flowchart that follows the logic in the machine's process can be created. This solution is only one of many logical flowcharts that can be used to simulate the reliability of the machine. The flowchart below determines the probability that the safety sensors fail, given the probability that a component fails.

RENO flowcharts allow for an attractive method to display and save a solution as well as its process. Usually flowcharts follow the same logic a programmer might use when developing code. For instance, the diamond shaped blocks with question marks serve as conditional "if statements," a commonly used term in computer programming.

In this flowchart solution (Figure 5), 100,000 simulations were run on the flowchart. The results show that there is a 0.42% probability that the safety detectors will fail to detect a given component failure within a preventive maintenance cycle.

Sensitivity Analysis

Sensitivity analysis is used to evaluate the effect of one or two variables on a result by performing a run or part of a simulation at a given range of simulation settings.

Using RENO, a two-variable sensitivity analysis may be performed on the above flowchart to determine the optimal number of preventive maintenance cycle hours, given a desired reliability. To the right a two-variable (two-variable modified) sensitivity analysis was performed within RENO.

The sensitivity analysis spreadsheet, as shown in Figure 6, displays the probability of system failure at chosen cycle times, given the current state, a 25% and a 50% reliability improvement.

An analysis like this might be useful to reliability engineers for predicting the level of improvement necessary, or the number of hours needed in a cycle to prevent a failure threshold.For example, assume our failure threshold is 0.1% and we are operating at 150

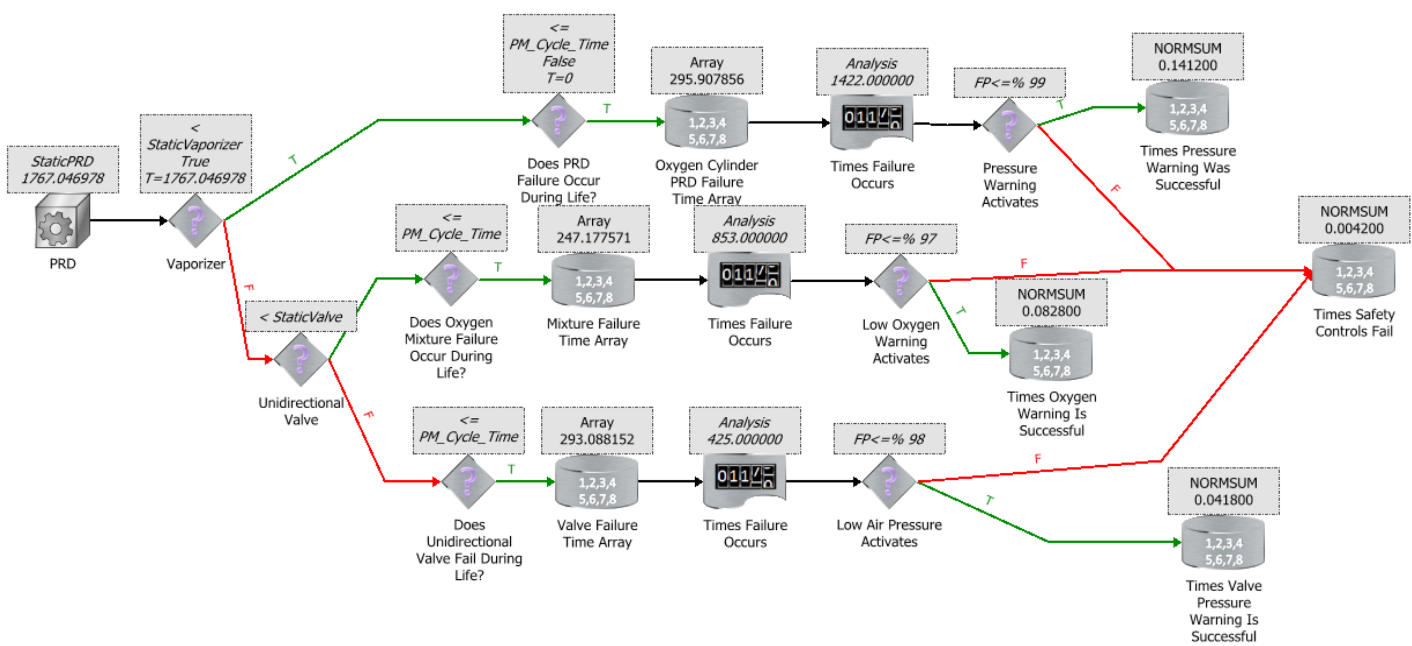

FIGURE 5

hours per preventive maintenance cycle. If we improved the reliability of each component by 50%, we would be able to add about 75 hours to our preventive maintenance cycle while keeping the probability of system failure below 0.1%. However, we can see that even with an increase of 50%, increasing the cycle time to 250 hours would put us over our failure threshold.

Block Name: Times Safety Controls Fail			
Flowchart(s) Location:	->Diagram		
Storage Type:	Normalized Sum		
Runs Stored:	27		
	Probability of System Failure		
PM_Cycle_Time \ Improvement	1	1.25	1.5
100	0.00034	0.00024	0.00018
125	0.00078	0.00056	0.00028
150	0.00088	0.0007	0.00032
175	0.0152	0.001	0.00064
200	0.00156	0.00112	0.0008
225	0.00184	0.00116	0.00092
250	0.00256	0.0017	0.00106
275	0.00278	0.0018	0.00152
300	0.00314	0.00228	0.00168

FIGURE 6

Cost Estimation & Analysis

Reliability flowcharts calculate values as functions of the logic inputted, so they may also be used as a tool for financial analysis and cost accounting. An example might be a comparison analysis of the summated cost of an anesthetic machine and its preventive maintenance incurred at different cycle times.

For example, assume the manufacturer advises that the current machine (original machine) be serviced (preventive maintenance) after every 150 hours of operation; however, the previous sensitivity analysis indicated that acceptable reliability will more than likely not be compromised with a preventive maintenance cycle time of up to 225 hours of operation, assuming a 150% improvement (improved machine). In this case, reliability flowcharts may be used to calculate the total costs at each cycle time assuming a cost for preventive maintenance. The difference between these costs would help determine the economic gain or loss by operating at 75 more preventive maintenance cycles with a different machine.

Assume that the original machine initially costs $95,000, while improving the machine by 150% costs an additional$15,000 (total initial improved cost $110,000). Also assume that each machine has a useful life of 10 years,operates 50 hours per week, and has a preventive maintenance cost of $500. Given these assumptions, the following flowchart (Figure 7) can be designed and simulated to find which machine option is less costly in the end.

As seen in Figure 7, simulation results on the original machine shows a life cycle cost of $181,500. A simulation of the improved machine will show a life cycle cost of $167,500. The $14,000 simulated difference demonstrates the monetary savings provided by spending $15,000 to improve the original machine by 50%. This analysis shows that a sensitivity analysis, as well as the ability to perform a financial analysis,may easily be done within a logical Monte Carlo flowchart simulation in a computerized environment.

Conclusion

As demonstrated, Monte Carlo flowchart simulations can be utilized to quickly estimate the reliability of a given system through the design of user friendly, visually appealing, and logically programed flowcharts. These flowcharts, which are easily reproducible, may utilize failure data or parameters that allow an engineer to more accurately estimate the reliability of a system.

Sensitivity analysis, designed through a logical flowchart, may prove useful to determine how to best improve maintainability of a system by either increasing component reliability or decreasing preventive maintenance cycle time. Cost analysis results, also derived through a logical flowchart, may be used to calculate the marginal benefit of a sensitivity analysis as well as other financial metrics.

In the case of medical equipment, such as anesthesia machines, the reliability of a continuous supply of oxygen or medication

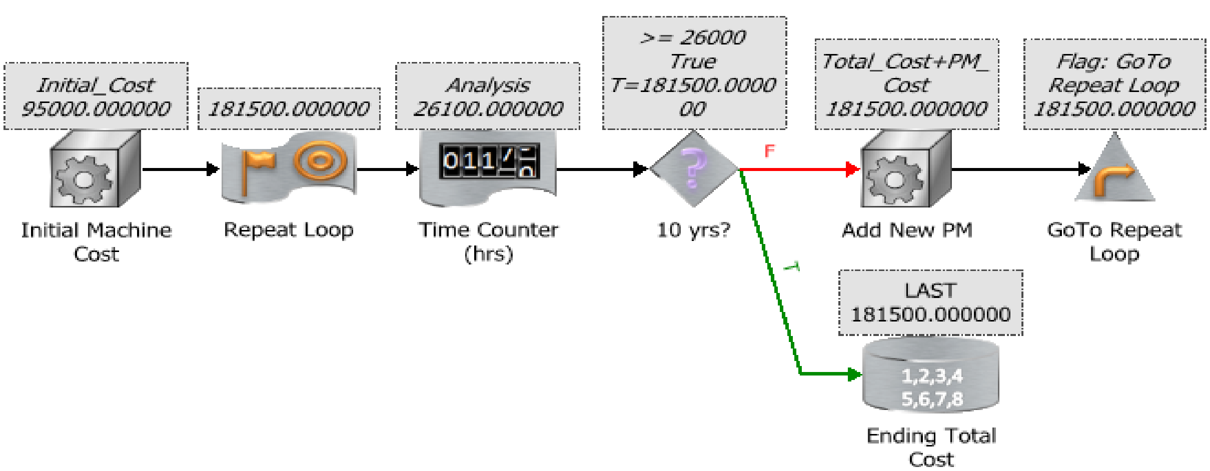

FIGURE 7

is an essential lifeline. A computerized Monte Carlo flowchart simulation allows for a complete failure analysis, sensitivity analysis, cost analysis, as well as other analyses, to ensure reliability and affordable maintainability of such equipment.

—

References

1. Dosch, Michael P., (July 2012) *The Anesthesia Gas Machine*. Retrieved from University of Detroit Mercy Graduate Program in Nurse Anesthesiology website http://www.udmercy.edu/crna/agm/02.htm.
2. Holton, Glyn A. (2014) "The Monte Carlo Method." In *Value-at-Risk: Theory and Practice*. 2nd ed. Retrieved from http://value-at-risk.net/the-monte-carlo-method/#_ftnref2.
3. ReliaSoft Corporation *(n.d.) Life Data Analysis (Weibull Analysis).* Retrieved from http://www.weibull.com/basics/lifedata.htm.
4. ReliaSoft Corporation (2013). RENO Version 9 [Computer Software] http://RENO.ReliaSoft.com
5. ReliaSoft Corporation (2013) Weibull++ Version 9 [Computer Software] http://Weibull.ReliaSoft.com

Are Your Measurements "Stacking Up"?

James Rodenkirch

Abstract

History and Federal law provide solid footing for exploring the process for measuring. One of our functions as systems architects and engineers is to influence the decision process. In that context, one approach to influencing decisions is via the delivery of analytical reports or presentations, backed up by relevant, quality measurements for the system, organization or project/program of interest. An understanding of the terminology and one example of a process to measure helps ensure one is on the right path to influencing, in a positive direction.

History and Federal Law

Measurements and the importance of reporting their outcome accurately have been promoted since the days of Machiavelli. A phrase, coined from the writings of Machiavelli and heard often as a heuristic, is, "If one cannot measure something, it has little value." From Thoughts of a Statesman, Chapter XI, "Notable Precepts and Maxims," "One of the most important things in this world is to know one's self and to properly measure the forces of one's mind and one's condition." And, from Miscellaneous Writings: Discourse on the Affairs of Germany and on the Emperor, with respect to choosing between war and negotiation, "To perform your duty well you have to say what the prevailing option is respecting the one and the other. War has to be measured by the number and quality of troops, by the amount of money, of conduct and fortune; and it is to be presumed that the party with the most of these advantages is to be victorious. After having thus considered who is likely to be successful, it is necessary to make it well understood so that the republic and yourselves may better decide on the courses to be adopted…"[1]

From a DoD Acquisition perspective, measurements are important. The Clinger Cohen Act requires the use of performance and results-based management in planning and acquiring investments in information technology, including national security systems (IT, including NSS). Additionally, DoD Instruction 5000.2 states: For a weapon system with embedded information technology and for command control systems that are not themselves IT systems, it shall be presumed that the acquisition has outcome based performance measures linked to strategic goals if the acquisition has a Joint Capabilities Integration and Development System document (Initial Capabilities Document, Capability Development Document or Capability Production Document) that has been approved by the JROC or JROC designee. (DoDI 5000.02, Jan. 23, 2007)

Metrics, MoEs and MoPs

Measures or measurements fall, usually, under a much broader heading: metrics. Metrics is a broad brushstroke expression that can cover a lot of ground so let's understand the terminology before we go further. What's a metric? According to Webster's Ninth New Collegiate Dictionary: [2]

A part of prosody that deals with metrical structure; a standard of measurement; a mathematical function that associates with each pair of elements of a set of real nonnegative numbers constituting their distance and satisfying the conditions that the number is zero only if the two elements are identical, the number is the same regardless of the order in which the two elements are taken, and the number associated with one pair of elements plus that associated with one member of the pair and a third element is equal to or greater than the number associated with the other member of the pair and the third element.

The above, in its entirety, is tough to decipher so let's take "a standard of measurement" and work with

that some. From Webster we find this about a standard: A gauge, a yardstick, a means of determining what a thing should be; standard applies to any definite rule, principle, or measure established by authority.

A "measure established by authority" should work for us all and there are three measurement "terms" that we can utilize in our efforts to influence the decision process—Measures of Merit (MoM), Measures of Effectiveness or Efficiency (MoEs) and Measures of Performance (MoP).An MoM can be likened to establishing a value to one of the measures; e.g., how well does/did the MoE(s) or MoP(s) work to influence the decision?

For MoEs we can turn to people like Michael Van Bruaene who offer a basic primer on Measures of Effectiveness and Efficiency. [3]

For effectiveness, this measure should be viewed in terms of the extent to what the service or system provided or how the organization meets the objectives and/or expectations. Examples include:

- Coverage: The number of customers you serve or the area of coverage for a cell site system.
- Accomplishment: Measures the overall outcome or achievement of a program or system.

For efficiency, this measure should be viewed in terms of how an organization, system or System of Systems uses its resources or how well it does something. Efficiency measures include:

- Per unit costs: A measure of per unit cost reveals how many resources are consumed in producing a unit of service.
- Cycle time: Measures the amount of time it takes for a process to be completed.
- Response time: Measures the amount of time it takes to respond to a request for service or how long it takes a system function to be completed; e.g., "waiting or queue-time."

- The Rate of something: i.e., measuring rise over run—sortie rate, loss exchange rate, repair rate.

Finally, Measures of Effectiveness (MoEs) represent the customer view, usually annotated qualitatively, and describe the expectations of a product, project or system; i.e., the voice of the customer.

A measure of Performance (MoP) is, simply, how well a system, unit or business entity performs a specific task or completes a function. Examples include: speed, payload, range, time-on-station, operating frequency, time to process a system function or other distinctly quantifiable system or unit performance feature. Most notably, more than one MoP is required to quantify a particular MoE; MoEs are identified as a rate, e.g., rise over run so two measurements are necessary. In an aside note context, MoEs—effectiveness or efficiency—can mean different things to different people, i.e.,the demarcation line between MoEs—effectiveness and efficiency—can be a bit fuzzy…however, the fundamental premise—use MoPs to 'measure' or quantify your expected/desired MoE(s)—remains intact.

Measures of Performance (MoPs) are the corresponding engineering view. They, typically, are quantitative and consist of a range of values about a desired point. Both can be constructed and depicted in a hierarchical diagram; each horizontal "grouping" represents/totals 100% of that effectiveness or performance. See Figure 1.

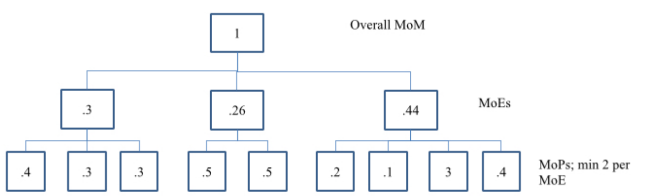

FIGURE 1. HIERARCHICAL COMPOSITION OF MOES AND MOPS.

A model of a hierarchical measurement diagram for a new stylish coffee cup can be seen in Figure 2.

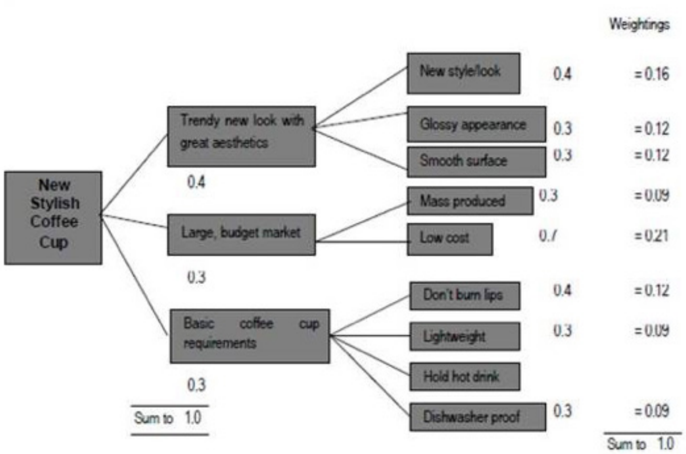

FIGURE 2. HIERARCHICAL DEPICTION OF MOES AND MOPS.

Deciding What and How to Measure

If you want a collection of useful and useable efficiency/effectiveness and performance measures that lead to a demonstrated improvement of performance, then certain things must occur. You must:

- Decide on what you should measure:
  - the measurement(s) must be valid and oriented to your mission, the complex system's capability and accompanying scenarios or the specific system functions you are measuring to support higher level MoEs.
  - the measurement(s) must be realistic, simple, discriminatory and reliable.
- Decide how you will measure it.
- Identify and collect the data for those measures.
- Make the data available to those people and systems who will analyze it.
- Summarize and analyze the data - turn it into performance information.
- Communicate that information to the people who will use it to make their decisions.
- Interpret that information so implications for the business or system analysis are understood.
- Most importantly, present and use that information correctly so correct actions can be selected.

The Process

At a balanced scorecard organization website, I found oodles of information on measuring including the seven phases of the performance measurement process that influence one's assessment of the value that performance measurements can bring to your system analysis or organization improvement efforts. [4] The phases are complementary and supportive; i.e., they work together in an ongoing cycle of measuring, monitoring and applying performance measures.

Phase 1: Choosing and Defining What's Worth Measuring or your System or Organization

Decide what specific results should be measured. Usually these things are decided through the strategic and operational planning processes and end up being written as critical success factors, objectives, goals or priorities. The language will depend on your program/project or organization.

Design measures that give the best evidence of those results. Brainstorming, just seeing what you can do with the data you already have, measuring what you've always measured, benchmarking to find what others measure and hiring consultants to tell you what to measure are all approaches you want to avoid, at least until you have really thought through the kind of evidence that will let you know the degree to which your results have been achieved.

Define performance measures to specify the operational details of how to bring them to life. For each measure, before you can bring it to life, you need to formulate how it is calculated, identify the data you need, decide its reporting methods, define its signals and agree how to take action, know who is best to own it.

Phase 2: The Process of Collecting Performance Data is Critical to its Integrity and an be Very Resource-intensive

It's worth giving serious consideration to how you will go about it, so your data can be qualified as "fit for purpose."

Define the data requirements for a collection of performance measures you want to report. Extract from the measures' definitions the specific items of data, where the data is and how to extract it. It's like an action plan for gathering the data that will go into the performance report.

Design, improve and implement data collection systems to optimize data availability and integrity. Not all the data you need for your measures will be available, and even if it is, it might not be accurate or reliable enough. Designing data collection systems is a fairly big task and to do it without great waste and cost, expert knowledge or assistance should be sought.

Phase 3: Where and How You Store Your Data

This directly determines what data you can access, when and how quickly you can access it, how easy or difficult it is to access and how much cross-functional use you can get out of it.

Use a data referencing model to make data management cost effective and enable cross-functional use of data. A data referencing model maps out how individual data items are named and organized in your database systems. Your organization's IT department may already have a data referencing model and, if so, it will help you find and extract the data you need for your measures. If they don't have one, then you'll need to help them out by explaining your measure definitions to them, so they can get more information about how to design database systems that will better serve your information needs.

Extract, integrate and prepare data for analysis. There are some business intelligence systems that can automate the calculation of your measure values for you. However, most database systems are so complex you can't just pull your performance measure values straight from them. You often need to extract the subset of data you need (e.g., by running queries), and organize this subset in a spreadsheet where you can create your measure values yourself. When you are bringing different sources of data together, a challenge can be no obvious way to link your data together (e.g., trying to link employee training records with their years of service without having a unique employee number to match the two sources).

Phase 4: Analysis Turns Raw Data into Information

Make sure it's the most appropriate information by adopting the simplest analysis approach that can produce the information in the form required to answer your driving questions.

Choose analysis techniques that produce performance information that answers driving business questions. You need to be able to clearly articulate the questions you designed your measures (accomplished in phase 1) to help you answer, because that's the key to choosing the right analysis method. Don't create totals for each department of your organization if your question is about change over time. Instead you'd need totals by week or month so you can examine the time series.

Apply analysis procedures to raw performance data. Working again with your spreadsheet, this means summarizing your raw data into totals or averages or ratios for each time period, such as week or month. It might also mean performing some analysis on this summary data, such as a correlation analysis, trend analysis or statistical process control.

Phase 5: Communicating Performance Information

In communicating performance information, you are influencing which messages the audience focuses on. Take care to present performance measures in ways that provide simple, relevant, trustworthy and visual answers to their driving questions. [Ed: the heuristic KISS comes to mind here]

Design graphs that facilitate interpretation and decision making. Spreadsheet software products, e.g., Microsoft Excel, really don't know what is/are the best thing(s) to do with your performance measures. So its default charts are not something to take for granted. For example, use line charts for trend information, use bar charts for comparisons between things like departments and use Pareto charts to focus on the biggest reasons or causes.

Design and develop performance reports for the owners and audiences of performance measures. Reports shouldn't just contain the measures. They need to contain all the information that the audience needs to understand the context of the measures, how to interpret what the measures are saying, and how to respond to what the measures are saying. There is a bit of science and a bit of art needed here.

Design and implement performance reporting processes. Reporting measures on a regular basis (like weekly or monthly) takes time and effort and designing and mapping the process that does this can make it more controllable, more consistent and able to be improved as you learn how to do it better.

Phase 6: Interpreting Your Performance Measures

This means translating messages highlighted by performance information into conclusions about what's really going on. To turn information into implication, you must discern which messages are real messages (e.g., when a trend is really a trend).

Define guidelines that signal which differences in performance results are real and which are not. Traditional approaches like comparing this month to last month are dangerous. They often lead to over-reacting to trends that just aren't there, or under-reacting to trends that are small but very significant.

Draw conclusions about performance results to decide if action is needed (or not). Program protocols on how to prioritize which performance results need attention and which need to be left alone, are very important to develop. Scarce resources and time quickly passing through the hourglass mean we have to be very deliberate and focused in how we spend our action.

Phase 7: Decisions About What to Improve

When you have worked out what is really going on with your system or organization performance, you are ready to make some decisions about what to improve, how much to improve it by and how to do that improving.

Design decision making processes which make effective use of performance measures. If your decision process doesn't make obvious and effective use of performance information, then it needs some fixing.

Identify the root causes of performance results (getting deeper than the symptoms). Having the skills and approaches and tools for root cause analysis is what will make the difference between reducing the symptoms of a problem that keeps recurring, or fixing the problem for good.

Set performance targets that encourage sustainable improvement. Target setting is much more than just plucking a number from thin air (or any other place). The goals for improvement that you set need to motivate those that will do the improvement, need to be a worthwhile return on the effort and time that will be invested to achieve those goals, and need to be easy to maintain once the goals are reached.

Use performance measures to link improvement cycles back to earlier phases. A feedback loop works. Use measures in decision making processes, to check if investments in improvement action are really working to achieve the results expected for your system or set out in your organization's plans.

A cautionary note: Treat performance measurement as a system and a process! If any of the above phases are missing or not performed effectively you're probably sacrificing one or more of the principles of excellent performance measurement. Additionally, without thinking carefully about which measures to select, you'll risk having measures that aren't relevant to your purpose or don't help you understand the causes of current performance results.

The Final "Measure" of Our Measurement Efforts

Finally, the ONE question we need to keep asking ourselves as we measure, analyze and report: Are our performance reports stacking up? If they are stacking up, i.e., unread and unused, then they're obviously not "stacking up" well, in terms of their value, and one "measure" you don't want to see as a report on your efforts. One way reports can "stack up" is to not identify and separate leading and lagging indicators; there is nothing more frustrating to "the boss," than receiving supposedly quantifying measurements that clearly are indicators that appear at the end of the process—when nothing can now be done to change the outcome. Lagging indicators are measurements taken after it's all over, i.e., exit criteria of the measurement process. While lagging indicators aren't bad (we do need to know what the end result is), leading indicators are measurements that focus on what caused the original lagging or end measure. Leading indicator measurements can help one uncover causes of the "end MoE "and, perhaps, alter or influence the end condition (overall or along the way; e.g., a proactive/leading MoP at step 9 to better assure the outcome instead of just having one MoP at end step 20); leading indicators should appear as part of the entrance criteria for the measurement process. Note the use of the term "indicator"; the use of Key Performance Indicators—within the context of measuring and "influencing"—is, to me, paramount in gaining an understanding of how to use or employ measurements effectively.

One way to ensure your measurement reports are relevant and germane is to look at leading indicators within the context of the MoEs and MoPs domain, e.g., select an MoE, dissect it and then plan MoPs that one can use to predict the final outcome; remember, more than 2 MoPs really helps move the importance of leading indicators along. Look for MoPs that change before the results of the overarching MoE come along or are due to appear as well as MoPs that are easy to acquire, track and document.

Summary

We see where history and best practices are on our side. Machiavelli provided us rationale for measuring, DoDlaws and policy demand the same and there is a process to follow to help us influence decisions andremain relevant to the S.E. process.

—

References

1. On Line Library of Liberty, A collection of scholarly works about individual liberty and free markets, n.d., http://oll.libertyfund.org/titles/775
2. "Metric." Merriam-Webster.com. 2011. http://www.merriam-webster.com (9 May 2014)
3. Van Bruane, Michael, Guidelines for Developing and Using Efficiency and Effectiveness Measures, *Pragmatic Approaches to Move You and Your Organization Forward*, n.d., http://www.advancingyourorganization.com
4. Balanced Scorecard Institute, *Are You Underestimating the Performance Measurement Effort?* , n.d., https://balancedscorecard.org/Resources/Performance-Measures-KPIs/Underestimating-Measurement

Developing Reliability Requirements for Potable Water Solutions in Politically Discontinuous Areas: Part 3 of 3, Hydro-Political

Katherine Pratt

Prelude to Compendium

The last century created major industries based upon petroleum development. This century will likely be known for significant accumulated damages affecting our planet and, ultimately, our social fabric. In addition to nuclear arms races and terrorism, the national security issues in the Middle East for the twenty first century are going to be environmental issues, such as potable water scarcity, along with drivers or the affects of crime, overpopulation, disease, tribalism and mass extinction of multitudes of wildlife. [1] Because of the forgoing factors, a new term, hydro-politics, has been coined to describe the desperate struggle countries will be involved in as they ensure their survival under new climate-driven realities, where water will be a key factor in determining power-sharing strategies and political alliances.

Countries without adequate water resources may well find themselves at a disadvantage vis-à-vis their political spectrum. [2] The term political spectrum connotes a system of classifying different political positions upon one or more geometric axes that symbolize independent political dimensions. Although the descriptive words at polar opposites may vary, the axes are often split between cultural issues and economic issues, scaling from some form of individual to multinational perspective. [3]

Power sharing is a strategy for resolving disputes over who should have the most powerful position in the social hierarchy. Rather than fighting over who should have more power over whom, power sharing relies upon the joint exercise of power. If conflicts can be reframed to focus on how such power sharing might take place, they can become much more constructive. Power sharing takes many forms or approaches. One approach is to grant autonomy to minority groups over some—or all—aspects of their own affaires. This autonomy can be limited to cultural issues—religion and education for example—or it can be extended to cover the social, economic, and political spheres as well. At the extreme, it can take the form of granting complete independence, allowing a minority group to form its own sovereign nation state. Another approach to power sharing is more integrative. Leaders from each group, who work jointly and cooperatively to make decisions and resolve conflicts, also handle governance. This approach relies on ethnically neutral decision-making and public policies. Typically the electoral system will be structured to encourage multi-ethnic coalitions within the political system.

Implementing either approach is difficult; e.g., groups holding power are reluctant to relinquish power, and groups without it tend to want massive change to occur more quickly than the dominant group is likely to accept. For this reason, demands for power sharing and autonomy often ferment conflict more than they resolve it. However, if minority groups can frame their demands in a way that emphasizes joint benefit, and focus on developing a mutually acceptable way of achieving self-determination for all groups, they are likely to meet with more success than if they may take a more combative approach. [4]

Traditionally, an alliance is a formal political, military or economic agreement between two or more nations. Military alliances usually contain promises of support between signatory nations, often in the event of war. The nature of this support is outlined in the alliance document. It can range from financial or logistics backing, such as the supply of materials or weapons, up to military mobilization and a declaration of war. Alliances may also contain economic elements, such as trade agreements, investments or loans but, in most cases, alliances are a strategic tool.

Most alliances and ententes are formulated behind closed doors and later revealed to the public. Some nations even conduct negotiations without informing their other alliance partners. Some alliances also contain 'secret clauses' not revealed to the public nor placed on record. Alliance does not, as is often suggested, make war inevitable. The ultimate authority to mobilize forces or declare war still rests with national leaders. Their moral commitment to these military alliances is the telling factor. [5]

Regardless of the superstructures involved, the simple truth is there are an on-going degradation of water quality, lack of policy integration and a lack of coordination and cooperation between relevant sectors. The increase in demand for fresh water caused by steady population growth, has led to a considerable increase in demand for investment and financial resources. [6]

This paper highlights, after an exhaustive search of the known hydro-political influencers on the countries/states making up the Arabian Peninsula, the findings; the focus is from three perspectives—Multi-national/cultural, Climate Change (as an emergent stressor) and Eco-geographic. Additionally, opportunities for involvement by an RMSL-centric group/organization are introduced.

The Alteration/Management of Water Sources; a Multi-national, Multi-cultural Perspective

The damming and other diversion strategies of major rivers are used for the most part without concern for lower riparian users, including providing treatments for heavy metal and other industrial waste streams, pollution from domestic and agricultural waste streams, such as sodium, fertilizers and other untreated sewage. Neither are there basin-wide agreements on any water, be it a stream, river, floodplain or groundwater that protects biodiversity and other natural systems associated with watercourses, such as marshes and flood plains. A floodplain is a strip of relatively flat and normally dry land alongside a stream, river, or lake that is covered by water during a flood. [7] Damages associated with flooding would undoubtedly be worse if the floodplain and its wetlands are not in place.

Wetland(s) hydrologic and water-quality functions include storage of water, transformation of nutrients, growth of living matter, and diversity of wetland plants that provide unique habitat for wildlife as well as other value for the surrounding ecosystems, and for people. Not all wetlands perform all functions, nor do they perform all functions equally well, as its geographic location may determine its habitat functions and the location of a wetland within a watershed may determine its hydrologic or water-quality functions. Climatic conditions, quantity and the quality of water entering the wetland, or disturbances or alteration within the wetland or surrounding ecosystem are some of the factors pre-determining wetland functionality. Wetland disturbances can be natural, such as draught, or man-made, such as non-native species introduction, or land clearing or dredging. [8]

Traditionally, we have used terms that described geologic areas during great expanses of time. Many times the peoples populating these areas may be driven out or some other catastrophe occurs whereby that area is eventually "re-homed" by new peoples with different cultures. For the few remaining peoples that inhabited the lands earlier, the land is still called by their earlier nomenclature, even though the newer peoples may choose to re-name this area. Frequently the original earlier area is partitioned as populations grow, and there may be dissimilar areas then being described by the earlier nomenclature. As a modern-day example, consider Palestine, and its accepted boundaries that changes depending upon the group of people you ask.

Also, some countries are 'newly formed' as outcomes from war, e.g., Turkey and Israel. Without a way to re-define the legal nomenclature and update the mapped areas to correspond with these political and other types of changes, it becomes difficult to find common ground when attempting to create multi-national and multi-cultural treaties and other environmental resource sharing, and protection documentation.

As countries progress to nuclear and bio-weapons without even having developed the infrastructure or technical knowledge to ensure potable water for their own people and for others downstream from them, how are these new types of waste streams going to be safely managed? These are some of the new realities we must consider to develop effective mediations for resources that cannot be replaced.

Emergent Stressors: Climate Change

Despite the absence of historic large-scale water conflicts, there is growing concern that the prevalence of water conflicts will increase as even more new stressors, such as climate change, emerge or intensify and place even more pressure on already limited water resources. Because, historically, conflict(s) have occurred less often when institutional mechanisms facilitating dialogue and disputes were present, the potential for future conflicts ignited by an emergent stressor may be abated by instilling mechanisms that enhance institutional capacity, such as river basin organizations or treaties.

Cooperation over international waters is, therefore, seen as an important step in building and securing regional peace. Cooperation promises substantial economic benefits, as well, including access to external markets, improved management and coordinated operation of water infrastructure and optimal location of infrastructure, to name a few. Additionally, joint development of a shared river can increase the sustainability of the resource, and help the needs and interests of all countries involved. "Beyond the river benefits" can also be created, such as opportunities for regional cooperation over labor, markets, and infrastructure not directly related to the river; growing literature documents the many benefits of cooperative action. [9]

An Eco-geographic Approach

By using an eco-geographic rather than a nation-state approach, the entire catchment area of water basins, surface and underground, are examined as a single unit. [10] Eco-geographic can be likened to a system of systems approach applied to an environmental problem.

The analytical perspective described in the term eco-logical is a method for achieving an ecosystem approach by forming partnerships between Federal, State, local governments, tribes, landowners, foreign governments, international organizations, and other stakeholders, to work together, and with the public, to integrate their respective plans to determine environmental priority areas.

By designing consensus building, with priorities understood upfront, mitigation options, where impacts are unavoidable, can then be explored. The performance of implemented mitigation can then be measured, providing information useful to future iterations of the integrated planning process, thereby creating an ecosystem approach to developing infrastructure projects.

An ecosystem approach is a method for sustaining or restoring ecological systems and their functions and values. It is goal driven and is based on a collaboratively developed vision of desired future conditions that integrates ecological, economic, and social factors. It is applied within a geographic framework defined primarily by ecological boundaries.

Over the last several decades, an understanding of how infrastructure—the basic facilities needed for the functioning of a community or society—can negatively impact habitat and ecosystems has grown. Awareness of how to better avoid, minimize, and mitigate these impacts has also matured. Regarding the latter, mitigation of project impacts has commonly been focused on replacing similar resources as close to the impact site as feasible. This approach generally focuses on satisfying regulatory requirements, but may not be serving the highest ecological needs in a given area.

Within an ecosystem approach, the context of a particular infrastructure project(s) and the partners implementing it determine the ecosystem's boundaries. For this reason, an ecosystem approach can help move agencies from being confined to project boundaries and regulatory checklists to addressing permitting predictability and habitat conservation on broader, ecosystem scales. An ecosystem approach can allow for more efficient and cost-effective ways to avoid and minimize impacts. It can also help to identify and capitalize on opportunities for meaningful mitigation and conservation—opportunities that may be quickly disappearing or becoming too expensive to realize as areas of ecological importance are developed. [11]

Opportunities for an RMSL Focus/Involvement

Planning and Implementing Water Scarcity Mediation Solutions

Throughout the ages, many of these countries have implemented various strategies attempting to redistribute the scarce water available to them, in order to better use or preserve their dwindling water supplies. Not all of their attempts have been effective long-term strategies for their peoples, and, in many cases, they have not taken into account how their usage has affected the down-stream users. The following RMSL-related support initiatives are provided for consideration as a first step toward improving management for local water source and downstream users.

Defining End-User Requirements

Requirements define precisely what you are going to create or accomplish—what the effort will include, what it will not include, how it will be done, as well as by and for whom.

Requirements often also include ancillary (but relevant) information such as possible risks to the project and criteria by which to measure the project's success. Requirements can be about any existing or future system, product, process or procedure.

The need as well as the solution needs to be defined, plus a strong understanding of existing capability before a system can be defined or a new one built.

Development of Goals and Requirements: Design

This is a process to ensure that high quality systems are designed and developed by also specifying the technical management support and production processes. Task-driven layered hierarchal systems keep the what from the how separate.

Development of Goals and Requirements: Analysis

This is an effective means to assess the different solution sets for the repair policy requirements and to plan for replacement or upgrading products.

There is an increasing pressure to reduce the time to market of new products, while assuring high levels of durability and reliability. To accommodate this accelerated testing of advanced components and systems, there is an increased reliance on test data observation and accurate data interpretation. Therefore, the testing plan and test allocation must be carefully determined to find a reasonable compromise between the accuracy and the cost of the test. [12]

Life Cycle Planning

With Life Cycle Planning, reliability and other requirements are considered that may impact the expected useful product life through a process of goal setting. This analysis considers levels of reliability at each stage, and plans for end-of-life measures such as re-use or disposal. This analysis is significantly impacted by repair policies and product durability.

Analytical Modeling and Simulation

Analytical Modeling and Simulation provides an understanding of the impact of a unit failure on a product by creating a representation or model, usually graphical or mathematical for estimating the expected reliability of a product and validating the selected model through simulation.

Predictions Analysis

Predictions Analysis can indicate the scope of fault tolerance appropriate for challenging requirement levels. It provides an estimation of reliability from the available or proposed design, analysis, test data or data from similar products. It is a means to estimate the realism of potential hardware, and software reliability goals and requirements.

Thermal Analysis

Thermal Analysis determines the relationship between intended design reliability and the thermal use environment to establish reliability requirements such as heat dissipation analysis, transfer paths, and cooling sources to determine if part or product temperatures are consistent with reliability needs.

Translations Analysis

Translations Analysis is an analytical model that will translate the customer operational or performance based requirements into product design reliability goals or requirements.

Benchmarking

Benchmarking can be used to establish a competitive position with respect to reliability by identifying the goals necessary to develop a customer's product by comparing it to a supplier's product and process performance attributes, or with those of the best level achieved by any supplier in a comparable activity. The purpose is to implement changes in the product, services, or processes needed to meet or beat the competition.

Quality Function Deployment (QFD)

There are other techniques that can be used such as Quality Function Deployment (QFD), which translates a user's needs into appropriate design requirements at each stage of design and development. Also, it provides a means of weighting or prioritizing the needs by defining quantitative reliability goals and tasks to effectively satisfy them.

Market Surveys

Market Surveys is another tool to identify customer needs and expectations and as an input to develop supplier product goals.

Environmental Characterization

Environmental Characterization is used to define the operational and environmental stresses that the product will experience when put into use by the customer. Without an understanding of the stresses to be experienced by a product, the statement of reliability objectives, explicitly or implicitly, is meaningless.

New Methods and New Opportunities

Water management, by definition, is conflict management; it is based on reconciling co-existing and competing interests and their associated risks. If a country is unable to find a way to moderate their perceived risks, they may forgo an opportunity for regional cooperation over water issues.

The following are five broad areas for which multiple countries with shared water issues, may experience to some degree and which could potentially affect their negotiations:

Capacity and Knowledge

Confidence in their ability to negotiate a fair deal by having enough of and the correct information and knowledge; e.g., Egypt wanted better understanding of upstream hydrology, and Ethiopia wanted a rapid update of their dated basin studies.

Accountability and Voice

Deliverability of benefits by the regional entity and co-riparians, often related to trust; having a say in decision-making in the governing structures of the regional entity.

Sovereignty and Autonomy

The ability to act in the country's best interest, without constraints; i.e., making decisions independently.

Equity and Access

Realizing a fairness of (relative) benefits to country—the timing of benefits and costs and the ability to obtain/retain fair access to rivers; e.g., Egypt saw equity as continuing with their historic uses of the rivers; whereas Ethiopia was keen to develop Nile waters to address serious food and security challenges.

Stability and Support

Developing the longevity potential of the agreement; ensuring there is support for ensuring completion of the design, build, and life cycle phases; i.e., building in-country support of/for the agreement, including likelihood of ratification.

In order to progress towards cooperation or even sign an agreement, risks need to be addressed. In some cases, with sufficient political opportunity, some countries may be willing to cooperate even with some risks remaining.

Bank and development partners can also have important risk reduction roles. For example, assistance can include engaging with the country at the appropriate scale (e.g. entire basin, sub-basin, country-level); conducting detailed risk assessments; designing risk reductions strategies, including financing and guarantees to target dominate risks, periodically reassessing the risk situation and employing new strategies as needed. [13]

In doing so, substantive contributions to species, watershed, and ecosystem health and recovery can be made that are sometimes missed when regulations are administered on a project-by-project basis and not viewed or treated from a holistic perspective.

Although the approach can have significant and tangible benefits to the environment and the public, and has the potential for improved interagency coordination it cannot eliminate conflict completely. Instead, an ecosystem approach should be viewed as a tool for partners to develop acceptable solutions that complement agency missions. [14] Together, partners can work to implement an ecosystem approach to infrastructure projects. The RMSL communities have unique skillsets that will enable this type of brand new multi-nation, multi-task to be accomplished correctly, on time and within budget.

Some of the other mutual benefits of an ecosystem approach to infrastructure projects include:

Safer, Improved Infrastructure

All agencies and stakeholders contribute to the delivery of infrastructure. The collective abilities and knowledge shared within an ecosystem approach should allow a more balanced understanding of ecological and social concerns.

Improved Watershed and Ecosystem Health

A systematic approach to the preventive, diagnostic, and prognostic aspects of ecosystem management and to the understanding of relationships between ecological issues and human activities.

Increased Connectivity and Conservation

Since an ecosystem approach to infrastructure projects takes a broad view of interacting human and natural systems, it can help agencies plan and design infrastructure in ways that minimize habitat fragmentation and protect larger scale, multi-resource ecosystems.

Efficient Project Development

Uncertainty during project development imposes a high cost on agencies and partners, in both time and money. An ecosystem approach fosters cost-effective environmental solutions that can be incorporated early in the planning and design of infrastructure projects.

Increased Transparency

Infrastructure projects developed with an ecosystem approach provide opportunities for and encourage public and stakeholder involvement at all key stages of planning and development.

New Application for RMS-L

With the ever-increasing inter-connectivity of regional stability with natural resource availability, effective political solutions will need to be broadened to address near-term sustainability requirements balanced against long-term inter regional resource availability.

When creating a strategic plan, and considering technological improvements it is important to consider your external environmental key elements, such as the competition, the technology, your markets: customers, supplier, and labor, the economy and the regulatory environment.

Technology management should be a key responsibility of strategists using effective strategies such as one built on a penetrating analysis of technology opportunities and threats with an assessment of the relative importance of these factors to the overall national strategy. There may also be a possible synergy obtained by tailoring watercourse management systems to align with technology for upriver, down river, and the below ground aquifers.

Declining water quality has become an issue of global concern as it is causing major disturbances for water use, to ecosystems health and functioning, and to the biodiversity that ecosystems underpin. While international chemical and physical water quality guidelines and standards for drinking water and some other uses are well articulated and in place with better enforcement and reporting mechanisms for many governments and authorities, the same cannot be said of frameworks relating to water quality for the health of ecosystems. Around the world a large number of water treaties exist, however, only 4% of all treaties deal with water pollution. Treaties protecting the ecosystem are very scarce. The declining water quality has become an issue of global concern as it is causing major disturbances for water use and ecosystem health.

Modern Basin Planning

Modern basin planning is increasingly developing ecological based objectives, related to species and ecosystems.

Because criteria for toxic substances are in general not site-specific, it may be recommended that these criteria could be derived by working through international resources and putting together available scientific and indigenous knowledge concerning methods, quality measures and available toxicity data to assess the status of global aquatic ecosystems, as well a facilitating the development of sustainable approaches for addressing water-related problems. [15]

There is a new need to provide a common guideline for protection and restoration of freshwater ecosystems that will offer a framework for setting goals and development of quality criteria, analysis of quality stressors, identification of high-value areas, estimation of the category of ecosystem quality, monitoring, setting of future management goals, identification of issues of governance, legal framework, compliance and enforcement and stakeholder participation.

The tools and tests used in the field of RMSL are sufficiently broad-based to appropriately cover this scope of effort for effectively managing the systems of systems type of planning called for in this type of exercise. It will require working cooperatively with other experts in the field, such as the U.S. EPA however the RMSL group is uniquely qualified to tackle this type of challenge.

Compendium

The first and second parts of this three-part article series address hardware and software solutions; part three addresses systems that are least likely to be reliably sustained or maintained. Without education and understanding, the shortsighted development of water infrastructures in the Middle East will continue to adversely affect human populations. Additionally, the potential for a next generation of fish and other ocean life to develop and survive are being compromised. Specifically, the disposal of salts and other materials removed from sea water during desalination are frequently returned to the oceans, killing off the young sea life nearer the shoreline that traditionally mature into the sea life that many countries depend upon for their livelihood and survival.

The full compendium—parts 1 through 3—will be available in June 2015 at the RMS Partnership's website: *www.rmspartnership.org.*

—

References

1. "The Coming Anarchy," by Robert D. Kaplan, The Atlantic Magazine, February 1, 1994
2. Hydro-Politics in the Arab World," by Gitanjali Bakshi, World Press Org, July, 2010
3. http://www.definitions.net/definition/Political%20spectrum
4. http://www.colorado.edu/conflict/peace/treatment/powrshar.htm
5. J. Llewellyn et al, "Alliances as a cause of World War I" at Alpha History, http://alphahistory.com/worldwar1/alliances/,2014, accessed April 13, 2015
6. http://www.escwa.un.org/information/publications/edit/upload/ESWA06E.pdf
7. http://water.usgs.gov/edu/dictionary.html
8. National Water Summary on Wetland Resources USGS Water

Supply paper 2425, "Restoration, Creation, and Recovery of Wetlands: Wetland Functions, Values, and Assessment"

9. Wolf, A. T., K. Stahl, and M.F. Macomber. 2003a. Conflict and cooperation within international river basins: The importance of institutional capacity. Water Resources Update, 125. Universities Council on Water Resources.

10. "Water Disputes in the Jordan Basin region and their Role in the Resolution of the Arab-Israeli Conflict" by Stephan Libiszewski, ENCORP Environment and Conflicts Project Occasional Paper No. 13, Aug. 1995

11. "Eco-Logical: An Ecosystem Approach to Developing Infrastructure Projects," US Department of Transportation, Federal Highway Administration, Environmental Toolkit http://environment.fhwa.dot.gov/ecological/eco_1.asp

12. "Accelerated Durability Testing and Data Analysis for Products with Multiple Failure Mechanisms" by Zhigang Wei, Shengbin (Burt) Lin Limin Luo, Fulun Yang, Dmitri Konson, January 3, 2013

13. Ashok Subramanian, Bridget Brown, and Aaron Wolf, "Reaching Across the Waters –Facing the Risks of Cooperation in International Waters," Water Papers, March 2012

14. http://environment.fhwa.dot.gov/ecological/eco_1.asp

15. "Review of Existing Water Quality Guidelines for Freshwater Ecosystems and Application of Water Quality Guidelines on Basin Level to Protect Ecosystems" UNEP First Intl. Environment Forum for Basin Organizations, Towards Sustainable Freshwater Governance 26-28 Nov 2014, Nairobi, Kenya

About This Issue's Authors

Geetha Chary is a Mechanical Engineer on the Physics of Failure Mechanical Systems Team at the US Army Materiel Systems Analysis Activity (AMSAA), located at the Aberdeen Proving Ground, MD. At AMSAA, she has provided systems engineering analysis support to Army programs for over 8 years and her areas of focus include conducting finite element analyses, utilizing the modeling and simulation tools to identify dominant failure mechanisms, developing methodologies to assist in evaluating program reliability and performing engineering data analyses to improve test efficiencies. She holds a B.S. degree in Mechanical Engineering from M.V.S.R Engineering College affiliated to Osmania University and Master's degree in Mechanical Engineering from University of Maryland Baltimore County.

Michael Pohland leads the Physics of Failure Mechanical Systems team for the US Army Materiel Systems Analysis Activity (AMSAA), located at the Aberdeen Proving Ground, MD. He has more than 15 years of experience in product design, finite-element analysis, failure mechanism modeling, and system / component / materials testing. Prior to working at AMSAA, Mr. Pohland spent several years at Northrop Grumman as a senior mechanical engineer working on a variety of programs ranging from sea to space and as a test engineer at the Naval Surface Warfare Center, Carderock Division. Mr. Pohland holds a B.S. degree in Mechanical Engineering from the University of Maryland at College Park and Master's degree in Mechanical Engineering from The Johns Hopkins University.

John Leavitt is a research scientist at ReliaSoft Corporation where he works to develop and support ideas for reliability engineering software products. His work includes risk based inspection (RBI) software, application programming interface (API) software, probabilistic event and risk analysis software. He earned a M.S. in Management Information Systems and a B.S. in Accounting from the Eller College of Management at the University of Arizona.

Miklós Szidarovszky is a research scientist at ReliaSoft Corporation located in Tucson, AZ. He is currently involved in the development of various reliability software products and the delivery of training seminars. His areas of interest in reliability include risk based inspection, system reliability, and probabilistic event and risk analysis.His non-reliability interests include rheology and filtration based water treatment. Mr. Szidarovszky holds a B.S. and an M.S. in Chemical Engineering from the University of Arizona.

Jim Rodenkirch enjoyed 40 years of Government service (20 years in the U.S. Navy, retiring as a Chief Petty Officer and 20 years in Civil Service as a Systems Engineer for the U.S. Navy). Albeit retired, he enjoys teaching a graduate Systems Architecting course for the Engineering, Management and Information Systems Department at Southern Methodist University in Dallas, Texas and providing support to the RMS Partnership as editor of the semiannual RMSP Journal.

Katherine Pratt holds a B.A of Business Administration in Management Systems from the University of Iowa. She is president of Enviro-Logistics Inc., West River, Maryland and has provided comprehensive services to agencies and corporations in the areas of Access SQL, technical writing and contract administration. She has been a professional logistician and contracts administrator for over 17 years, currently serves as the Coordinator of Environmental Affairs for RMS Partnership Organization and has been a member of the Board of Directors for The Society of Logistics Engineers (SOLE).

The Journal of Reliability, Maintainability, & Supportability *in* Systems Engineering

Editor-in-Chief: *James Rodenkirch*
Managing Editor: *Russell A. Vacante, Ph.D.*
Production Editor: *Phillip Hess*

Office of Publication: *Post Office Box 244, Frederick, MD 21705*
ISSN 1931-681x

Instructions for Potential Authors

The Journal of Reliability, Maintainability and Supportability in Systems Engineering is an electronic publication provided under the auspices of the RMS Partnership, Inc. on a semi-annual basis. It is a refereed journal dedicated to providing an early-on, holistic perspective regarding the role that reliability, maintainability, and supportability (logistics) provide during the total life cycle of equipment and systems. All articles are reviewed by representative experts from industry, academia, and government whose primary interest is applied engineering and technology. The editorial board of the RMS Partnership has exclusive authority to publish or not publish an article submitted by one or more authors. Payment for articles by the RMS Partnership, the editors, or the staff is prohibited. Advertising in the journals is not accepted; however, advertising on the RMS Partnership web site, when appropriate, is acceptable.

All articles and accompanying material submitted to the RMS Partnership for consideration become the property of the RMS Partnership and will not be returned. The RMS Partnership reserves the rights to edit articles for clarity, style, and length. The edited copy is cleared with the author before publication. The technical merit and accuracy of the articles contained in this journal are not attributable to the RMS Partnership and should be evaluated independently by each reader.

Permission to reproduce by photocopy or other means is at the discretion of the RMS Partnership. Requests to copy a particular article are to be addressed to the Managing Editor, Russell Vacante at president@rmspartnership.org.

Publication Guidlines

Articles should be submitted as Microsoft Word files. Articles should be 2,000 to 3,000 words in length. Please use ONE space after periods for ease of formating for the final publication. Article photos and graphics should be submitted as individual files (not embedded into the article or all into the same file) with references provided in the article to their location. Charts and graphics should be submitted as PowerPoint files or in JPEG, TIFF, or GIF format. Photos should be submitted in JPEG, TIFF, or GIF format. All captions should be clearly labeled and all material, photos included, used from other than the original source should be provided with a release statement. All JPEG, TIFF, or GIF files must be sized to print at approximately 3 inches x 5 inches with a minimum resolution of 300 pixels per inch. Please also submit a 100-125 word author biography and a portrait if available. Contact the editor-in-chief, James Rodenkirch at rodenkirch_llc@msn.com for additional guidance.

Please submit proposed articles by November 1 for the Spring/Summer issue of the following year and May 1 for the Fall/Winter issue of the same year.