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Where Are We Now?: Re-examining the IOM/NAE Call for Engineering and Healthcare Integration

Nearly twelve years ago, back in July of 2005, the National Academy of Engineering (NAE) and Institute of Medicine (IOM), released a report[1] that has impacted the healthcare system in the United States and the role that Systems Engineers play. However, the results after nearly a decade have still not fully addressed all the existing challenges. So where did it go right, and what is still left to do?

Building a Better Delivery System: A New Engineering/Healthcare Partnership concluded that the U.S. healthcare industry had neglected engineering strategies and technologies that are wide-spread throughout other industries. These strategies and technologies have had dramatic impacts on quality, reliability, productivity, and safety across a diversity of industries. The call in that report was for the engineering and healthcare communities to work closer to address the challenges of implementation.

Many organizations took on the challenge and began attempting to integrate engineering principles into process improvement, operational efficiency, data analytics, as well as hiring engineers (usually industrial and systems) to work inside the healthcare system. The U.S. Veterans Health Administration established four national centers for engineering expertise and resources to be deployed throughout the entire 150 plus hospital system. Typically, focus was on increasing patient throughput and access to care, increasing the collection of process related data, use of simulation, and bringing Lean and Six Sigma improvement methodologies into the healthcare domain.

In 2014, the President's Council of Advisors on Science and Technology released an updated report[2] on the state of systems engineering, as it was currently being integrated in the healthcare fabric of the US. Some significant progress had been made in some areas, specifically in the increase in the use of data. The key recommendations of that report were:

Recommendation 1: Accelerate the alignment of payment incentives and reported information to provide better outcomes for individuals and populations.

Recommendation 2: Accelerate efforts to develop the Nation's health-data infrastructure.

Recommendation 3: Encourage national leadership in systems engineering by increasing the supply of data available to benchmark performance, understand a community's health, and examine broader regional or national trends.

Recommendation 4: Increase technical assistance (for a defined period 3–5 years) to healthcare professionals and communities in applying systems approaches.

Recommendation 5: Support efforts to engage communities in systematic healthcare improvement.

1 Compton, W. D., Fanjiang, G., Grossman, J. H., Reid, P. P., Institute of Medicine (U.S.), & National Academy of Engineering. (2005). Building a better delivery system: A new engineering/healthcare partnership. Washington, D.C: National Academies Press.

2 President's Council of Advisors on Science and Technology (U.S.), (2014). Report to the President, better healthcare and lower costs: Accelerating improvement through systems engineering.

Russell A. Vacante, Ph.D.

Reliability Significance Increases as Systems Technology Advances

Nearly every aspect of our lives is touched by advanced technology. The airplanes we fly in, train transportation, the communications systems we use, complicated and complex System(s) of Systems (SoS) and yes, even something we might take for granted—the water we drink—command highly efficient and safe, designed-in reliability. So, let us explore reliably advanced technologies in the context of the above mentioned topics while acknowledging that there are a myriad of systems and SoSs that touch or influence our daily lives and require similar high reliability requirements; remember, most systems and SoSs can offer increased safety and reliability if we are willing to pay for it.

The aviation industry has a reliability and safety record that is outstanding; this is especially true of commercial

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Recommendation 6: Establish awards, challenges, and prizes to promote the use of systems methods and tools in healthcare.

Recommendation 7: Build competencies and workforce for redesigning healthcare.

A majority of these recommendations tend to gravitate around the data side of the challenges. Still, there remained significant work to be done on other aspects of systems engineering, specifically in the areas of supply chain management and reliability engineering. That, fortunately, has begun to change for the better in recent years.

Supply chain management, or logistical control, which plays a huge part in the management of healthcare costs and improvement opportunities has begun to see rapid developments as of late. Mega Sub Basements (MSB), basements of hospitals that can span multiple city blocks and multiple floors, completely out of sight of patients and the majority of the hospital staff, with autonomous delivery systems have begun to spread in new hospital construction through the world. Reducing waste and increasing speed of supply delivery. MSB are not efficient or even safe, if transportation is done by human participants. In addition, new federal regulations in both the U.S. and Canada have made improvements in traceability within the supply chain a major driver for upcoming years. The forecast on global healthcare supply change expenditures is expected to reach over $13 billion dollars by 2019[3]. All of which, in order to grow and be implemented successfully will require the adoption of complex supply chain management practices, specifically those from other industrial domains. A lot of opportunity for systems engineers looking to transfer their skills from traditional manufacturing and service industries where the technology is mature and in effect in maintenance mode, to a domain where the opportunities are nearly endless.

This leads to the third leg of the stool in healthcare improvement with which engineering can assist namely, reliability engineering. This is an area that has not gotten much attention in the healthcare domain due to the zero-defect mentality that pervades healthcare. To express the goal of a system to achieving anything less than 100% reliability is looked upon as substandard by the heath care professional communities. This is a significant challenge that will require cultural and education transformation in order to fully integrate reliability engineering practice in to the hospital setting. Reliability and its objectives need to be better understood by healthcare professionals as well as the modification of the definition of reliability to one that incorporates the objective of patient-level certainty by the engineering practitioner will be the key to success. Perception of the reliability of the system ultimately lies in reliability of the processes as viewed by the patient. Patients are fully aware that at times the best that can be achieved is not really full recovery, but a process that is certain as to what the next steps might be regardless of outcome is more appreciated than processes that change without warning or uncertainty as to the future. This is a special case in healthcare that needs to be heeded as reliability engineers begin to spread their integration into the fabric of the healthcare domain.

A long journey has been travelled thus far in the integration of healthcare and engineering practices. It has been a rocky road, to be certain, but in some areas quite successful. The opportunities for the engaged practitioner are still plentiful and available in the cutting-edge of healthcare delivery, a market that is only expected to grow for over the next few decades. ●

3 Healthcare Supply Chain Management Market by Product, Delivery Mode (2015, April 28). The Free Library. (2015). Retrieved May 29, 2016 from http://www.thefreelibrary.com/Healthcare Supply Chain Management Market by Product, Delivery Mode

Ralph Tillinghast

Can STEM Increase Your Company's RMS Bottom Line?

It is difficult to go more than a week without hearing a reference to the term STEM, which stands for Science, Technology, Engineering and Math. This is due to the large educational push to promote these fundamental disciplines in hopes of being able to solve our society's future issues and challenges. This initiative has high level backing as indicated with the estimated $2.95 billion that was spent by the federal government alone in 2015 and another $3.06 billion that is estimated for 2016.[1,2,3] As with most initiatives there are other variations, such as STEAM that adds the elements of the Arts into the mix to give it a more holistic well-rounded application or STREAM that adds both religion and the arts to the intuitive. All of which are attempting to promote awareness and the idea that STEM disciplines are critical to our future.

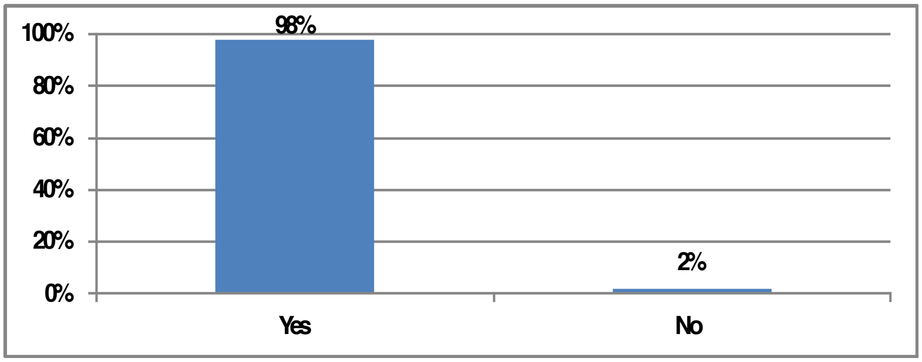
As outlined by Jim Rodenkirch's introduction in the spring 2015 Journal[4], this initiative is a complex area to discuss and to fully understand all of its aspects. Because of this it is difficult for companies to understand the potential benefits of aiding in the STEM movement. How does a company who is focused on paying salaries and insuring stock growth justify community outreach and volunteering? Moreover will providing outreach increase a company's Reliability, Maintainability, and Sustainability (RMS)? The following four discussion areas come to mind when considering these concerns:

1 (2011), "The Federal Science, Technology, Engineering and Mathematics (STEM) Education Portfolio," Federal Inventory of STEM Education Fast-Track Action Committee, National Science and Technology Council.

2 Kuenzi, J. J. (2008). "Science, technology, engineering, and mathematics (stem) education: Background, federal policy, and legislative action," Congressional Research Service, RL33434, www.crs.gov, last viewed May 2016.

3 (2015) "Progress Report on Coordinating Federal Science, Technology, Engineering, and Mathematics (STEM) Education," National Science and Technology Council.

4 Rodenkirch, J. (2015), Introduction, The Journal of RMS in Systems Engineering, RMS Partnership, Spring 2015.



Does Providing Outreach Increase Your Job Satisfaction?[5]

1) **Level of Investment:** The first thought is how much this is going to cost your organization and as always the answer is, it depends. Many corporations donate large sums of funds to schools or other groups to purchase new technologies and infrastructure. For example the Zuckerberg family (Facebook) recently donated $120 million to update technologies in local schools. The other end of the spectrum is donating your employee's time. A few hours a month would enable a Science and Engineering (S&E) professional from your organization to conduct outreach activities, such as meet-an-engineer, classroom workshops or lectures in your local schools. This level of support may vary and result in an investment of only a few hundred dollars each month. This type of outreach is also more personal and allows for direct student contact, which may have a longer overall impact.

2) **Satisfaction and Motivation:** To further expand on the benefit of sending S&E professionals into local schools, we can quickly see how this can also be used to sustain your current work force. A recent survey of approximately 150 S&E professionals who conduct STEM outreach found that 98% of the participants felt an increase in job satisfaction.[5] This has a strong impact on your ability to maintain and sustain your workforce, as a happy motivated employee will most likely perform at a higher level.

3) **Community Awareness:** A fundamental building stone of any company is its ability to market itself. As supporting STEM is considered good practice and a positive activity, it is easy to see how supporting your local schools will result in positive marketing and community awareness. S&E professionals will inspire students who will be reporting back home to their parents and family members. This word-of-mouth[6] method can have just as much marketing impact as large one time donations as mentioned before. Students are not the only ones reached through this method, as awareness is expanded to teachers, administration, school boards, and parents. This keeps your company's stature and branding maintained within the community.

4) **Future Workforce:** The ultimate goal of STEM outreach is to inspire young minds to take on STEM based careers.

5 Tillinghast R. et all (2015), Utilizing Science and Engineering Professionals in the Classroom: How Your Workforce Can Positively Impact STEM and our Company's Bottom Line," IEEE Integrated STEM Education Conference.

6 Sernovitz, A. (2012) "Word of Mouth Marketing: How Smart Companies Get People Talking" ISBN 9781608323661, Greenleaf Book Group Press.

STUDENTS RECEIVING A 3D SCANNER DEMO FROM AN S&E PROFESSIONAL

Based on the statistics that ~25% of college graduates will return back to their home towns[7] it is a good idea to inspire those graduates to join the workforce that you will need to maintain and sustain your organization's success. It is also logical that they will remember your interaction with them and reach out to you when looking for a career.

All of these discussion points illustrate that investing in STEM provides opportunity to increase your organization's maintainability and sustainability. That will directly impact your company's ability to reliably provide your products and services to your customers. A future area to discuss is how one goes about creating a STEM organization and mindset within your corporation's architecture. Related discussions on how one constructs a STEM organization while considering Reliability, Maintainability and Sustainability philosophies should naturally follow. ●

7 Parker, K. (2012) "The Boomerang Generation, Feeling OK about Living with Mom and Dad" PEW Social & Demographic Trends, PEW Research Center.

About the Authors

William "Ike" Eisenhauer *is an adjunct assistant engineer professor at Portland State University. His engineering teaching experience began while a US Naval Nuclear Power Instructor in 1994. His current research interests include: Probabilistic Programming for Adaptive Belief Management, Shared Resource Constrained Data Envelope Analysis, Conflict Under Deceptive Irrationality, and Sustainable Quality Management Program Development. In addition to teaching, Ike is the Executive Director, Office of High Reliability Systems and Consultation for Veterans Health Administration. His work there is focused on the systemic improvement of health care delivery. Prior to joining the VHA, Ike held positions in Credit Risk and Loss Management, Project Management, and Multimedia Development. He lives in Tigard, with his wife of 23 years and his two boys, where he spends his downtime collecting 19th century Japanese stamp forgeries and really bad 70's horror films.*

Ralph Tillinghast *began his career outside the DOD designing and developing medical and industrial endoscopic devices. He currently works for the US Army's Armaments Research Development and Engineering Center (ARDEC) in the Fire Control Systems Branch. He has held various roles as design engineer, lead system engineer, project lead and Army Project Officer. Currently Mr. Tillinghast is the director of the Collaboration Innovation Lab, which he founded. This position is focused on identifying and developing new technologies that can positively impact the Warfighter, while creating collaborative relationships among government and commercial groups to ensure the best possible solutions are developed. Furthermore Mr. Tillinghast continues to be a subject matter expert on digitized fire control providing support and guidance on multiple programs.*

Along with these roles he is a strong advocate for STEM (Science, Technology, Engineering and Math) outreach programs. Mr. Tillinghast visits schools on a monthly basis, giving workshops to introduce students to STEM related materials. He conducts research in methods to optimize STEM outreach.

Mr. Tillinghast has undergraduate degrees in both Electrical and Mechanical Engineering along with a Masters in Manufacturing Engineering from Worcester Polytechnic Institute. He is currently continuing his studies in System Engineering with Stevens Institute of Technology. He is an ARDEC Leadership Level III graduate. Mr. Tillinghast is also an Eagle Scout and hopes you will support your local scout troops (BSA & GSA) as they serve as America's first line in training our future leaders.

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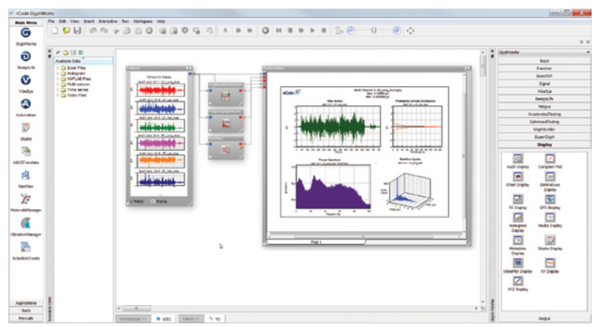

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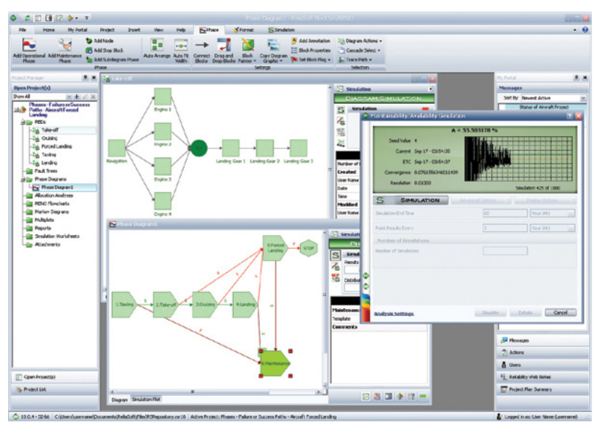

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aviation. The high reliability of its aircraft, in part, is responsible for the rapid growth in passenger travel. Conversely, poor reliability would deter passenger air travel and, probably, lead to bankrupting the industry. This leads us to an awareness—reliable systems translate into corporate profits—thus reliability becomes an inherent, core requirement of aircraft system design.

Given some fundamental best practices in reliability, such as redundancy, are being ignored, small chinks in system safety/reliability may be appearing. While the reliability of pieces of equipment or a system may be high, it does not mean that the overall system of systems is equally reliable. For instance, if a fly-by wire commercial aircraft electronics systems fails, due to mechanical or nefarious reasons, loss of flight control can, and probably, will occur. There is no mechanical link from the pilot to the control surfaces that would permit hands-on control of the airplane. Our confidence that design-engineers and others can design safe/reliable computer technology, in most cases, is warranted. Nevertheless, it would only take a few reliability failures of the fly-by wire computer system to cause a precipitous decline in passenger commercial air travel; i.e., the aviation industry's economic success is solidly dependent on its willingness to invest resources in building highly reliable aircraft.

With respect to railway accidents, all one has to do is conduct a quick internet search to discover the relationship between profit and highly reliable train service. Such a search will uncover railroad workers engaging in track maintenance getting killed by trains, trains crashing into other trains with resultant death and injury, pedestrians at railroad crossings being hit by trains and people being killed and maimed after a train jumps a track at a curve.

Most of us are familiar with the fact that train travel in Europe is a highly preferred mode of transportation. As such, it is efficient, clean, comfortable and most of all—uses technology that is highly reliable. European railways, for instance, have installed Automatic Train Warning Systems (ATWS) to protect people working in red zones, Railway(s) Warning Systems (RWS) to help prevent trains from slamming into cars and a Train Protection and Warning Systems (TPWS) which prevent trains from crashing into other trains. Most recently, the introduction of a Positive Train Control (PTC) system has been undertaken – the system automatically slows trains down when approaching a curve at an unsafe speed.

Most of the systems cited above are integral to the European railroad system—the same cannot be said for U.S. train transportation. Most railway systems in the U.S., with the exception of Amtrak and a few private companies, are managed and owned by industry. Their primary mission is to transport products as opposed to people so it's understandable that safe standards for cargo trains could differ greatly than those of passenger trains. However, this reasoning loses weight when the public knows that U.S. passenger trains travel on tracks, more often than not, owned and maintained by corporations.

As long as more cargo than people travel by railroads in the U.S. there is little financial incentive for improving the reliability of our railway systems. Advanced railroad technologies that parallel the European level of reliability offers little, if any, economic incentive for corporate America. Such an investment would shrink the profitability of their organizations.

Changing environmental factors, congested roadways and airport facilities and a number of other socio-economic factors in the U.S. are leading to a growing interest by people in train travel. The fact that much of Europe and Asia have clean, safe, efficient and relatively inexpensive railroads as a major mode of their transportation systems is also creating public demand for similar systems in the U.S. As government and industry begins to respond to increased public demand for passenger rail service they would be advised to use European railroad reliability standards.

In an age of digital communication, reliable systems demand secure systems and SoS. However, the reliability of our communication systems can be vastly improved. Our mobile phones are subject to dropped call(s) and our computer systems are susceptible to virus and cyber attacks. Consequently, our personal, corporate and defense communication systems are vulnerable. A system cannot be stated as being reliable if it is not free from outside interference and attacks. A car that has brakes that work intermittently or can be controlled and operated by someone other than the driver would be deemed highly unreliable. So why is it that we tolerate this type of situation within our communications systems? In the 21st century, digital communication is the backbone and heart of our commercial and defense industry. It contains vital networks that keep systems of systems communicating with each other, however, it has a fragile heart in its coding that can be violated and manipulated from within and without. News reports recently have highlighted, for instance, the fact that many U.S. government agencies are using computer systems that are at least 30 years old. More unbelievable and shocking is the fact the coding for the U.S. nuclear defense missile system programming is reportedly contained on floppy disks.

Certainly, cuts in the defense budget, during recent years, is a contributing factor in the ongoing use of antiquated systems and systems of systems with questionable safety and reliability records, by the government. Similarly, from a private industry prospect, it is the lack of available funds for computer and software improvements that is partially responsible for the electronic theft of data and funds. Until such time that government and industry decides to invest in advanced technology that has well-established, high reliability numbers, system(s) intrusions, with negative economic and national security consequences, can be expected.

The importance of safe drinking water has recently been making news headlines. For example, in Flint, Michigan lead particles were found, tainting the water supplied to resident homes and poisoning the local population. This water crisis stems from an economic desire and resulting water management choices to reduce the cost of water to city residents; the lead that is present in the drinking water can be traced back to local government agencies not providing funds for the replacement of old, contaminated water pipes.

An automated system that monitors and evaluates water quality as it is discharged from the water plant facility to the point of entry into homes, schools and business is required and technically feasible. In the overall scheme of things, such a water monitoring system, in the long run, will be cost-efficient while safeguarding the health and wellbeing of the U.S. population. There are highly reliable technical tools/equipment that can be employed to help ensure safe drinking water for U.S. citizens. Reliable advanced technology to safeguard U.S. drinking water needs to be a high priority for Congress. Our growing population, challenges related to climate change and potential infrastructure attacks from nefarious outside sources create a sense of urgency for the near-term implementation of a reliable U.S. water supply.

It may be sufficient to say that the rapid turnover in technology, changing environmental conditions, expectations of a growing population, as well as pressing socio-economic and global defense challenges make it increasingly necessary to ensure that systems and SoSs are designed under stringent reliability requirements. The time has come to minimize, or possibly eliminate, the trade-off of reliability requirements in the total lifecycle engineering process for short-term economic gains or changing budget priorities.

The safety and security of systems of systems are an integral to reliability and the required expertise and technology exist—so let's get 'er done! ●