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Maintainability in the Context of Systems Engineering: Some Challenges for the Future

1) BACKGROUND

Maintainability is a characteristic of design which can be expressed in terms of the ease and economy in the performance of system maintenance and support. The objective is to design and develop systems which can be maintained in the least amount of time, at the least cost, and with a minimum expenditure of supporting resources (e.g., people, material, equipment and software, facilities, data, etc.), without adversely affecting the overall performance of the system in question. Maintainability is the *ability* of a system to be maintained, whereas maintenance constitutes those actions taken to restore a system to (or retain a system in) a specified operating condition. As such, maintainability (along with reliability and other related disciplines) is inherent within and a major contributing factor in the overall *availability* of a system.[1]

In the United States, the concept of maintainability, as a design discipline, was first formally recognized by the Department of Defense and the military services around the mid-1950s. The concept evolved from the results of reliability programs conducted in the late 1940s and early 1950s, which indicated that 100 percent reliability of systems was an unobtainable goal. Despite the fact that the reliability programs in being at the time were effective in prolonging the life of systems, it became evident that maintenance requirements could not be eliminated. With the increased size and complexity of defense systems, the maintenance costs for these systems approached one-third of all the operating costs. In addition, it was established that nearly one-third of all personnel were engaged in system maintenance and support functions. Maintainability was conceived to deal with these problems of maintenance and support, with an immediate objective to reduce the costs of sustaining those systems already in operational use.

Maintainability, as envisioned at that time, was intended to deal with "systems" in total, and to address *all* aspects of system support from a total *design* perspective. This included both: 1) design of the prime mission-related elements of a system such that they can be supported effectively and efficiently throughout the system life cycle; and 2) design of the system maintenance and support infrastructure to facilitate this objective. In other words, there were two sides of the spectrum that must be properly integrated in design, from the beginning, in order to meet the overall system objectives; i.e., the "prime" elements of a system and

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Russell A. Vacante, Ph.D.

Not All Reliability and Safety Transportation Deficiencies are Technical

Individuals suffer injuries in all modes of transportation—on airplanes, railways, ships, buses and automobiles. There is a general underlying public assumption that these incidents are “accidents” and mostly cannot be avoided. Evidence suggests, however, that some transportation related injuries and deaths could be prevented with increased transparency and greater government and corporate accountability in the design, management and operation of safer transportation systems.

Some of these “accidents” may

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the various elements of its logistic support.[2]

To this day, the principles and concept(s) of maintainability continue to be important, and incorporation of the proper characteristics (attributes) into the *design-for-maintainability* is critical if the resultant system configurations are to ultimately perform their respective missions in a cost-effective manner. While specific definitions of "maintainability," and the overall spectrum of activity within a given maintainability program, have changed somewhat, the ultimate design-related objectives (as initially intended) basically remain the same. However, in our world today, many of these same objectives may be categorized within a broader spectrum of activity to include the *design for maintainability, design for supportability, design for operability (or human factors), design for system availability*, and so on. Further, many of these same requirements have been nicely combined and integrated within the overall requirements of systems engineering, and implementation of the system engineering process. This, of course, is not intended to diminish the importance of "maintainability in system design," but to place greater overall emphasis through the implementation of multiple approaches.[1]

2. THE CURRENT ENVIRONMENT

Having a good understanding of the overall *environment* in which we operate and sustain is certainly a pre-requisite to the successful implementation of maintainability principles and concepts. Although perceptions will differ, depending on what various individuals observe, there are a few trends that appear to be significant relative to the requirements for designing new systems and/or the modification and upgrade of those systems already in operational use. For instance, such trends include:

1) **Constantly changing requirements:** the requirements for new systems are frequently changing because of the dynamic conditions worldwide, changes in mission thrusts and priorities, and the continuous introduction of new technologies.
2) **Greater emphasis on "systems":** there is a great degree of emphasis on total *systems* versus the *components* of systems. One must look at the system in "total," and throughout its entire life cycle, to ensure that the functions that need to be performed are being accomplished in an effective and efficient manner. Further, we are dealing more with systems within the context of some overall higher-level hierarchy, or the concept of *system-of-systems (SOS)*.
3) **Increasing system complexities:** it appears that the structures of many systems are becoming more complex with the introduction of evolving new technologies. Further, the interaction effects between different systems, within a "SOS" configuration, often lead to added complexity.
4) **Extended "system" life cycles with shorter "technology" life cycles:** the life cycles of many systems in use today are being extended for one reason or another while, at the same time, the life cycles of various technologies are often much shorter. It will be necessary to design systems with an *open-architecture* approach in mind so that the incorporation of new technologies can be accomplished easily and efficiently without destroying the overall architectural configuration of the system in the process.
5) **Greater utilization of commercial off-the-shelf (COTS) products:** with current goals pertaining to lower initial costs and shorter and more efficient procurement and acquisition cycles, there has been a greater degree of emphasis on the utilization of best commercial practices, processes, and COTS equipment and software.
6) **Increased globalization and international competition:** the "world is becoming smaller" (as they say), and there is more trading and dependency on different countries (and manufacturers) throughout the world

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than ever before.

In addressing these and related trends, the overall requirements for *maintainability* still exist and are critical in design; that is, to reduce maintenance frequencies, downtimes, the consumption of supporting resources, and life-cycle cost for the system(s) overall. On the other hand, the emphasis has shifted more to the system and major subsystem level of design, versus the design of smaller modules and components. Design goals pertaining to accessibility, functional packaging and interchangeability, modularization, condition monitoring and diagnostics, etc., continue to be important and, when combined with reliability and other design requirements, are critical in meeting the overall *availability* goals for the system.

3. INCREASING EMPHASIS ON SYSTEMS ENGINEERING

In response to some of these trends, there has been an increased degree of emphasis during the past several decades on systems engineering. Systems engineering may be described as: "an engineering discipline whose responsibility is to create and execute an interdisciplinary process to ensure that the customer's needs (i.e., a system) are satisfied in a high-quality, trustworthy, and cost and schedule efficient manner throughout a system's entire life cycle. This process is usually comprised of the following seven tasks: state the problem, investigate alternatives, "model" the system, integrate, launch the system, assess performance, and re-evaluate."[3]

While there are a variety of accepted definitions of "systems engineering," the basic thrust includes thinking in terms of total systems as an "entity," addressing systems from a total "life-cycle" perspective, and applying a total "integrated" top-down/bottom-up (versus just bottom-up only) approach to system design and development (Reference 1, Chapter 1). Of critical importance is an on-going iterative process which includes: 1) the initial establishment of system *requirements* (system needs and feasibility analysis, system operational requirements, development of the initial maintenance and support concept); 2) functional analysis and the allocation of these requirements downward to the subsystem level and below as required; 3) synthesis, analysis, and design optimization (accomplishment of design trade-off studies); system test and evaluation; and requirements validation. Inherent within this process is the integration of various design requirements (and associated programs) to include reliability, maintainability, human factors, safety, security, producibility, supportability, sustainability, disposability, quality, value/cost, and other related factors into the ultimate system design configuration.

4. MAINTAINABILITY: A MAJOR REQUIREMENT IN SYSTEMS ENGINEERING

Maintainability requirements, in the form of specific quantitative and qualitative "design-to" criteria (an *input* to the design process), must be included from the beginning during the conceptual design phase as system-level requirements are being initially defined. Such requirements may be specified in terms of (Reference 1, Chapter 13):

1) Maintenance frequency factors; e.g., *mean time between maintenance* (MTBM);
2) Maintenance time factors; e.g., *maintenance downtime* (MDT), *mean corrective maintenance time* (Mct-bar), *mean preventive maintenance time* (Mpt-bar);
3) Maintenance labor-hour factors; e.g., *maintenance labor hours per operating hour* (MLH/OH);
4) Maintenance cost factors; e.g., *cost per maintenance action* (Money/MA); and/or:
5) Various combinations of these, or some equivalent factors.

Maintainability requirements must, of course, be "tailored" to the system in question and must be mission-related; i.e., must make sense in terms of the mission or the functions that the system is to perform. Maintainability requirements must be integrated with the other system requirements (e.g., applicable reliability factors such as MTBF, failure rate, etc.); allocated to the subsystem level and below as appropriate; design analysis and trade-off studies are conducted; a maintenance task analysis (based on the system-level functional analysis) is accomplished; maintainability test and demonstration requirements are initiated; and the system maintainability requirements, as initially specified, are validated as part of the overall system validation effort.

In essence, the implementation of maintainability program requirements is accomplished as an integral part of the system engineering process. The appropriate analytical techniques, models, and tools are utilized as necessary to facilitate the system design process. This includes the accomplishment of maintainability prediction, failure-mode-effects-and-criticality analysis (FMECA), level-of-repair analysis (LORA), maintenance task analysis (MTA), life-cycle cost analysis (LCCA), and related analyses, as necessary. All of this must, of course, be planned and integrated in a timely and effective manner. As design changes are introduced throughout the system life cycle, the applicable maintainability requirements must be re-initiated to the extent and depth needed.

5. SOME CHALLENGES FOR THE FUTURE

One of the most significant requirements for an individual (or organization) responsible for the implementation of a maintainability program, and actual *realization* of the desired maintainability characteristics in system design, constitutes an "active" involvement in the system design process on a *pro-active* basis. While it is not uncommon to accomplish many of the individual required tasks such as maintainability prediction, maintenance task analysis, etc., these tasks have often been accomplished "after-the-fact" and have had little (if any) impact on the actual design process itself. Given the current trends, and the quick-reaction requirements in making design decisions, there are some additional challenges ahead if one is to be an effective participant in the design process. For example:

1) A familiarization with the overall environment in which the system is to be utilized is required; e.g., geographical location, country (or countries) where operational, language and culture for operation and maintenance support, etc. The design requirements for a given system may vary depending on where the system is to be operated and maintained (supported), and for its entire life cycle.
2) An in-depth knowledge of the system and its "technical" requirements, the technologies being utilized and incorporated, the functional interfaces both within a given system configuration and external between other systems in a "SOS" hierarchy, and the design process is essential.
3) An in-depth familiarization with the available design aids, tools, computerized models, and techniques that are utilized to facilitate the overall design process is necessary; e.g., computer-aided design (CAD), computer-aided manufacturing (CAM), computer-aided support (CAS), rapid-prototyping models for software development, or equivalent. Knowledge of model applications, the information acquired and conveyed, input-output requirements, etc., is desirable if one is to comprehend the processes being simulated.
4) A rapid and more comprehensive approach in the implementation of maintainability analysis tasks is necessary if one is to adequately respond to current design requirements and the shorter procurement and acquisition cycles in a timely manner; e.g., shorter turn-around times in the accomplishment of FMECA, LORA, MTA, LCCA, and related analyses.

While much of this is not new in terms of the desired results in the implementation of maintainability engineering requirements, the big question remains: are we truly having a significant impact on the overall system design process in continuing to function as we have in the past? ●

References

1) Blanchard, B.S. and W.J. Fabrycky, *Systems Engineering And Analysis*, 5th Ed., Pearson Prentice Hall, Upper Saddle River, NJ, 2011.
2) Blanchard, B.S., *Logistics Engineering And Management*, 6th Ed., Pearson Prentice Hall, Upper Saddle River, NJ, 2004.
3) Inaugural Issue, *Systems Engineering: Journal of the International Council on Systems Engineering (INCOSE)*, Vol. 1, No.1, July/September 1994. INCOSE constitutes an international technical society, established in 1990, with the objective of promoting and enhancing the discipline of systems engineering worldwide.

About the Author

Benjamin S. Blanchard *is a Professor of Engineering-Emeritus at Virginia Polytechnic Institute & State University and a consultant in such fields as systems engineering, reliability and maintainability, maintenance, logistics, and* *life-cycle costing. Before officially retiring, he served as Assistant Dean of Engineering for Public Service, College of Engineering (until June 1996), and as Chairman of the Systems Engineering Graduate Program, Virginia Tech (1979-1997). Earlier, he was employed in industry for 17 years where he served in the capacity of design engineer, field service engineer, staff engineer, and engineering manager (Boeing Airplane Co., Sanders Associates, Bendix Corp., and General Dynamics Corp.). In conjunction, he also served as an Adjunct Professor for several years at the Rochester Institute of Technology (1966-1969). Prior to his industry career, he was an electronics maintenance officer in the U.S. Air Force (during the Korean War timeframe). Professor Blanchard's academic background includes a BS degree in Civil Engineering, graduate course work in Electrical Engineering, and a MBA degree (through an Executive Development Program at the University of Rochester). He has authored four textbooks, and has co-authored four additional texts. He has published numerous monographs and journal articles and has lectured extensively throughout Africa, Asia, Australia, Europe, and North America. Professor Blanchard is a Charter member, Fellow, CPL, member of the Board of Advisors (BOA), and past-president of the International Society of Logistics (SOLE); a Fellow of the International Council on Systems Engineering (INCOSE); and a member of some other professional organizations (ASEE, IIE, AFA, NDIA, and CLEP).*

Dr. Jezdimir Knezevic

Impact of Cosmic Phenomena on In-service Reliability

ABSTRACT

The main objective of this paper is to argue that the scientific approach to functionability* is the only way forward for the engineering community if accurate predictions regarding occurrences of negative functionability events are to be made, which are to be confirmed during the operational processes of the future man made, managed and maintained systems. Hence, science based understanding of the mechanisms that cause occurrences of functionability events generated by the surrounding natural environment are required. Then and only then, accurate and meaningful functionability predictions become possible, which will ultimately lead to the reduction of the probability of the occurrence of failure events during the life of man made, managed and maintained systems. This paper focuses on the scientific understandings of the relevant cosmic phenomena on the in-service reliability of systems, as conducted within Mirce Mechanics principles.

1. INTRODUCTION

The blackout on 13 March 1989 in Quebec was caused by the magnetic storm. Mainly, they cause transformer saturation, which reduces or distorts voltage. Power supply systems with long lines and static compensators are particularly sensitive to such natural phenomena. Quebec utility's experts noted a correlation between the exceptional intensity of the magnetic storm and the tripping of several static compensators, at Chibougamau and La Verendrye substations. Immediately after this event took place records show voltage oscillations and power-swings increase until the lines from James Bay failed. Within seconds, the whole grid lost functionability. This negative functionability event was caused by the strongest magnetic storm ever recorded at this location. The storm, which resulted from a solar flare, tripped five lines from James Bay and caused a generation loss of 9,450 MW. With a load of some 21,350 MW at that moment, the system was unable to withstand this sudden loss and failed to function within seconds. The system-wide blackout resulted in a loss of some 19,400 MW in Quebec and 1,325 MW of exports. An additional load of 625 MW was also being exported from generating stations isolated from the Hydro-Quebec system.

The main objective of this paper is to argue that the scientific approach to reliability and safety is the only way forward for all members of the reliability community who wish to make accurate predictions regarding

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* Functionability, n. ability to deliver at least one measurable function, Reliability, Maintainability and Supportability – A probabilistic Approach, Text and Software package, pp. 291, Knezevic, J., McGraw Hill, London 1993. ISBN 0-07-707691-5

occurrences of failures that will be confirmed during the operational processes of the future systems. For that to happen a scientific understanding of failure phenomena is required. This paper advocates that research of this nature must include the understanding of the cosmic phenomena, in order for the occurrence of functionability events to be understood.[1] Then and only then, can accurate and meaningful reliability and safety predictions become possible, enabling the ultimate goal of reducing the probability of failure event occurrences during the life of man made, managed and maintained systems.

2. SCIENTIFIC PRINCIPLES OF MIRCE MECHANICS

Mirce Mechanics is a new scientific theory, developed at the MIRCE Akademy, that aims to scientifically understand the physical causes and human actions that shape the motion of functionability through the lives of man made, managed and maintained systems.[2] For years, research studies, international conferences, summer schools and other events have been organised in order to understand just a physical scale at which failure phenomena should be studied and understood. In order to understand the motion of functionability events it is necessary to understand the physical mechanisms that cause their occurrences. That represented a real challenge, as the answers to the question "what are physical and chemical processes that lead to the occurrence of given functionability events" have to be provided. Without accurate answers to those questions the prediction of their future occurrences is not possible, and without ability to predict the future, the use of the word science becomes inappropriate.

After a numerous discussions, studies and trials, it has been concluded that any serious studies in this direction, from Mirce Mechanics point of view, have to be based between the following two boundaries:

- the "bottom end" of the physical world, which is at the level of the atoms and molecules that exists in the region of 10^{-10} of a metre,[3]
- the "top end" of the physical world, which is at the level of the solar system that stretches in the physical scale around 10^{+10} of a metre.[4]

This range is the minimum sufficient "physical scale" which enables scientific understanding of relationships between system life processes and system functionability events.

One of the interacting factors from the physical world that directly impacts the functionability trajectory of man made systems are cosmic phenomena, as illustrated by the example given above. This paper therefore considers the major causes of cosmic phenomena from the physical world that can influence system functionability from a reliability and safety point of view.

To illustrate scientific principles of Mirce Mechanics this paper briefly examines the nature of the cosmic phenomena to understand the mechanisms of their occurrences as well as their possible impacts on systems reliability and safety.

3. ATMOSPHERIC RADIATION

In the natural environment there are two fundamental radiation particles that can cause transient errors in electronic devices, which can be classified into the following three groups:

- High-energy cosmic ray neutrons.
- Thermal or low energy cosmic ray neutrons.
- Low energy alpha particles emitted from within the semiconductor device and packaging materials.

Each of these particle categories is different in terms of flux, energy level, charge or composition, but in essence a single particle of any of the above forms could result in a soft error if it deposits sufficient charge within the susceptible volume of a device.

4. COSMIC RAYS

Cosmic rays are individual energetic particles that originate from a variety of energetic sources ranging from our Sun to supernovas and other phenomena in distant galaxies all the way out to the edge of the visible universe. The majority of energetic particles however come from our galaxy with only the most energetic particles believed to have originated from extra-galactic sources. Although the term cosmic ray is commonly used, this term is misleading because no cohesive ray or beam actually exists. Cosmic rays are in fact independent energetic particles that travel at approximately 87% of the speed of light.

Victor Hess first discovered cosmic rays in 1912, when he discovered the fourfold increase in ionisation rates as he ascended to altitude in a balloon. From this experiment he concluded that "the results of my

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observation are best explained by the assumption that a radiation of very great penetrating power enters our atmosphere from above.” In 1936 he was awarded the Nobel Prize in Physics for this discovery, although the term ‘cosmic rays’ is actually credited to a fellow scientist, R.A Millikan in 1925.

The majority of cosmic rays consist of the nuclei of atoms (atoms stripped of their outer electrons) ranging from the lightest elements in the periodic table to the heaviest. In terms of composition about 90% of the nuclei are hydrogen, therefore just single protons, 9% are helium, alpha particles with the remaining 1% a mix of heavier element nuclei, high energy electrons, positrons and other sub-atomic particles.

Cosmic rays must not be confused with gamma rays (high energy photons) that constitute the most energetic form of electromagnetic radiation. However there is a component of cosmic rays, < 0.1% which consists of gamma ray photons produced after high energy particle collisions with matter.

Within the atmosphere the three most important parameters used to define the variability of the particle flux at a specific location are altitude, latitude and energy. Within the field of cosmic ray physics altitude is expressed in terms of atmospheric depth, which is the mass thickness per unit of area in the Earth’s atmosphere. At sea level this is approximately 1033 g/cm^2 of oxygen and nitrogen and reduces as the altitude increases. Atmospheric depth is the key determining factor in the particle flux for a specific point in the atmosphere. For example at an altitude of 3000m the flux of neutrons within the atmospheric cascade is around 10 times greater than at sea level.

Energy is usually shown as the flux per unit of energy called the differential flux, and geographic latitude is expressed in terms of the geomagnetic field strength expressed in units of GeV and also referred to as a locations geomagnetic rigidity or cut-off.

Cosmic rays can be broadly divided into two main categories, primary cosmic rays and secondary cosmic rays. Primary cosmic rays are particles accelerated at astrophysical sources and generally do not penetrate the Earth's atmosphere. Primary cosmic rays are composed from a mixture of different energetic particles that can be categorised based on origin and energy level into the groups listed below in order of descending particle energy:

1) Extra galactic cosmic rays,
2) Galactic cosmic rays,
3) Solar cosmic rays,
4) Anomalous cosmic rays.

Secondary cosmic rays are created when primary cosmic rays collide with particles and break into lighter nuclei in a process known as cosmic ray spallation. Cosmic ray spallation is a naturally occurring form of nuclear fission and nucleosynthesis. Spallation can also occur with the dust and gas that inhabits the interstellar medium. However the resultant products from these interactions are not relevant to the avionics radiation environment.

As cosmic ray particles are charged, magnetic fields in space will bend their motion paths. Due to the impact of magnetic fields, cosmic ray particles are incident on the Earth from all directions and as a consequence it is impossible to retrace their trajectories to determine their point of origin. However, the trajectory of a gamma ray photon is a straight line, due to their neutral charge. This makes it possible to retrace the trajectories of gamma rays to discover their source.

4.1 Extra Galactic and Galactic Cosmic Rays

Extra galactic cosmic rays originating from outside our galaxy and galactic cosmic rays from within bombard the top of the Earth’s atmosphere with a low but continuous flux of protons and heavy ions. The majority of energetic particles are accelerated from within our galaxy but external to the solar system. Cosmic ray particles from extra galactic and galactic sources are typically highly energetic and arrive at the Earth with an approximate flux rate of between 2 to 4 $cm^{-2}\ s^{-1}$.

4.2 Solar Cosmic Rays

Solar cosmic rays, also termed Solar Energetic Particles, SEPs or Solar Proton Events SPEs, are produced by highly energetic processes that occur on or close to the Sun’s surface. Unlike galactic cosmic rays that arrive at the Earth with an almost steady constant flux, the occurrence of solar particles is not only irregular but also highly variable in terms of flux rate. Typically most solar protons arriving from the Sun lack the energy level required to penetrate the Earth’s magnetic field.

Solar cosmic rays consist of heavy ions and protons with a less energetic spectrum than galactic cosmic rays. In comparison to the maximum energy possessed by galactic cosmic ray protons of 1021eV, the solar proton peak energy of about 20 GeV is many orders of magnitude smaller.

In the case of very powerful flux ejections, SPEs manifest as Ground Level Enhancements or Events, GLEs, on the Earth's surface and typically last between 20 minutes to a few days dependent on the originating solar mechanism. SPEs can therefore be categorised as either an impulsive event linked to solar flares or gradual events linked to coronal mass ejections, CMEs. The main concern however regarding SPEs are the significant neutron flux enhancements generated at aircraft altitudes particularly at high geographic latitudes where the Earth's level of magnetic shielding is reduced.[5]

During the Sun's eleven year solar cycle the flux of solar particles incident upon the Earth's upper atmosphere can increase by a million fold during a GLE relative to the level at a quiescent period close to or at the solar minimum. In contrast the difference between the flux rates between solar minimum and solar maximum, whilst still significant, are less dramatic than the sporadic peak flux rates caused by the most energetic SPEs., as shown in Table below:

Energy Range	Solar Maximum (Particles : $cm^{-2}s^{-1}$)	Solar Minimum (Particles : cm-2s-1)
Above 30 MeV	3×10^{2}	2×10^{-2}
Above 100 MeV	20	2×10^{-3}

GLEs in general occur 1 to 3 years after a solar maximum and to date since 1942 in total 63 of them have been observed. Over a longer period analysis of nitrate spikes obtained from polar ice cores indicate 154 large SPEs have occurred in the last 450 years. These powerful and evidently rare events are believed to be caused by the most energetic solar flares rather than CMEs.

In terms of energy levels SPEs typically range from 10 MeV to 100 MeV although protons up to 20 GeV travelling at near relativistic speeds can be discharged from the Sun during extremely energetic events. The proton energy level determines the speed and hence the arrival time of incident protons. At 1 MeV, protons arrive in 2.9 hrs but at 1 GeV the arrival time is reduced to just 9.5 minutes.

4.3 Anomalous Cosmic Rays

Anomalous cosmic rays are the final component of primary cosmic rays and possess energy levels significantly lower than any other type of cosmic ray, typically less than ~10 MeV. They are created when electrically neutral atoms enter the heliosheath of the Sun's solar wind, become ionised and are then accelerated by the termination shock. The termination shock region forms the inner edge of the heliosheath where the solar wind becomes subsonic. This region varies between 75 and 100 AU (1 AU is a unit of length approximately equal to the semi-major axis of Earth's orbit around the Sun) from the Earth.

5. CONCLUSION

This paper has demonstrated that if accurate predictions regarding the occurrences of functionability events are to be made, it is mandatory to implement the Mirce Mechanics scientific approach to understanding the competing mechanisms driving negative functionability events, as the consequence of the diverse range of interactions between man made systems and the surrounding natural environment. Then and only then, can the reduction of the probability of the occurrence of failure events during the life of man made, managed and maintained systems could be achieved. This paper focuses on the scientific understandings of the physical mechanisms originated by the cosmic phenomena.

As science is the proved model of reality that is confirmed through observation, the summary message of this paper to reliability professionals is to move from the universe in which the laws of science are suspended to the universe that is based on the laws of science in order for their predictions to become future realities.

6. References

1) Baumann, R., " Radiation-induced soft errors in advanced semiconductor technologies, " IEEE Transactions on Device and Materials Reliability, vol 5, No 3, pp. 305–316, Sept. 2005.
2) Knezevic, J. Physical Scale of Mirce-Mechanics," Lecture Notice, Master Diploma Programme, MIRCE Akademy, Woodbury Park, Exeter, UK, 2009.
3) Knezevic, J/, Atoms and Molecules in Mirce Mechanics Approach to Reliability, SRESA Journal of Life Cycle Reliability and Safety Engineering, Vol 1, Issue 1, pp 15-25, Mumbai, India, 2012. ISSN-22500820
4) Knezevic, J., Functionability in Motion, Proceedings 10th International Conference on Dependability and Quality, DQM Institute, 2010, Belgrade, Serbia.
5) Zaczyk. I, "Analysis of the

Influence of Atmospheric Radiation Induced Single Event Effects on Avionics Failures", Master Dissertation, MIRCE Akademy, Exeter, UK, 2010.

About the Author

Dr. Jezdimir Knezevic *is a world class researcher, educator and entrepreneur. Over 350 publications disseminated world-wide through books, papers, monographs and reports are attributed to his name. In addition, he has delivered numerous technical presentations, key note addresses and speeches; has been congress, conference, symposium chairman, track leader, workshop presenter, round table moderator on many hundreds international events which took part in all six continents in over 40 countries. He has been elected as a Fellow, Member or Official of many leading Professional Societies and Institutions worldwide, and has been actively involved in editorial work with the world's leading and prestigious referred journals and publishing houses. Dr Knezevic has received several international awards for his contribution to research and education in the field of Logistics Engineering including the prestigious Armitage Medal (1993) and Eccles Medal ("In recognition of his outstanding achievements in the development of Logistics Education", 1996) from the Society of Logistics Engineers, SOLE, in USA.*

Encouraged by the excellent response from industry to his research and educational activities, in 1988 Dr Knezevic established a self-financing Centre for Management of Industrial Reliability, Cost and Effectiveness, MIRCE, at Exeter University, UK. Together with his colleagues, he has developed and delivered over 100 vocational courses and 12 international summer schools for practitioners from industry. Under his leadership, the Centre has attracted over 3000 professional engineers and managers and generated an income in excess of 3 million US dollars.

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actually be the result of unnecessary but economically motivated trade-offs made by industry. Since industries' goals are profit driven, board members across the country engage in cost-benefit economic analysis that regularly trades-off more costly and safer transportation designs to realize greater profits. The sad truth is that if it is less expensive to settle or pay damages to family members injured or killed in transportation related accidents, then implement more costly but safer manufacturing and design changes that will prevent injuries and save lives, industry board members are likely to choose the less costly and more profitable option.

Exacerbating the problem is also the fact that elected and government officials, especially those who are short-term political appointees, often also intentionally or subconsciously, engage in similar self-interest trade-off analysis. Congressional representatives who are looking for election funding support or a well paying jobs after leaving office have a financial incentive to relax safety and reliability standards in an effort to appease industry. Political appointees, and possibly other government officials, may fail to rigorously enforce safety and reliability standards knowing that to do so would likely jeopardize a future well paying industry job. This is internally recognized, but seldom publicly acknowledged.

In 2014, approximately 32,675 individuals lost their lives in traffic related accidents[1], 269 in railroad crossing incidents[2], and 761 on commercial aviation flights.[3] It is reasonable to assume that the majority of these accidents did not occur due to factors related to government and industry relaxation of safety and reliability standards. On the other hand, it is nevertheless important to ask the question how many, if any, transportation related deaths could have been avoided if industries' profit motivated trade-offs were not made and proper enforcement of governmental transportation regulations and policies occurred. What followers are a few recent examples where these questions should be further examined.

On May 12, 2015 an Amtrak train derailed near Philadelphia killing eight and seriously injuring 200 passengers. This is an accident that could have been potentially been avoided if the congressionally mandated positive train control (PTC), system, did not encounter "budgetary shortfalls, technical hurtles and bureaucratic rules" that delayed it becoming operational.[4] In 1943, on the very same rail curve 79 people were killed and a 117 passengers were injured.

On February 12, 2009, 45 passengers, 4 crew members, and 1 local resident, a total of 50 individuals,

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

lost their lives when Colgan Air Flight 3407 crashed on its' approach to Buffalo Niagara International Airport. On March 25, 2009, the NTSB reported that the plane's captain failed three check rides and may not have been sufficiently trained to adequately handle emergency situations. According to a June 3, 2009 New York Times article, when an FAA inspector reported concerns, the inspector was demoted and, as a result, corrective action was deferred.

Pilot fatigue may have played a major role in the crash of Colgan Air Flight 3407.[5] For 20 years the NTSB has been asking regulators to make safety improvements pertaining to flight distraction caused by fatigue without success. Reportedly, the airline industry has resisted any schedule changes that would decrease the number and/or duration of pilot flight hours since it would increase the number of pilots on their payroll. This may demonstrate the possible stronghold the airline industry has over elected officials and the agency.

On March 26, 2010, eleven individuals were killed when a tractor-trailer crossed the highway median on Interstate 65 near Munfordville, Kentucky. "In this accident, one fact was clear from the outset: the truck driver was on his cell phone. He had "taken a call just 18 seconds before the crash and didn't hear the horn until impact."[6] A similar distracted driver incident occurred, in Baltimore, Maryland on May 28, 2013, when a tractor-trailer failed to ensure that a road crossing was cleared. The driver was talking on a hands-free device. In this case, five individuals were injured. According to the NTSB, the driver was distracted by the telephone conversation, which resulted in a 15-car train derailment. As part of its' findings, the NTSB recommended a ban on cell phone usage by all commercial drivers.[7] As late as December 18, 2014, the Federal Motor Carrier Safety Administration recommended the use of "an earpiece or the speaker phone function" and the use of "voice-activated or one-button touch features to initiate, answer, or terminate a call."[8]

As a result of a defective ignition switch General Motors recalled approximately 800,000 small vehicles on February 7, 2014. By September 2015, however, the number of vehicles recalled had grown to nearly 2.6 million. The defective ignition switches resulted in 124 deaths. The criminality of GM's conduct is not in doubt; "from in or about the spring of 2012 through in or about February 2014, GM failed to disclose a deadly safety defect to its U.S. regulator... It also falsely represented to consumers that vehicles containing the defect posed no safety concern."[9] Despite GM's knowledge of the ignition switch defect no one from the corporation is facing criminal charges. Instead, GM has will pay $900 million as apart of a settlement agreement with the U.S. Justice Department.[10] Now we roughly know the economic value of 124 lives by both GM and the government.

Increased public understanding and greater transparency into the decision-making processes by industry leaders and governmental officials, for all modes of transportation, will likely lessen injuries and save lives. The total number of lives saved may be statistically low to government number crunchers and industry leaders, however, to the family members of loved ones injured or lost in transportation related accidents, these figures and the related suffering is real. ●

References

1) National Highway Traffic Safety Administration (NHTSA), http://www.nhtsa.gov/NCSA, (visited 9/19/2015).
2) Operation Lifesaver, Rail Safety Education, http://oli.org/about-us/news/collisions-casulties, (visited 9/19/2015).
3) CNN, Casey Tolan, Thom Patterson, & Alicia Johnson, Is 2014 the Deadliest Year for Flights – Not Even Close, available at: http://www.cnn.com/interactive/2014/07/travel/aviation-data/ (visited 9/19/2015).
4) Wikipedia, 2015 Philadelphia Train Derailment, available at: https://en.wikipedia.org/wiki/2015_Philadelphia_train_derailment, (visited 9/19/2015).
5) The Wall Street Journal, Andy Pasztor and Susan Carey, Colgan Air, Pilots at Odds on Safety, available at: http://www.wsj.com/articles/SB10001424052748703762504575037570231180684 (visited 9/19/2015).
6) WBTAL TV 11, Distracted Truck Driver Caused Rosedale Train Crash, available at: http://www.wbaltv.com/news/ntsb-distracted-truck-driver-caused-rosedale-train-crash/29275356, (visited 9/19/2015).
7) HDT Trucking Info., NTSB Recommends Trucker Cellphone Ban in Wake of Kentucky Accident, available at: http://www.truckinginfo.com/news/story/2011/09/ntsb-recommends-trucker-cellphone-ban-in-wake-of-kentucky-accident.aspx, (visited 9/19/2015).
8) Federal Motor Carrier Safety Association (FMCSA), http://www.fmcsa.dot.gov/driver-safety/distracted-driving, (visited 9/19/2015).
9) The Wall Street Journal, Mike Spector & Christopher M. Matthews, GM Admits to Criminal Wrongdoing, Wall Street Journal, (Sept. 18, 2015).
10) Id.

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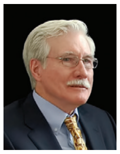
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