The Journal of Reliability, Maintainability, and Supportability in Systems Engineering

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Table of Contents
Winter 2017

Editor’s Note

John Blyler

“Efficiency is doing things right; effectiveness is doing the right things."
—Peter Drucker

Effectiveness is the theme for this issue of the Reliability, Maintainability and Supportability (RMS) journal. We begin with a challenging approach to Measures of Effectiveness (MOEs) that uses black boxes to represent the users or the whole view of the system - penned by three distinguished authors in the field of systems engineering: Jerrell Stracener, Ph.D; John M. Green, and Glenn S. Tolentino, Ph.D.

Current MOE methodologies focus on the selection of a solution through the use of decision-making techniques. This authors explain that this approach does not compute actual effectiveness. The mathematical approach presented in their paper, “starts with an explicit definition of an MOE and uses the concepts of black boxes and desired emergent behavior to develop a probability-based approach to developing the hierarchy of required effectiveness measures as stated by the user.”

In the second article, effectiveness becomes part of a paradox. This oddity emerges when comparing the trend of increasing automotive electronic reliability requirements versus the lack of reliability of electronics as demonstrated by automotive recall data. The authors explain that one of the reasons for the increase in recalls stems from the increase in system complexity that makes it even harder to test for reliability. Also, harsh operating parameters such as temperature, humidity, etc., increasingly impact the reliability of electronic systems in vehicles. Short time to market and ineffective design for reliability methodologies have created a lag in providing components and systems that match the more stringent reliability requirements for vehicles, notes the authors. The proposed solution is a greater effort in understanding reliability in systematic design.

Next, we turn to the world of three-dimensional (3D) integrated circuits for our third story. 3D chips provide the twin benefits of high performance and cost efficiency in manufacturing. However, this new technology comes with new reliability and failure issues. One example is faults—electrical opens and shorts—in through-silicon vias (TSVs) that interconnect the stacked chips. Researchers at imec—a leading European R&D center for nanoelectronics and digital technologies—have now developed a new technique that can rapidly localize these interconnection failures in a non-destructive and cost-effective manner at wafer scale.

The fourth article focuses our attention on the anticipated effects of climate Change in the U.S. The author treats this subject in a tutorial fashion by first describing the operational environment and then considering the influence on the overall reliability and maintainability of that environment.

The last offering in this issue is a book review of a work authored by Lev-Klyatis and published by SAE: "Successful Prediction of Product Performance." This book approaches the prediction of product performance by focusing on safety and reliability issues during the early part of the product life cycle. The author points out that most recent publications in this area concentrate on post-manufacturing economics and injury recall issues (recall previously mentioned automotive article) that result from poor product quality, reliability and durability. The source of these problems is the inefficient or inadequate prediction of product safety, reliability and other "ilities" performance components that should have been determined early in the design and manufacturing process. The author suggests a new approached to improve these predictions.

I hope you find that this issue of the RMS Journal covers the selected topics in an effective and useful manner. Please don't hesitate to share your comments and potential future articles with me via the email below. Cheers!

—John

Measures of Effectiveness through Transfer Characteristics of Black Boxes

Jerrell Stracener, Ph.D.
John M. Green
Glenn S. Tolentino, Ph.D.

Abstract

This paper presents a conceptual methodology for developing Measures of Effectiveness (MOEs) using black boxes to represent the users or whole-system view. It recognizes that system behavior emerges from the synthesis of the system's functions and architecture. It starts with a gestalt view of the system represented as a black box. Black boxes are ideal for this analysis because of their isomorphic properties. As long as input A yields output B, the internal transform mechanism is solution independent. The result is wide latitude in developing solutions; however, the solution must satisfy the system's purpose and required effectiveness as specified by the user. Current methodologies focus on the selection of a solution through the use of decision-making approaches which, by their very nature, do not compute actual effectiveness. The mathematical approach presented in this paper starts with an explicit definition of an MOE and uses the concepts of black boxes and desired emergent behavior to develop a probability-based approach to developing the hierarchy of required effectiveness measures as stated by the user. This approach is applicable at the systems level.

Introduction

The question of what is a Measure of Effectiveness (MOE) and how to determine one is a problem that has perplexed both the communities of Operations Research and Systems Engineering since Morse and Kimball first coined the term during World

War II.[1] The reasons are many. First, there is no generally accepted methodology for developing an MOE. This paper provides a definition based on an extensive literature search. Second, while MOE is a general term, a search of the literature shows inconsistency in the definition. Third, the relevant body of literature appears to have been developed in three phases. Phase one occurred between 1958 and 1968 (approximately) and was led by the Reliability Community. Phase two started in the late 1970's and tapered off in the early 1990's. It was led primarily by the military command and control (C2) community with a focus on C2 models and assessing data fusion. The current phase is denoted by a shift to a decision-making paradigm as identified by Campbell.[2] While usable for concept selection, the major issue in using the decision-making paradigm is that it represents an opinion and thus is not testable. The three phases were disjoint. They represent shifts in thinking that led to Reed and Fenwick's[3] comment about MOE issues in the literature:

> *"Most formulae for calculating MOEs are heuristic and ad hoc and have led to concern in some quarters about the rationality, coherence, and reliability of performance assessment."*

Reed and Fenwick do not identify the culprits but provide a good list of deficiencies. Some of their problems addressed by the approach presented in this paper are:

1. MOEs with different physical units which cannot be easily compared or combined
2. MOE values in the range [0, ∞] are difficult to understand in terms of significance comparisons
3. Lack of a physical meaning
4. Limited to one data type (usually continuous numeric)
5. No provision for uncertainty in the measurements

Reed and Fenwick also raise the issue of Measures of Performance (MOP) and the relationship between MOPs and MOEs. They borrow their definition from the literature as follows:

> *"In the sense used here, MOE expresses the extent to which an MOP satisfies a declared user requirement. As with MOPs, there could be multiple MOEs, and there could be even more to cater to different users as well. An MOE is calculated from an MOP and a related user requirement."*

The implication of this definition is that MOEs are outcomes of MOPs. The premise of this paper is that this concept is inconclusive because it is based on a reductionist point of view. Clymer[4] defines reductionist as follows:

> *"Each process is understood independently of each other. Additionally, process interactions are understood only in reference to the functional transformations that result from the cause and effect between processes."*

The discussion supporting this paper's premise is organized into a discussion of MOEs followed by a discussion of black boxes. These two ideas will be brought together in a concluding section that integrates black boxes with MOEs. Thus, providing an approach which the relationship between the two can be effectively addressing MOE utilization.

Before proceeding, it should be understood that "user" in this paper refers to the acquiring organization such as the U.S. Navy, not a system operator.

1 Morse, Philp M., and George E. Kimball. *Methods of Operations Research.* Los Altos, California: Peninsula Publishing, 1970.

2 Campbell, Philip L. "Measures of Effectiveness: An Annotated Bibliography," Sandia Report SAN D2004-2902, July 2004.

4 Clymer, John, R., *Simulation-Based Engineering of Complex Systems*, Hoboken, NJ, John Wiley & Sons, 2009.

3 Reed, C.M., and A.J. Fenwick. "A Consistent multi-framework for assessing system performance" Internet: http://arxiv.org/abs/1011.2048 [accessed November 22, 2014].

Measures of Effectiveness

Churchman[8] noted that the systems (holistic) approach perceives the problem in terms of desired objectives where objective is defined as the system's goals, ends, and purpose. His view was, that at the systems level, all goals were unified into one measure of system effectiveness. This view can be construed one of two ways. The first way is that the lower level goals are aggregated together to achieve the system level goal which is the reductionist approach. As will be shown shortly, there may be problems with this approach. The second way is to start with the system's goals and allocate performance to system elements which is the approach used in this paper.

User versus Developer Points of View

There are two points of view that come into play. That of the user and that of the developer, such as a defense contractor, tasked with satisfying the user's perception of an effective system. From the discussion in the previous section, it is clear that the user's view is that of the black box and is represented by Churchman's one measure of effectiveness. The developer's view is that of the clear box. The developer is tasked with the "how."

Measures of Effectiveness (MOEs) Defined

A search of the literature of over 200 sources pertaining to MOEs resulted in the following definition of an MOE:[9]

An MOE is a standard against which the performance of a system solution to the user's needs can be judged. As such, it has the following characteristics:

1. It is evaluated at the system level
2. It is mission focused
3. It is solution independent; i.e., what the system should do, not how it should be done
4. The user's view is that of a black box
5. It is quantitative, measurable, and testable
6. It captures the probability that a system can successfully meet an overall operational demand within a given time when operated under specified conditions

Definition of an MOE Hierarchy

Just as systems exist in a hierarchy, so do MOEs. At the systems level, there is a specific level of effectiveness required to satisfy the user. Given that the user views the system as a black box, the developer has any number of potential solutions available to achieve that MOE. By using black boxes, the developer can create a performance budget from the top-level MOE in the same manner that reliability is allocated from the system level to the components. Building a system from components of known reliability does not necessarily result in the desired system reliability. The same is true in the world of MOEs. Creating systems from components of known performance will not necessarily generate the emergent behavior required to achieve the desired performance. Quite often system components are developed outside the mission context. Thus, while their performance may be impressive in isolation they may not improve system effectiveness.

Using the concept of a performance budget as a starting point, Sproles[10] provides a usable definition of an MOP as follows:

> *"An MOE refers to the effectiveness of a solution and is independent of any particular solution; an MOP refers to the actual performance of an entity."*

Where the entities are the selected elements chosen to implement the solution. This concept would also promote elasticity

Measures of Effectiveness through Transfer Characteristics of Black Boxes

8 Churchman, C. West, *The Systems Approach*, New York, Delta Books, 1979.

10 Sproles, Noel. "Establishing Measures of Effectiveness for Command and Control: A Systems Engineering Perspective." Report, DSTO report #DSTO.GD-0278. 2001, Internet: http://dspace.dsto.defence.gov.au/dspace/bitstream/1947/3862/1/DSTO-GD-0278%20PR (accessed January 18, 2017).

9 Green, John M., "A Review of the MOE/MOP Literature," 76th Military Operations Research Society Symposium, New London, CT, 2008.

of the black box by being able to effectively interchange the black box based on changing requirements without the user being negatively affected.

Holism Defined

Checkland[5] defined holism as:

> *"a principle according to which entities meaningfully treated as wholes are built of smaller entities which are themselves wholes… and so on."*

Restated, it is the fundamental principle of a whole made up of interconnected parts that cannot exist independently of the whole. System behavior emerges from functions and how they are organized in the system architecture. To be holistic requires that the MOPs aggregate to the MOE.

In viewing how the relationship is expressed, traditional notation is problematic as noted in the following example. Consider a system composed of n components:

$$S = \{c_1, c_2, [?], c_n\}$$

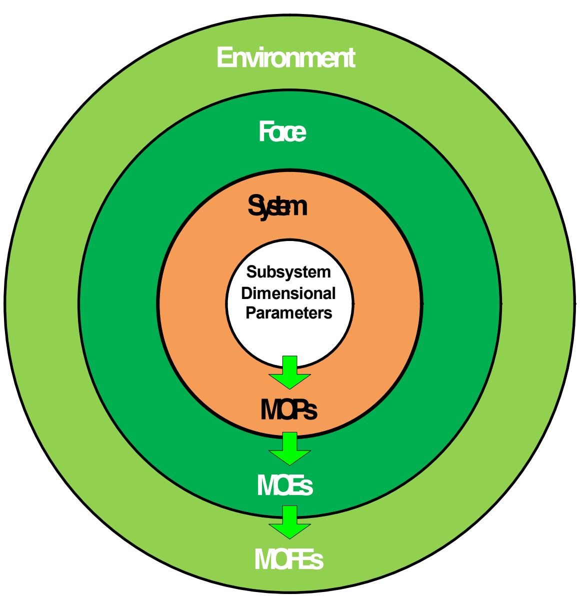


Figure 2 – Measure Relationships (After Sweet, Metersky, and Sovereign[12])

The system has an overarching MOE that is related to the set of system components. The components are described by their MOPs. Figure 2 is a common representation of this relationship. Note that arrow points outward and implies that there is a hierarchical relationship that starts with the dimensional parameters at the lowest level. Note also that dimensional parameters and MOPs are defined within the boundary of the system and that the MOE is defined external to the system. Dimensional parameters are the properties or characteristics that are inherent in the physical entities whose values determine system behaviors and MOPs measure the attributes of system behavior.

Figure 2 represents the Military Operations Research's view that, in general, the system MOE is a function of the set of system MOPs (Sweet, Metersky, and Sovereign[12]):

Sweet, Metersky, and Sovereign[12] define the MOE in the diagram in simple terms as a measure of how well the system performs its functions within an operational environment. They also introduced the term Measure of Force Effectiveness (MOFE) which is defined as **a measure of how a system and the force of which it is a part performs missions.**

This term is not commonly used but has utility in the assessment of systems of systems.

There are three ways to aggregate MOPs: conjunctively, disjunctively, or in a combination of both forms. Following the premise that the user provides the MOE, for this expression to be true, each MOP relationship must, when combined, be equal to the MOE. However, the conjunctive case is of the same form as the series structure function from reliability theory, and from Lusser's Product Law (Kopp[13]) the overall series system product is less than the performance of the lowest component. This result

5 Checkland, Peter, *Systems Thinking, Systems Practice*, Hoboken, NJ, John Wiley & Sons 1999.

12 Sweet, Ricki, Morton Metersky, and Michael Sovereign, "Command and Control Evaluation Workshop, 1986," Internet: http://www.dtic.mil/get-tr-doc/pdf?AD=ADA321474, [accessed January 18, 2017].

13 Kopp, C., "System Reliability and Metrics of Reliability," Peter Harding & Associates, Pty Ltd. p. 7, Available: http://www.ausairpower.net/PDF-A/Reliability-PHA.pdf, 1996, [January 18, 2017].

violates the definition of system holism; therefore, it is an incorrect statement or, in other words the system MOE is not a function of the set of MOPs.

Figure 2 is incorrect as well. Reversing the direction of the arrow in Figure 2 as shown in Figure 3 gives the correct relationship. The set of MOPs are a function of the MOE. Given that the conjunctive case is the limiting case, and assuming that the MOPs are equal and independent, then:

If

$$MOP_i = MOP \text{ for } i = 1, [?], n$$

then:

$$MOE = \prod_i^n MOP_i = \prod_i^n MOP = (MOP)^n$$

or

$$MOP_i = \sqrt[n]{MOE} \text{ and } MOP = (MOE)^{1/n}$$

It may well be for the conjunctive case that the MOPs are not equal. The only requirement is that their product equals the MOE; however, the equality assumption is a reasonable starting point for analysis. Note that the dimensional parameters are driven by the MOP.

Consider an open system described by its three basic functions: sense, decide, act. Assuming equal values for MOP_{sense}, MOP_{decide}, and MOP_{act} then:

$$MOP_{sense} = MOP_{decide} = MOP_{act} = \sqrt[3]{MOE}$$

Figure 3 omits the MOFE circle for clarity, and the MOE circle is identified as belonging to the user whereas the MOP circle belongs to the developer of the system. It is the developer's responsibility to ensure that the user's MOE is achieved.

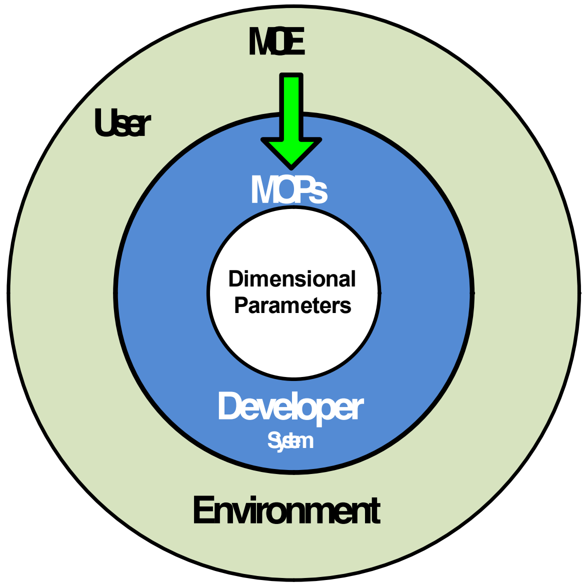


Figure 3 – Revised Measure Relationships

The sense, decide, act paradigm applies to many systems such as military weapons systems, command and control systems, and emergency response systems.

Systems and Black Boxes

According to Clymer[4], there are two ways to view a system. First is the reductionist approach where the system is broken down into its constituent elements, and then each of the decomposed elements is studied in isolation. The interdependence and interaction of the elements are lost in the decomposition. The second view is the systems approach where the view is of the complete system and its resultant behavior; the holistic view. Clymer refers to this view as an expansionist/context sensitive paradigm. The system is viewed as if it had never been decomposed or analyzed—a black box.

Black Boxes

Black boxes have several unique characteristics that make them a useful tool in the development of MOEs. First, the black box encapsulates complexity. The user of the black box sees only the resultant behavior. Thus, the user view is holistic. Second, black boxes are isomorphic. As long as the desired output results from the selected input, the user is indifferent as to the nature of the transfer function that generates the output. Finally, because black boxes are the most abstract instantiation of a system, they embody all the properties of a system. In this regard, the black box becomes the context diagram; it delineates the system boundary; it identifies input and output interfaces, and it has the property of hierarchy. In a hierarchy, emergent properties denote the levels within the system. Black boxes can be used to identify the difference between one level and another.

Box-Structured Methods

Mills, Linger, and Hevner developed what they referred to as box-structured methods (BSM)[7]. The basic system structures they used are the black box, the state machine, and the clear box as shown in Figure 4. The black box focuses on external behavior; "what" the system does, not "how" it is done. The clear box describes "how" the behavior is achieved.

The state machine can represent a variety of state conditions from the trivial to complex nested behaviors. Because of their focus on external behavior, stimulus and response, the resulting black box description corresponds to how users interact with the system.

The machine element of the state machine can be expanded into a clear box with the same external behavior as the state machine. This is done through the application of four basic or primitive control structures: sequence, alternation, iteration, and concurrency. Therefore, the clear box describes the procedural control of the state box's internal black box. This internal black box is then expanded at the next level of detail in accordance with the type of clear box control used.

Measures of Effectiveness through Transfer Characteristics of Black Boxes

7 Mills, Harlan D.; Linger, Richard C.; and Hevner, Alan R., *Principles of Information Systems Analysis and Design*, New York, Academic Press, 1986.

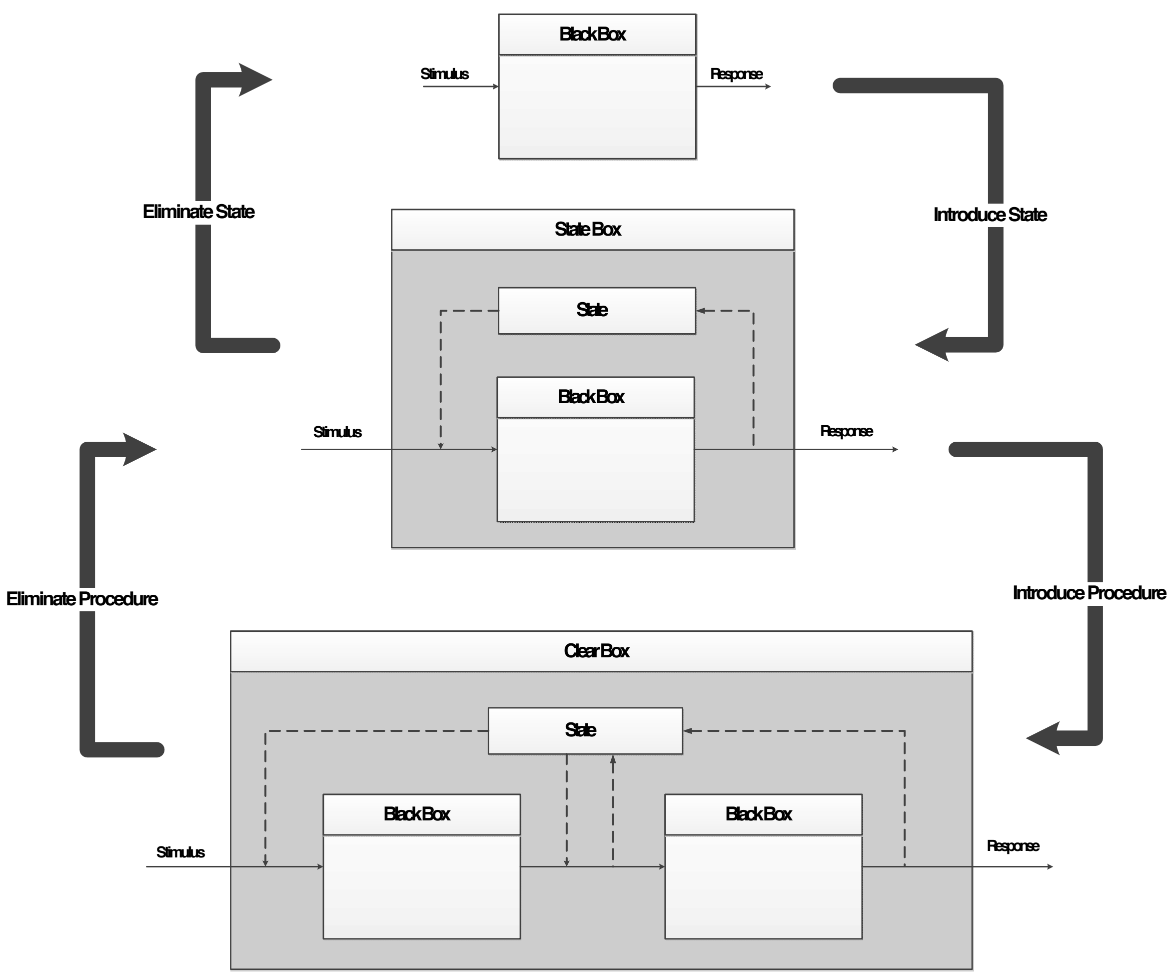


Figure 4 – Box Structure Expansion/Reduction (Mills, Linger, and Hevner[7])

Each black box can be expanded to a state machine or a state-defined description. In turn, each state machine can be expanded to a clear box or a procedure defined description. These are not unique results because of the isomorphic properties of black boxes; however, as shown in Figure 1, state machines can be deduced from clear boxes and black boxes from state machines. These are unique results because the process starts with known entities.

Emergence

Hitchins[6] states that the systems paradigm focuses on "wholes" and their hierarchical structure. This idea is based on the premise that at each level of complexity, properties will emerge that cannot be explained by lower levels. That is, systems have emergent properties that define their effectiveness. The use of the BSM provides an approach to positive control of emergent behavior.

At the clear box level, the process starts over. Each clear box is comprised of black boxes that can be expanded in the same manner. This hierarchical relationship facilitates the development of both MOEs and MOPs as presented in the next section.

Black Boxes and MOEs

The parallel between the MOE concept and the BSM is straightforward. The use of BSM facilitates the development of the MOE/MOP relationship in that the derivation of the clear box from the state box results in the assignment of MOPs to the clear box elements. The approach is top down. The user first establishes the intended purpose of the system. The user also provides the top-level MOE at this point. What is the probability that the system will perform as desired? Because the user views the system as a black box, there may be many ways to solve the problem though the intended purpose may well imply characteristics which will contribute to the ability of the system to meet its intended purpose.*

Figure 5 – Fire Detection Black Box

As a simple example, consider a requirement to monitor the western half of the United States for forest fires. The black box view is shown in Figure 5.

The state box would be described by the sense, decide, act paradigm discussed earlier as shown in Figure 6. In other words, the fire must be sensed, recognized as a fire, and the fire reported as appropriate. These three functions are independent of each other.

There are a number of ways to address this problem, but for this example, it is assumed that a satellite system is appropriate. If it is also assumed that the required probability of fire detection (MOE) for a region (it could be the western United States or a subset thereof) is 0.9 then from equation 1, the MOP for each function is approximately 0.97 (assuming equal performance is required of each function).

This MOP value has several uses. Using the sense function as an example, sensor performance is given by the probability of detection. This MOP can drive the top-level sensor architecture through the application of the redundancy concept from reliability theory to increase effectiveness. It also specifies the required signal-to-noise ratio for the single sensor case providing a starting point for the development of sensor parameters per Figure 3.

Conclusion

The mathematical approach of this paper is based on the concept of holism and positive emergent behavior. The foundation for this

**The authors have a paper in progress that details how the clear box can be derived from the black box and how a capability/mission architecture can be derived as a result. This methodology works with systems that follow the sense, decide, act paradigm.*

6 Hitchins, Derek K., *Systems Engineering: A 21st Century Systems Methodology*, London, John Wiley & Sons, Ltd. 2007.

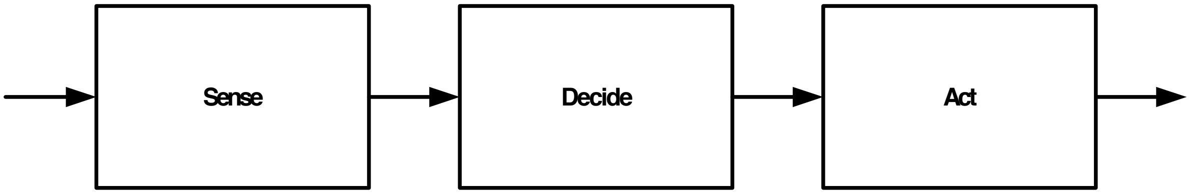


Figure 6 – The Sense, Decide, Act Paradigm

approach was developed by the Reliability Community during the 1960s and 1970s. It starts with the user's view and describes how to transition to the developer's view.

The approach uses three premises;

1. The user views the system holistically
2. The user views the system from a black box perspective
3. The result is captured probabilistically.

The approach successfully resolves the issues raised by Reed and Fenwick[3] and can be used as part of a performance modeling methodology. This is accomplished by developing the system architecture in black box form such that it realizes the desired behavior using the MOE and resultant set of MOP's as goals. It is a step-by-step process that starts from the top and develops goals for each black box and its constituent process and recurses by layer until the appropriate parameters are identified. An important result of this paper is the proof that the common view of the MOE as a function of a set of MOPs was incorrectly derived. The set of MOPs must aggregate to the user's MOE that can be both verified and validated for convincing results.

Global Automotive Electronics Faces Reliability Paradox

Editorial comments by John Blyler, EIC, RMS Journal.
The following work was first published in the 2017 IEEE Reliability and Maintainability Symposium (RAMS). It is used here with permission from the IEEE (see end of article).
http://ieeexplore.ieee.org/document/7889654

1. Introduction

The Customer is a prime factor for any product or service offered by a company. In globalization of market, it can be a costly affair when it comes to delivering and maintaining the reputation for a company, especially in the automotive industry. This is made even harder for the automotive industry today as it is facing product individualization and increasing customer expectations [1]. Consequently, an increasing number of product variants and functions are observed, and new innovative solution concepts are needed. It is found that 90% of all automotive innovations are in the field of electronics [2], and an increasing number of automotive electronic functions are observed in a vehicle that renders an increase in vehicle complexity [3]. The consequence is a growing need for the integration of comprehensive intelligent systems, procedures, and processes in order to ensure the product quality and innovation maturity over the entire life cycle of a vehicle.

This increase in complexity comes at a price of reducing system reliability unless the components' reliability can be improved significantly [4]. Therefore, the reliability requirements for the electronics components in the automotive industry have been growing and will continue to grow in the future.

In this work, the trend of increase in the reliability requirements of automotive electronics is shown. However, the actual reliability of these electronics does not grow accordingly as demonstrated from the automotive recall data. The reasons for this Paradox are proposed in this work.

2. Development Trends in Automotive Electronics and Paradox

The basic electronics in automotive today consists of voltage sources, sensors, actuators, and Electronic Control Units (ECUs) which consists of hardware and embedded software [5]. The ECU plays an important role in the vehicle architecture and mainly consists of a standard micro controller, specific signal processing units, and a controller integrated circuit, with specific packaging, power supply, and power electronic components [6]. With continuous advancements in electronic technology, the automobile electronic components have been improving significantly in terms of their functionality and capability that make the vehicles intelligent, but at the expense of great complexity of the electronic systems in vehicles that could reduce the systems' reliability if proper care is not taken in their design and assembly. The complexity of automotive electronic systems in a vehicle can be seen from Figure 1. Figure 2 shows the trend for the functionality versus the number of control units present in an automobile. While the number of control units is reducing after 2007, the number of functions requested from these control units is increasing as can be seen in Figure 2, depicting the increased complexity of the control units.

The advancement in automotive electronics not only improves the functionality and capability of vehicles, it also improves the safety of vehicles. Figure 3 shows the reduction in the loss of lives and injuries [9] and Figure 4 shows the development of active and passive safety systems over the years [10]. However, the number of accidents has increased due to an increase in more numbers of people driving vehicles and higher traffic density.

A point worth noting here is the correlation between the trend of the total number of accidents shown in Figure 3 and the development of safety systems shown in Figure 4. It can be clearly observed that there is a 50% increase in the total number of accidents during the period of 1970-2000. In the same period, the automobile industry was less focused towards active safety systems which are dedicated to prevent accidents.

The growth of automotive electronics as discussed above renders a significant increase in the complexity of vehicles, and this calls for more stringent reliability requirements for individual components [4].

However, in reality, technologists and

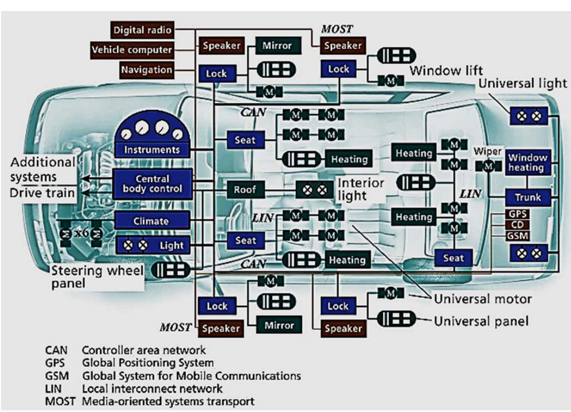


Figure 1 – Automotive Electronics complexity [7]

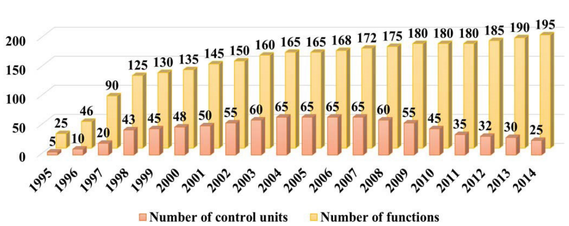


Figure 2 – Increasing trend of complexity with respect to number of control units per number of functions [8]

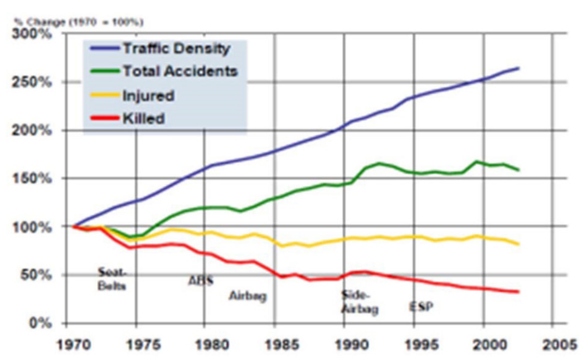


Figure 3 – Trend of accidents and injuries [9]

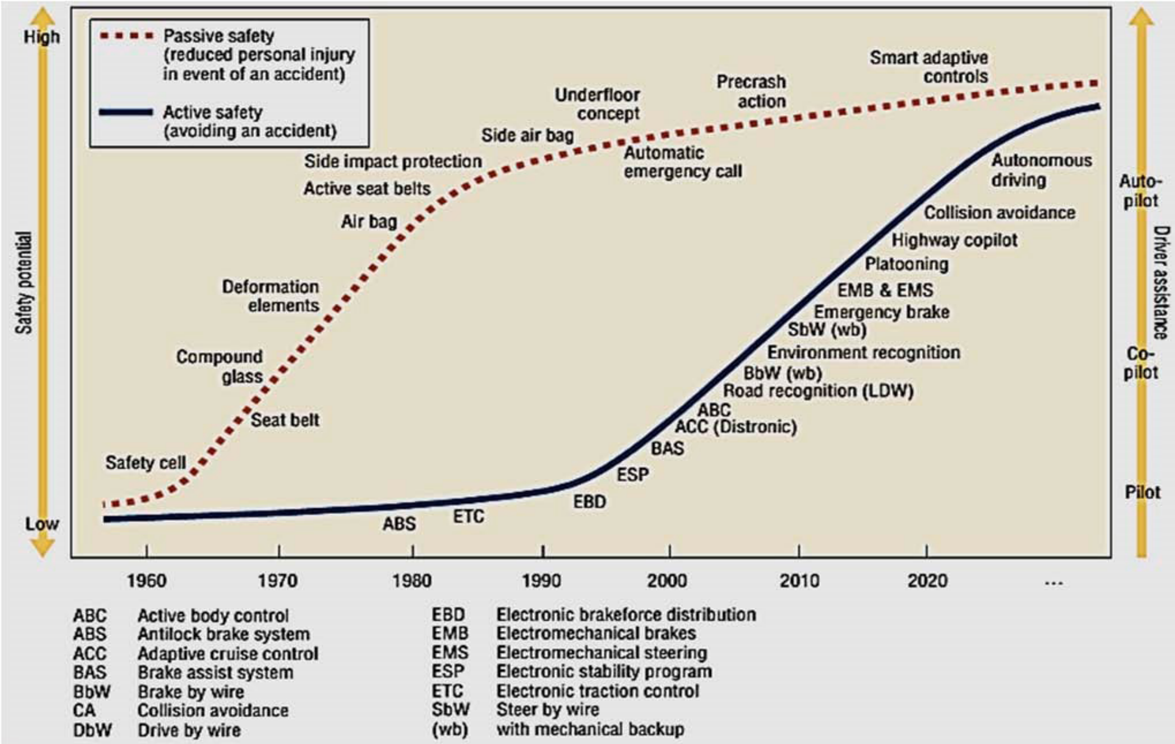


Figure 4 – Development of active and passive safety systems [10]

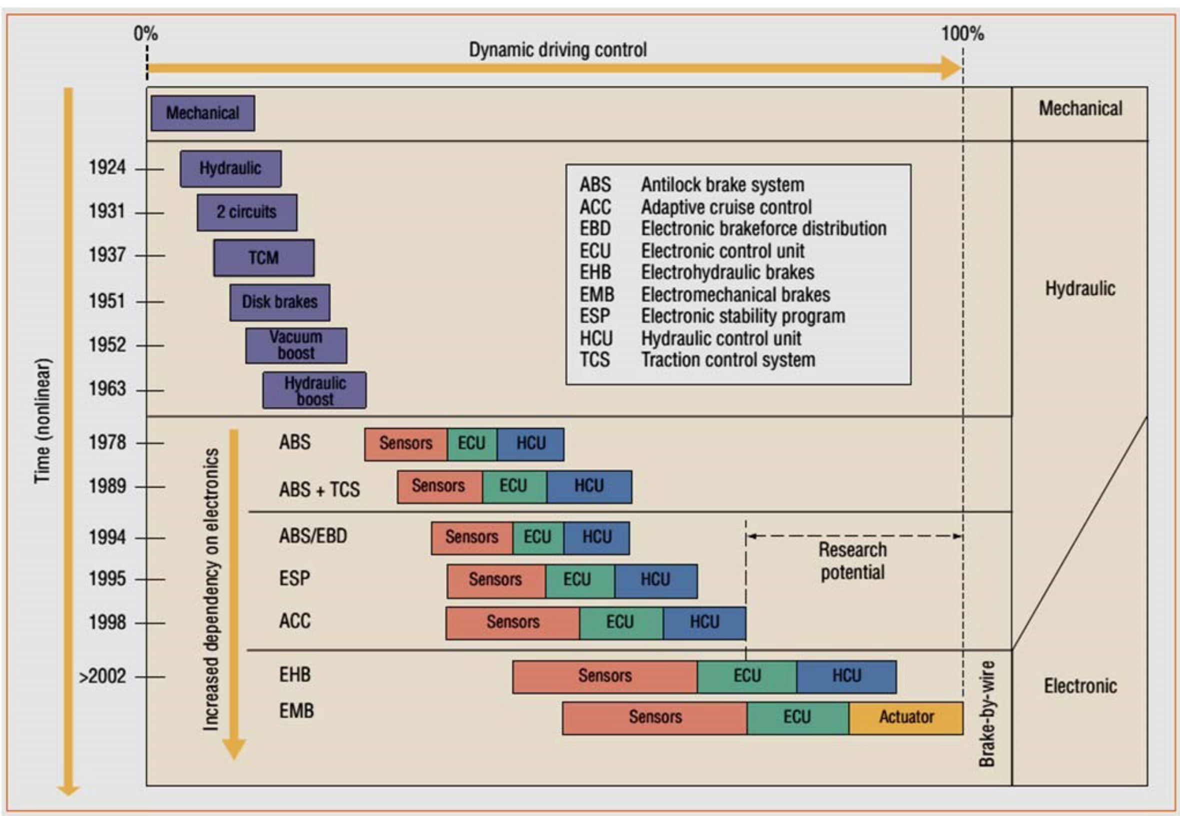


Figure 5 – Past and projected progress in dynamic driving control systems [7, 10]

companies seem to be not able to cope with the pace of the increasing reliability requirements, and create a 'Paradox' as will be elaborated later. Advancements in technology can be co-related to number of recalls, as will be discussed in section 4.calls for more stringent reliability requirements for individual components [4].

However, in reality, technologists and companies seem to be not able to cope with the pace of the increasing reliability requirements, and create a 'Paradox' as will be elaborated later. Advancements in technology can be co-related to number of recalls, as will be discussed in section 4.

It was only after the year 2000 that active safety systems became a priority to the automobile industry which completely incorporated electronic systems as shown in Figure 5.

3. Actual Reliability of Automotive Electronics

To study the actual reliability of vehicles, the total number of vehicles which were affected and hence recalled in the past must be known. Figure 6 and Table 1 show the comparison of the total number of vehicles affected from 1990-2015 [11-14] resulting in recalls and the total number of automotive sales worldwide [15].

From Figure 6 and Table 1, it is clear that even though the number of cars sold have been increasing for a given duration, the percentage of vehicles affected and hence recalled are also increasing for that respective duration. One can see that after year 2000, the increase in the percentage of vehicles recalled has a slight jump, which corresponds to the significant increase in the electronic contents in vehicles as shown in Figure 5.

There are mainly 11 causes found responsible for the recalls wherein powertrain, interior electronic/hardware, airbag, fuel and

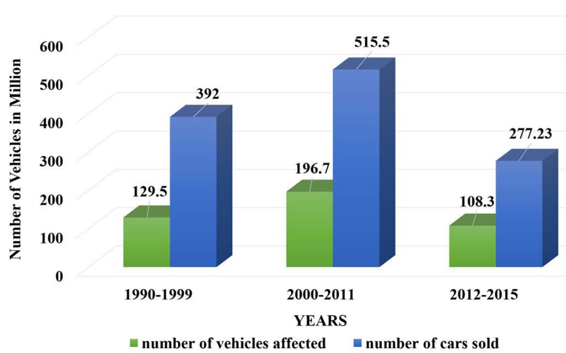


Figure 6 – Comparison between total number of vehicles potentially affected in years 1990-2015 [11-14] resulting in recalls and the total number of worldwide automotive sales. [15]

Years	Percentage of affected vehicles resulting in recalls with respect to worldwide automotive sales
1990–1999	**33.03%**
2000–2011	**38.16%**
2012–2015	**39.06%**

Table 1 – Automotive Recalls vs Worldwide Automotive Sales

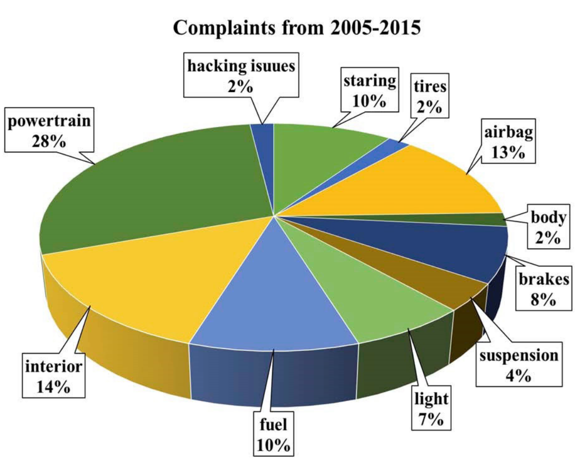


Figure 7 – Major causes for the number of recalls from 2005 to 2015 [11-14]

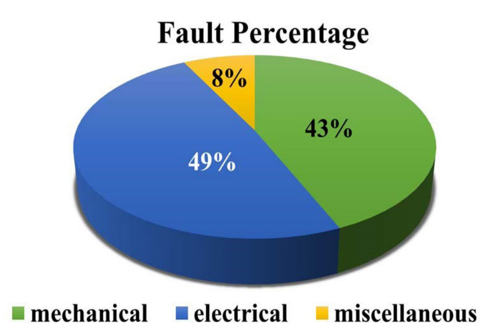


Figure 8 – Type of fault (mechanical, electrical and miscellaneous) in the automobile in percentage for 2005-2015 [11-14]

steering are the main contributors as shown in Figure 7 [11-14].

All the recalls are mainly related to mechanical and electronics issues, where 49% are of electrical faults and 43% are of mechanical faults as shown in Figure 8 [11-14].

The data shown in this section reveals the current status of actual reliability of automobile electronics which does not seem to be improving. The advent of new automotive electronics technology should expect to improve the reliability, but the reverse is true. The possible reasons for this are discussed in the next section.

Developing trends and actual reliability in the field of automotive electronics are correlated to each other which will be discussed in the next section. This correlation will be helpful for companies to understand the importance of reliability requirements in today's scenario.

4. Reason for Poorer Reliability in the Automobile Industry

The reasons for the unexpected poorer reliability for the Automotive Electronics industry are believed to be related to the following parameters:

4.1 Operating Temperature

Figure 9 shows the trend of operating temperature for automotive electronics.

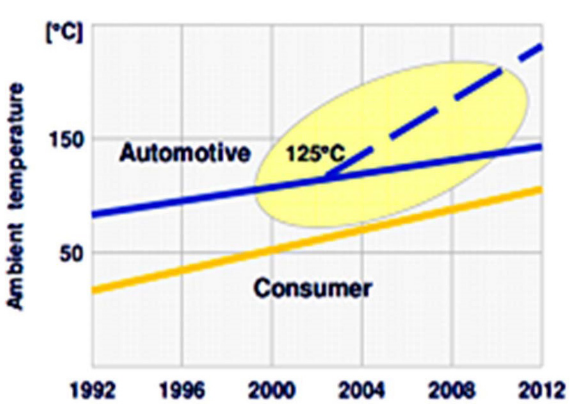


Figure 9 – Increase in operating temperature for the automotive industry [16]

The junction temperature for the silicon based actuators in particular has been increasing as shown. Similarly, other automotive electronics are also subjected to higher temperature ambience. Therefore, it is crucial to consider reliability for larger temperature range of 40–155°C [16].

The reliability for automotive parts has been ensured traditionally by extensive qualification tests performed at increased temperature in order to shorten the time of aging. The application of accelerated life testing with respect to temperature is a proven method to test components for their reliability in a shortened time [17]. Since the operating temperature is increasing as shown above and going up to the maximum allowable temperature for the operation of silicon circuits, there is little room for temperature acceleration. Test to failure method to evaluate product reliability is no longer possible. Degradation study based on the physics of failure should be used to overcome the limitation. A degradation study for LED driver was conducted and found that measurement errors incorporated can reduce the accuracy of its lifetime estimation [18].

4.2 Operating Time

From the investigation of the failure data from anonymized Pennsylvania vehicle safety inspections ranging from 2008 to 2012 from two different data sources, in addition to anonymized Pennsylvania vehicle registration records as of March 2012 and November 2013, we found that the number of failure increases with the age of vehicles in a population as expected in reliability shown in Figure 10 [19]. It is interesting to see that maximum number of failures occurs at the ages of vehicles around seven to nine years. For vehicles that can last beyond nine years, the number of failures becomes less, indicates that there are less vehicles that can last

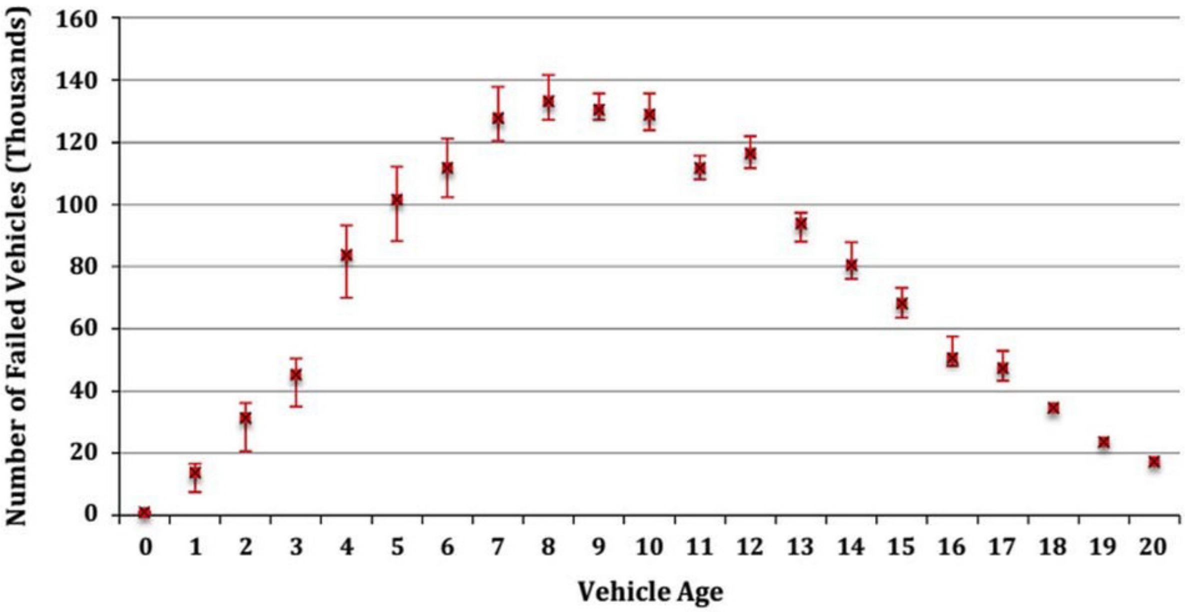


Figure 10 – Estimated number of vehicles that would have failed in 2012, by vehicle age (bars represent range between 2008 and 2012) [19]

so long, for example, only very few vehicles can stay up to 20 years, and hence the number of failures also become much less. In other words, most vehicles will fail around seven to nine years of usage.

On the other hand, the common operation time for a vehicle by most companies and users' expectation is above ten years [16,17]. This shows that design for reliability to sustain more than ten years for vehicles' design and manufacturing has not been implemented effectively. With the increasing complexity of vehicle system as mentioned earlier, this effectiveness is expected to decrease even more, if no concrete effort is placed in this area.

4.3 Humidity

The humidity levels experienced by automotive electronics due to varying operating conditions bring in favorable chances of failure on the electronics and the system as humidity at high temperatures might induce phenomenon such as metal dendrites [20], bond pad contamination [21], galvanic corrosion [21], delamination [21], package swelling [21], etc. The situation is worse in winter as salt is used for the melting of ice on roads and the salt water will accelerate the above-mentioned failure mechanisms.

The importance of humidity consideration can be understood by a recent example of recalls by car companies due to airbag faults by TAKATA Company [22]. According to TAKATA, manufacturing problems together with exposure to moisture in cars in humid regions can cause the propellant to degrade which is used in airbag's inflator. This can make the propellant burn too vigorously when the airbag is deployed, rupturing the inflator and sending metal fragments into the car's interior, injuring the driver or passengers - a potentially disastrous outcome from a supposedly life-saving device.

4.4 Misconception in Evaluating Reliability

There is an urgent need to develop a better metric rather than MTBF/MTTF [23], in order to characterize reliability performance and specify reliability requirements. This is in fact one of the few common misconceptions in evaluating product reliability. Tan [4] demonstrated eight common misconceptions on reliability evaluation from his experiences with the industry, and they are listed as follows:

1. Zero failure is better than having failures in reliability test.
2. Exponential distribution is all that is required for test data analysis.
3. High MTTF represents good reliability.
4. All test data are valid.
5. There is only one failure mechanism in the failure data.
6. Selection of right supplier through accelerated stress test.
7. To save time in reliability, simply increase the stress level.
8. Mil-Std handbook provides the basis for reliability calculation.

Also, in reality, a component may be subjected to various failure mechanisms, and the probabilities of these mechanisms must be considered in totality. Figure 11 illustrates this totality consideration as compared to the use of Mil-HDBK 217, based on a Physics of Failure (PoF) durability simulation produced using the Sherlock ADA PoF CAE App [24]. We can clearly see that while the Mil-KDBK-217 may project a nice prediction of ten years operation with less than 10% failure, a standard of ten years L10 reliability-durability objective that is commonly employed in the automotive industry, the reality is far from being true, and by the fourth year, close to 10% of the vehicles would have been failed. Therefore, PoF based reliability computation must be incorporated in the reliability evaluation of vehicles.

4.5 Inclusion of New Technology Without Adequate and Suitable Reliability Testing

Figure 12 shows the annual units affected over the years which includes reported recalls for reputed companies like BMW, Ford, etc [25]. Firstly, the recalls have increased as observed and secondly, at every technology advancement node in automotive electronics depicted in Figure 5, there has been an upward lift in the affected units' trend. For example, in early 1970s when electronics was introduced in automobile

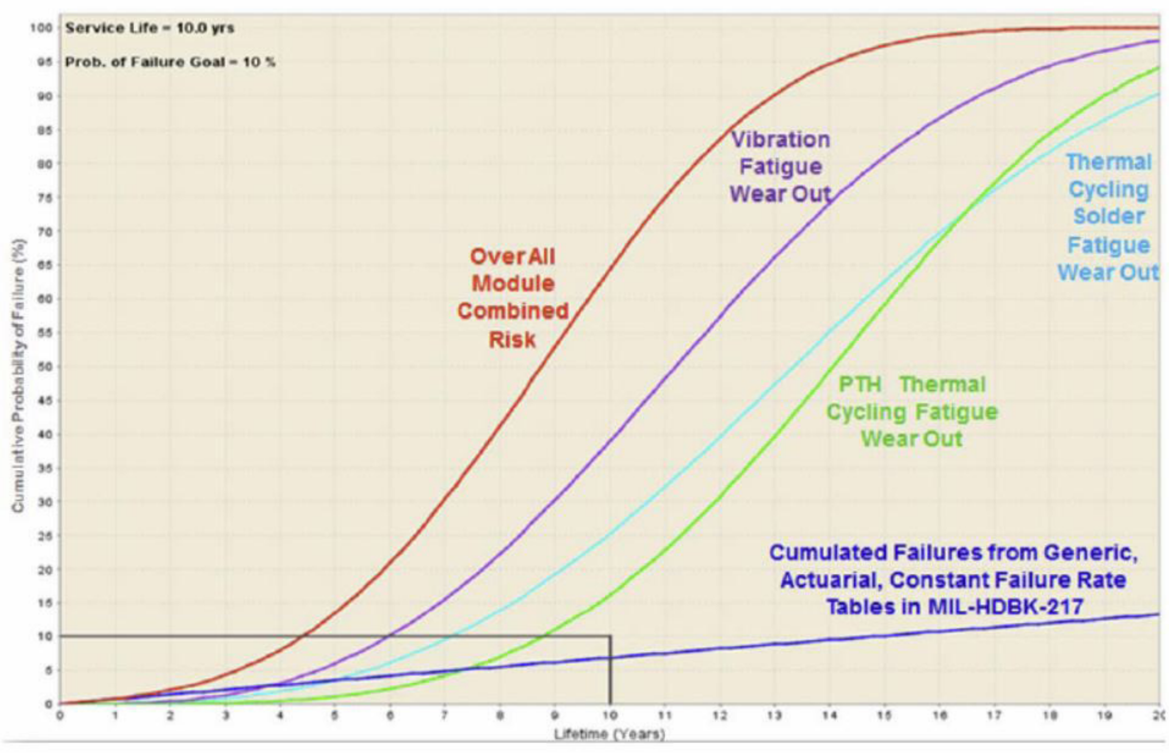


Figure 11 – Physics of Failure Cumulative Failure Risk Life Curves for an Electronic Module [24]

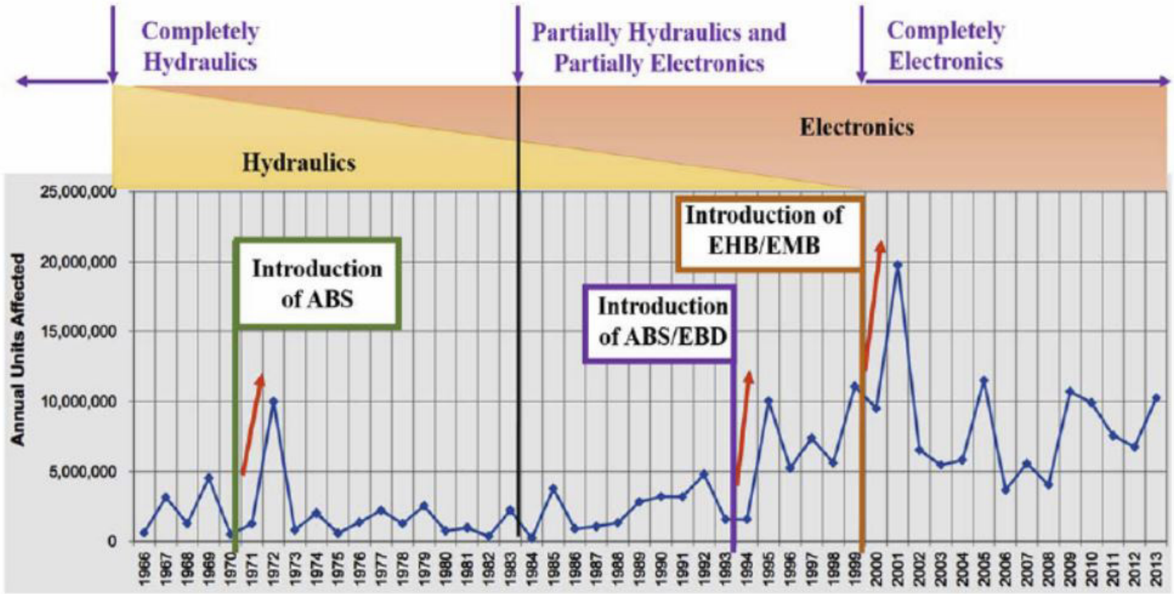


Figure 12 – Time series summary of recall [25] and a comparison with the automotive electronics growth trend; red arrows show the inclusion of new technology; Information from Figure 5 is superimposed on to this figure to correlate the jump in the recall number vs the introduction of new technology

industry, there was a little increase in recalls, then in early 1990s, where ABS+TCS changed to ABS+EBD, the number of recalls rose drastically. The complete electronics transformation in 2000 and later brought another wave of recalls.

Introduction of new technology is bound to result in new reliability issues that take time to reveal and overcome.

Methodology of design-in-reliability must therefore be incorporated in order to match the ever decreasing time to market of new products. Unfortunately, such methodology is seldom found in many companies, and time given for reliability test is often insufficient to ensure a good reliability. The consequence is a greater loss due to recall, including the loss of reputation. Hence, one needs to find the challenging balance of time given for reliability consideration and the time to market, and systematic method must be employed. Figure 12 shows a high probability that recall is from new automotive electronics introduction. When a new automotive technology is introduced, it takes some time to get into market and we can see in Figure 12 that a high recall has occurred after a few years of introduction of new technology.

Figure 5 gives the technological advancements of driving control systems and Figure 8 provides information regarding failure type, where electrical faults occupies a larger area than others. Figure 12 describes the correlation between faults and technology. The data is showing the correlation between manufacturing defects and changing trend of technology, and this can help us to see a bigger picture of reliability issue, in particular the reliability paradox that is plaguing the automotive industry.

References have been removed to meet copyright issues but are available on the IEEE website: http://ieeexplore.ieee.org/document/7889654/

New Technique Localizes Defects in 3D Chips for Reliability and Failure Analysis

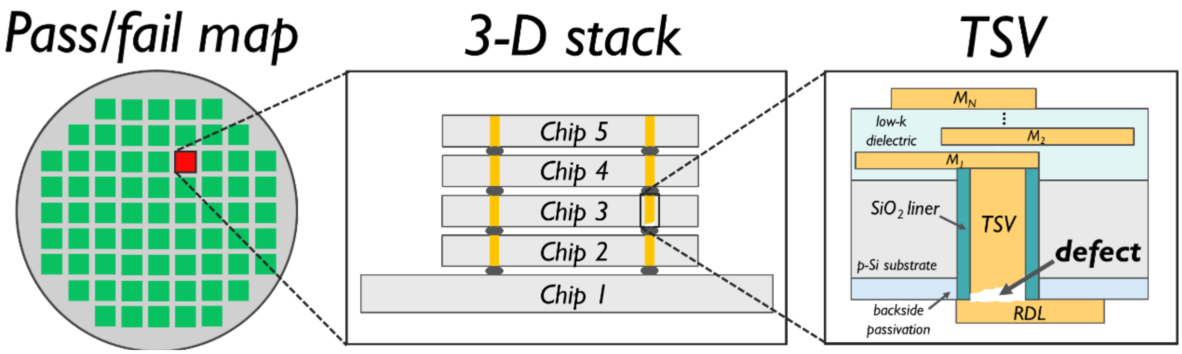
Kristof J.P. Jacobs

3D chips enable high-performance and cost-effective systems. But, as is the case with every new technology, it comes with new reliability and failure issues. One of these are faults – electrical opens and shorts—in through-silicon vias (TSVs) that interconnect the stacked chips. Researchers at imec have now developed a new technique that can rapidly localize these interconnection failures in a non-destructive and cost-effective manner at wafer scale. Postdoctoral researcher Kristof J.P. Jacobs sheds light on the new technique and unveils first results on a second, related technique which allows chips to be investigated at an even deeper level.

Through-Silicon Vias Form the Heart of 3D Chips

Stacking chips on top of each other is a well-known approach to make small high-performance systems, with the possibility to combine different technologies for each layer in the system. 3D chips are used in high-bandwidth handheld products and high-density multichip memory. At the heart of the 3D chips are through-silicon vias (TSVs) which provide the shortest chip-to-chip interconnects and the smallest pad size and pitch. The fabrication of these TSVs is a challenge, involving processes such as deep Si etch, chemical vapor deposition (CVD) oxide insulation, metal barrier & seed deposition, copper electroplating and chemical mechanical polishing (CMP).

These 3D specific processes and operations bring new reliability issues and failure mechanisms that require new failure analysis (FA) methodologies as traditional methods are becoming impractical for



Through-silicon vias are at the heart of 3D chips. TSV failure analysis is indispensable to optimize the production of 3D chips.

today's IC complexity. FA forms an important function for chip manufacturing as it provides valuable information for technology advancement and corrective action for quality and reliability improvement.

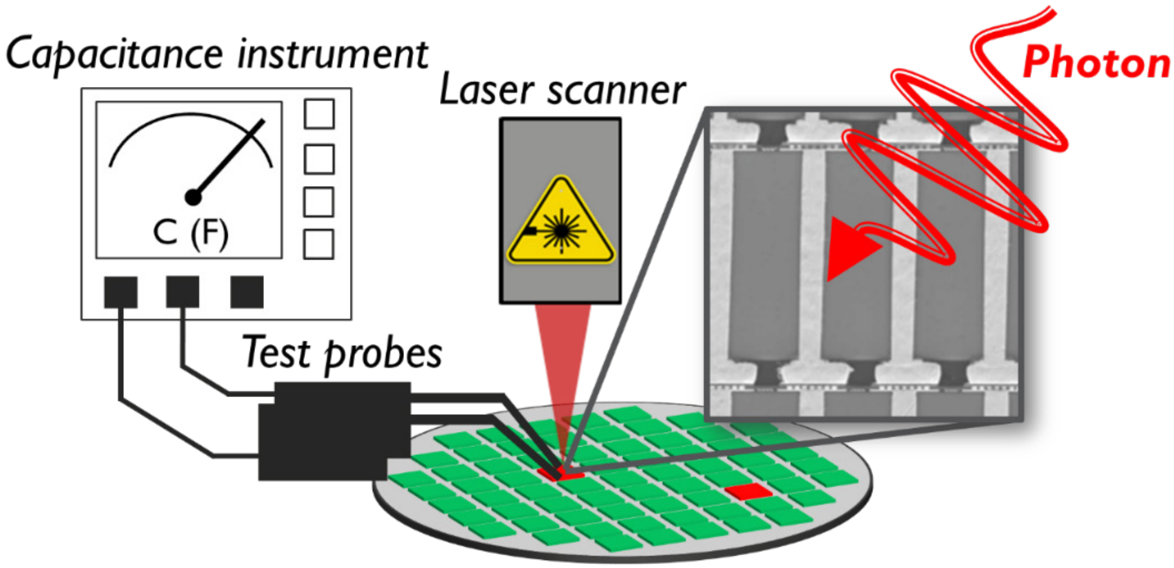
Today, only a limited number of non-destructive techniques are available to localize interconnection failures in 3D chips. The most promising techniques include magnetic field imaging (MFI), lock-in thermography (LIT), and electro optical terahertz pulse reflectometry (EOPTR). Whilst each of these techniques has unique characteristics and advantages (as well as limitations), they all require highly specialized and expensive FA apparatus that is not available in many laboratories.

To address the need for rapid, cost-effective, and scalable FA techniques, imec has developed a new method to localize interconnection failures in 3D chips. This technique, called LICA, exploits the effect of light on TSV capacitance for defect localization. Moreover, it only requires a scanning laser microscope, probing station, and capacitance meter which are all readily available lab tools.

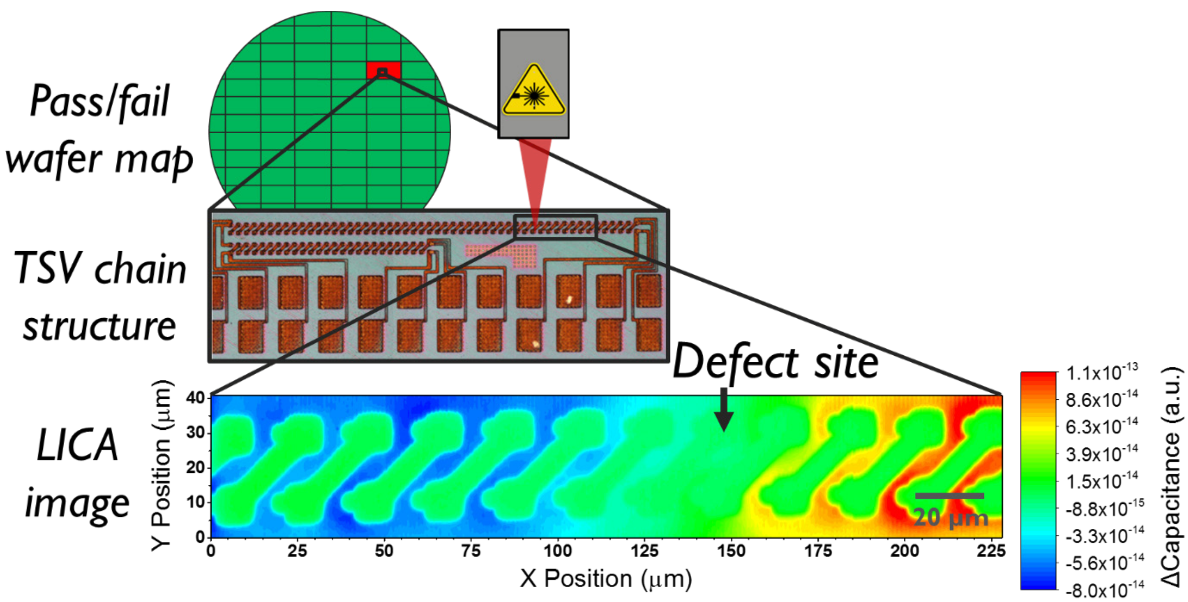
LICA: Defect Localization with Light Waves

LICA stands for light-induced capacitance alteration. It refers to the fact that the electrical capacitance of the TSV changes when it is illuminated with light (photocapacitance). However, when a fault is present in the TSV, and the light shines at this position, no change in capacitance will be detected as the electrical connection to the meter is interrupted. This way, the fault can be localized. The technique builds on the capacitance-voltage (C-V) measurement method, yet also allows to conduct the measurement on a local level. Unlike scanning capacitance microscopy (SCM), whereby the local capacitance is measured between the sample and a small tip that is scanned over the surface, a focused laser beam is used to induce a change in the TSV capacitance.

The photosensitivity of the TSV capacitance depends on many factors such as light wavelength and measurement frequency. Imec researchers investigated the effects of these factors to determine the optimal measurement conditions for maximum signal strength. It was found that up to ~70% of the TSV capacitance can be made sensitive to light under optimal conditions. As the signal is typically in the range of a few tens of femtofarads (10^{-15} F), commercially available capacitance meters can be used for the detection. While the sensitivity of commercial meters may be sufficient for single die measurements, the associated measurement time is considered too long for wafer level defect screening. To address this, imec developed an ultra-sensitive measurement instrument that further reduces the measurement time from hours to minutes.



With LICA, the light-induced change in electrical capacitance is measured while scanning a focused laser beam over the 3D TSV structure under test. Test probes provide electrical connections from the structure to the measuring instrument. The location of the defect is marked when a distinctive change in the capacitance response is detected.



The pass/fail wafer map shows the location of the die failures but contains no information on the exact failure location in the structure. With LICA, failures can be localized more accurately down to a single TSV.

Technology Demonstration

The technique has been demonstrated on a 5×50 µm via-middle TSV chain structure fabricated in imec's state-of-the art 300mm cleanroom. The purpose of a TSV chain structure is to evaluate the electrical continuity of multiple TSVs connected in a chain configuration. Measuring the chain resistance may indicate whether the structure is yielding or not, but it provides no information on the location of the defect. Accurate defect localization is required to understand the cause of the failure. To demonstrate the applicability of the LICA technique, an open failed TSV structure was selected which includes over 650 TSVs with a TSV pitch of 20 µm. By scanning the focused laser beam over the chain, and applying a differential capacitance measurement technique, imec researchers have been able to successfully localize the open defect in the structure down to a single TSV. The required measurement time to localize the defect was less than five minutes. We expect that the analysis time can further be reduced to less than one minute by instrumentation optimization. Today, the LICA technique is used within imec to assist in the development of 3D integration technologies.

Future Work: Thermal Technique for Stacked Chips

A limitation of the LICA technique is that the region of interest should be accessible by the laser. Unlike dielectric passivation—which can be transparent to the light—metal layers, underfill, and epoxy overmold can block the path of the light. This can be a problem when stacked chips are being investigated and the faults are in the middle or bottom chips. That's why the imec research team is currently developing a second, similar technique based on thermal waves (instead of light waves) which have the ability to penetrate through these materials. This technique will enable defect localization regardless of whether the defect is in the top or bottom die.

Want to know more?

If you would like to receive the technical paper on this subject, entitled “Light-induced capacitance alteration for non-destructive fault isolation in TSV structures for 3D integration”, please send an email to imec-magazine@imec.be

Anticipated Climate Change with Implications for the United States

Katherine Pratt

Prologue

The difference between weather and climate is the measure of time. Weather is what the conditions of the atmosphere are, when considered over a short period of time. Whereas, climate is the changes in the daily behavior of the atmosphere over relatively long periods of time.[1] Weather is the state of the current atmospheric pressures dependent upon a confluence of events; shaped by wind, sun, temperatures, clouds, precipitation, gravity and planetary gravitational forces. Our role is limited to measuring these confluences of barometric events and predicting outcomes from evaluating these systems within systems (SOS). As we gain knowledge and understanding from weather, we become better able to predict and understand climate more reliably.

Operational environments have considerable influence on reliability and maintainability analysis and management. To achieve effective reliability and maintainability analysis and management, all technical challenges and influence factors must be identified. Based upon the way these factors influence the failure mechanisms, maintenance processes and other support activities, appropriate statistical approaches are selected to quantity their effects.[2]

Introduction to Problem

Long-term changes in our climate will produce extreme weather events and put greater stress on critical Earth systems, such as oceans, freshwater, and biodiversity. These in turn will almost cer-

1 "NASA – What's the Difference Between Weather and Climate?" https://www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html

2 "Reliability and Maintainability Performance Under Artic Conditions" International Journal of Systems Assurance Engineering and Management, September 2011, Vol.2, issue 3, pp. 205-217

tainly have significant effects, both direct and indirect, across social, economic, political, and security realms during the next 20 years. These effects will be all the more pronounced as people continue to concentrate in climate-vulnerable locations, such as coastal areas, water-stressed regions, and ever growing cities. Climate is defined as long-term averages and variations over a period of several decades.

The Earth's climate system includes the land surface, atmosphere, oceans, and ice. Temperatures at the surface, in the troposphere (the active weather layer extending up to about five to ten miles above the ground), and in the oceans, have all increased over recent decades. The largest temperature increases are occurring closer to the poles, especially in the arctic. Snow and ice cover have decreased in most areas. Atmospheric water vapor is increasing in the lower atmosphere, because a warmer atmosphere can hold more water. The third line of evidence comes from using climate models to simulate the climate of the past century, so human and natural factors can be separated.[3]

Effects of Climate Change: Possible Timeframes

The complexity of the climate, the uncertainties of modeling, and human choices make it difficult to project when and where specific severe weather events and other effects will affect national security most significantly.

However, climate models do not diverge significantly on their estimates of future surface temperatures, or on changes in other climate variables during the next 20 years, particularly when fluctuations in the climate system are considered.

- **Now**, the effects resulting from changing trends in extreme weather events suggest that climate-related disruptions are already under way.
- Over the **next five years**, the security risks for the United States linked to climate change will arise primarily from distinct extreme weather and from the exacerbation of currently strained conditions, such as water shortages.
- Over the **next 20 years**, in addition to increasingly disruptive extreme weather events, the projected effects of climate change will play out in the combination of multiple weather disturbances with broader, systematic changes, including the effects of sea level rise.[4]

There is a variance between the measurements of global and local sea level trends. Just as the surface of the Earth is not flat, the surface of the ocean is also not flat. Sea level rise at specific locations may be more or less than the global average due to many local factors such as:

- **Subsidence** Gradual settling or sudden sinking.
- **Upstream Flood Control** (dams, etc.)
- **Erosion** (loss of shoreline sediment)
- **Regional Ocean Currents** (**OC**) (currents send warm water to Polar regions or cold water to Tropic areas)
- **Variations in land heights** (tide and wave height + land heights + depths (sea levels))
- **Glacial Isostatic Adjustment** (some land is still rebounding from the compressive weight of the Ice Age glaciers)

Effects of Climate Change: Possible Pathways

Climate change and its resulting effects are likely to pose wide-ranging national security challenges for the United States and other countries over the next 20 years through the following pathways:

- Threats to the stability of countries.

Anticipated Climate Change with Implications for the United States

4 "Implications for U.S. National Security of Anticipated Climate Change," 21 September 2016 NIC WP 2016-01.

3 "Climate Change Impacts in the United States" U.S. National Climate Assessment – U.S. Global Change Research Program, Section 2: "Our Changing Climate," pg. 22

- Heightened social and political tensions.
- Adverse effects on food prices and availability.
- Increased risks to human health.
- Negative impacts on investments and economic competitiveness.
- Potential climate discontinuities and secondary surprises.

Systems Analysis

How Electricity Generation Works

British scientist Michael Faraday 1831 discovered the process of using motion to produce electric current via electromagnetic induction.[5] By spinning magnets inside of copper coils, Faraday was able to generate a small but measurable electric current. Modern power plants still use Faraday's discovery, but they do so on a massive scale—the generators weigh several hundred tons and the current can power hundreds of thousands of homes.[6]

Coal-fired power plant development started with the introduction of the first dynamo built for power generation in 1866 by Werner von Siemens.[7]

In 1882, Thomas Edison used coal to fuel the first power plant. In the system he built, coal-fired boilers heated water, which produced high-pressure steam, which turned a turbine, which powered a generator. Spinning turbines account for the lion's share of the electricity produced today.[8]

Power Grid

Worldwide, there are now forecasts suggesting that climate change impacts could lead to reductions in electricity production capacity for more than 60% of the power plants worldwide beginning in 2040 through 2069.

For nearly half of the American West's existing power plants, climate change could reduce their ability to produce electricity by up to 3% during an average summer and possibly up to nearly 9% during a decade-long drought. Coal-fired power plants in Wyoming, Utah, Arizona, and Colorado are especially vulnerable.

Climate change is expected to profoundly affect the Western U.S., possibly making the already-parched Southwest more arid and vulnerable to drought. Stream flows will decline and mountain snowpack will melt earlier as temperatures rise, constraining water supplies.[9] Wildfires and heat waves will be more frequent, and forests throughout the Northwest will be vulnerable to disease outbreaks and die-offs.[10]

Thermal Power

The majority of the power in the U.S. comes from thermal generation- using heat to create high-pressure steam and drive turbines. This is how coal, nuclear, and most natural gas plants produce electricity. In 2013, coal, natural gas, and nuclear power accounted for a combined 86% of total electricity generation in the U.S. (39.1% coal, 27.4% natural gas, and 19.4% nuclear.)[11]

Coal Industry: From Mining to Post-Combustion Disposal

The energy stored in chemical bonds within coal can be released via combustion, and then it can be used to drive steam turbines inside power plants.[12] Air pollution produced by coal combustion in power plants can affect the respiratory and cardiovascular systems, as well as cause abnormal neurological development in children, poor growth of the fetus before birth, and can cause cancer.

Coal used for heating and cooking indoor generates pollutants in indoor air that are known to cause respiratory ailments and cancer. Specifically, this includes sulfur dioxide (SO_2), which increases the severity and incidence of respiratory systems, including asthma, inflammation and hyper-responsive-

Anticipated Climate Change with Implications for the United States

9 NCA 2014, "Global Change Report on Southwest Regions" http://nca2014.globalchange.gov/report/regions/southwest

10 National Climate Assessment http://nca2014.globalchange.gov/node/9494

5 "The Work of Michael Faraday" http://www.engineering-timelines.com/how/electricity/generator.asp

http://channel.nationalgeographic.com/channel/cosmos-a-spacetime-odyssey/episodes/the-electric-boy/

6 "Electricity Generation", by IER Institute for Energy Research

11 Table 7.2a "Electricity Net Generation; Total All Sectors" http://www.eia.gov/totalenergy/data/monthly/#electricity

7 "Clean and Efficient Coal-Fired Power Plants" by Heinz Termuehlen & Werner Emsperger. DOI: 10.1115/1.801942.ch1, http://ebooks.asmedigitalcollection.asme.org/content.aspx?bookid=240&sectionid=38774789

12 The Institute for Energy Research (IER) "Electricity Generation", 9-2-14

8 "Electricity Generation" September 2, 2014 IER Institute fro Energy Research http://instituteforenergyresearch.org/electricity-generation ness of the airways, aggravates bronchitis, and decreases lung function.

Oxides of nitrogen (NO_X) are byproducts of fossil fuel combustion from automobiles and other coal-fired power plants. NO_X reacts with atmospheric chemicals to create pollution products, such as ozone (smog), nitrous oxide (N_2O), and nitrogen dioxide (NO_2). This source of the coal combustion contributes to climate change, which can harm human health on a global scale.

Every life cycle step in coal processing generates pollution. In the mining of coal, excess oil and slurry from the washing process contains hazardous substances, such as heavy metals, that can leach out of storage containers or into fills and thereby contaminating surface and ground water. NO_2 also increases susceptibility to viral and bacterial infections. At low concentrations, it can cause decrements in lung functions, and as concentrations increase, this can lead to airway inflation.

In 2015, total emissions of carbon dioxide (CO_2) amounted to 6,587 million metric tons of CO_2 equivalent. Even the diesel fuel used in the transportation for our cars, trucks, ships, trains, and planes contributes to local air pollution and amounts to 27% of the greenhouse gas emissions. Industry uses 21% from burning fossil fuel as well as greenhouse gas emission from chemical reactions needed to produce goods from raw materials.

Commercial and residential use is 12% of the greenhouse gas emissions, mainly from generating heat, but also from certain products that contain greenhouse gases and the handling of waste.

Agriculture only contributes to 9% of the 2015 greenhouse gas emissions, which come from cows, agriculture soils, and rice production. Land Use and Forestry, on the other hand offset 11.8% of the 2015 greenhouse gases emissions, as they act as a sink absorbing the CO_2 from the atmosphere. In the U.S., since 1990, managed forests and other lands have absorbed more CO_2 from the atmosphere than they emit.[14]

Post coal combustion, some coal ash is recycled into cement, but, most is disposed into dry or wet landfills, contributing to the ground and water contamination with arsenic, cadmium, barium, thallium, selenium and lead.

Emissions from coal-fired power plants are affected by the weather such as temperature, precipitation, wind-direction and speed. These emissions can even be transported globally. Currently 40% of the electricity produced in the world, is generated from the combustion of coal, and this percentage is likely to rise as worldwide energy demand increases. 76% of this new capacity is proposed by China and India. 95% of the external cost consists of the adverse health affects on the populations.[15]

Coal-Fired Power Plant Emissions

The U.S. have developed total maximum daily loads (TMDLs), which are the contributions from air sources that are estimated to be on the order of 98–99% of the total mercury loadings from the coal-fired power plant releases into U.S. water. These power plant emissions are a dominant source (50%) to the atmosphere. On December 2016, the U.S. Environmental Protection Agency (EPA) issued the first national standard to reduce mercury and other toxic air pollution from new and existing coal- and oil-fired power plants.

Noxious Emissions

Mercury becomes released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the air you breathe in the general environment. With the exception of mercury ore deposits,

14 "Sources of Greenhouse Gas Emissions," EPA https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

15 Yang A, Cui Y. "Global Coal Risk Assessment: Data Analysis and Market Research." World Resources Institute 2012 the air you breath generally has relatively low levels of mercury, however, the steady release of mercury has resulted in concentrations three to six times higher in our air now than was in the preindustrial era.

Approximately 80% of the mercury released from human activities is elemental mercury released to the air, primarily from fossil fuel combustion, mining, and smelting, and from solid waste incineration. About 15% of the total is released to the soil from fertilizers, fungicides, and municipal solid waste. Spills of metallic mercury from broken thermometers or damaged electrical switches in the home may result in exposure to mercury vapors in indoor air, and also when you handle and dispose metallic mercury. Very small amounts of metallic mercury (for example, a few drops) can raise air concentrations of mercury to levels that may be harmful to health. The longer people breathe the contaminated air, the greater the risk to their health. Metallic mercury and its vapors are extremely difficult to remove from clothes, furniture, carpet, floors, walls, and other such items. If these items are not properly cleaned, the mercury can remain for months or years, and continue to be a source of exposure.

An additional 5% is released from industrial wastewater systems into water in the environment. Most of the mercury found in the environment is in the form of metallic mercury and inorganic mercury compounds. Metallic and inorganic mercury enters the air from mining deposits of ores that contain mercury from:

- the emissions of coal-fired power plants,
- the burning of municipal and medical waste,
- the production of cement, and;
- uncontrolled releases in factories that use mercury.

Metallic mercury is a liquid at room temperature, but some of the metal will evaporate into the air and can be carried long distances. In the air, the mercury vapor can be changed into other forms of mercury, and can also be further transported to water or soil through rain or snow. Inorganic mercury may also enter water or soil from the weathering of rocks that contain mercury, from factories or water treatment facilities that release water contaminated with mercury, and from the incineration of municipal garbage that contains mercury (for example, in thermometers, electrical switches, fluorescent light bulbs, or batteries that have been thrown away).

Microorganisms (bacteria, phytoplankton in the ocean, and fungi) convert inorganic mercury to methylmercury. Methylmercury released from microorganisms can enter the water or soil and remain there for a long time, particularly if the methylmercury becomes attached to small particles in the soil or water. Mercury usually stays on the surface of sediments or soil and does not move through the soil to underground water. If mercury enters the water in any form, it is likely to settle to the bottom where it can remain for a long time.

Mercury can enter and accumulate in the food chain. The form of mercury that accumulates in the food chain is methylmercury. Inorganic mercury does not accumulate up the food chain to any extent. When small fish eat the methylmercury in food, it goes into their tissues. When larger fish eat smaller fish or other organisms that contain methylmercury, most of the methylmercury originally present in the small fish will then be stored in the bodies of the larger fish. As a result, the larger and older fish living in contaminated waters build up the highest amounts of methylmercury in their bodies. Saltwater fish (especially sharks and swordfish) that live a long time and can grow to a very large size tend to have the highest levels of mercury in their bodies.

Plants (such as corn, wheat, and peas) have very low levels of mercury, even if grown in soils containing mercury at significantly higher than background levels. Mushrooms, however, can accumulate high levels if grown in contaminated soils.

A potential source of exposure to metallic mercury for the general population is mercury released from dental amalgam fillings. An amalgam is a mixture of metals. The amalgam used in silver-colored dental fillings contains approximately 50% metallic mercury, 35% silver, 9% tin, 6% copper, and trace amounts of zinc. Part of the mercury at the surface of the filling may enter the air as mercury vapor or be dissolved in the saliva. The total amount of mercury released from dental amalgam depends upon the total number of fillings and surface areas of each filling, the chewing and eating habits of the person, and other chemical conditions in the mouth.

Because mercury is a heavy metal capable of traveling long distances across international boundaries, with subsequent deposition in all countries, including the U.S., reduction of mercury emissions and other releases of mercury should be managed at the global level.[16]

Part II will look at anticipated climate change reactions and present potential solutions...

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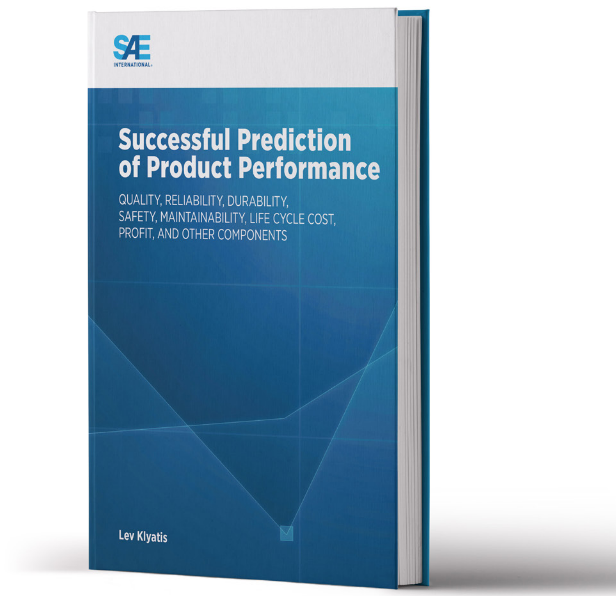
16 "Toxic Substances Portal" https://www.atsdr.cdc.gov/phs/phs.asp?id=112&tid=24

Book Review

John Blyler

Successful Prediction of Product Performance
by Lev Klyatis



This book approaches the prediction of product performance by focusing on safety and reliability issues during the early part of the product life cycle. As the author points out, most recent publications in this area concentrate on post-manufacturing economics and injury recall issues that result from poor product quality, reliability and durability. The source of these problems is the inefficient or inadequate prediction of product safety, reliability and other "ilities" performance components that should have been determined early in the design and manufacturing process.

The goal of successful product performance prediction (or product efficiency) is to mitigate problems that will eventually affect product performance during its service life. Performance problems often arise from the interaction of components in areas such as safety, quality, reliability, durability, maintainability, recalls, profit, life-cycle cost, and others.

Prediction of even modestly complex technical-human systems is a tricky exercise at best. The author points out that most books don't cover industrial product performance but rather deal with reliability prediction. In such cases, reliability is considered as a separate component, without interaction to other performance components. Taking a real-world approach to the subject, the author looks at how reliability interacts with other key performance components: both technical and economic.

This work is different from others in that it uses a complex integration methodology to form the basis for prediction of industrial product performance. According to the author, this new approach to prediction consists of two basic components:

- Methodology of prediction, which reflects common principles of changing parameters of the product's performance components during the service life in the real world, and
- Obtaining accurate initial information on how to change the above parameters for specific models of the product during its service life (or warranty period).

Several improvements in life cycle activities also help in improving predictions, including accelerated reliability and durability testing as an effective source of initial prediction information.

Finally, the author emphasizes the importance of incorporating field conditions such as the influence of interactions of all real-world inputs, safety problems, and human factors.

Overview of Book Structure

The book consists of eight chapters briefly described below:

Chapter 1: Terms and Definitions for Successful Prediction.

This chapter provides a long list of terms and definitions related to reliability and durability testing. To me, this seemed like an uncommon way to start the book. More common practice would place this chapter of definitions in the appendix.

Chapter 2: Analysis of Current Approaches in Simulation and Testing

Here, the author discusses the history and application of physical simulation in real-world conditions and relates it to accelerated testing in both the lab and field.

Chapter 3: Methodological Aspects as the First Basic Component of Successful Prediction of Product Performance

This chapter considers the methodology for product performance, including common principles and criteria, as well as the methodologies for reliability, durability, maintainability, quality, spare parts, recalls, life-cycle cost, and other financial components of performance.

Chapter 4: Basic Aspects of Accelerated Reliability/Durability Testing as the Second Basic Component of Successful Prediction of Product Performance

Now that the methodology has been described, the author introduces Accelerated Reliability Testing (ART) and Accelerated Durability Testing (ADT) as the second component for successful prediction of product performance.

Chapter 5: Integrated Equipment for Physical Simulation of Interacted Real-World Conditions

Here, an integrated approach to physical (environmental) simulation and test of real-world conditions is discussed. This chapter provides a good overview of traditional and more integrational environmental testing methods.

Chapter 6: Financial Considerations, Use of the Author's Approach, and Some Published Reviews to the Author's

In this chapter, the author highlights the financial costs through recalls and customer complaints of poorly designed and tested components. Several examples of financial savings through the use of ART and ADT approaches are provided. The author includes several favorable reviews to his approach to simulation, performance prediction and ART/ADT methods.

Chapter 7: Improving the Standardization of Accelerated Reliability and Durability Testing

This chapter is devoted to a summary of reliability testing related standards. The author pays particular attention to those standards related to ART and ADT, e.g. from the SAE International G-11 Division.

Chapter 8: Improvement in Engineering Culture for Successful Prediction

This chapter begins with an analysis of cultural interactions in engineering. The later part of this chapter is devoted to a comparison between ART/ADT and accelerated life testing (ALT), among other techniques.

In summary, this book addresses methods to improve product quality, reliability, and durability during the product life cycle, along with methods to avoid costs that can negatively impact profitability plans. The author's approach incorporates components that are based on simulations in the laboratory. The results are combined with in-field testing to determine degradation parameters. Among the methods of analyses included are Accelerated Reliability Testing (ART) and Accelerated Durability Testing (ADT).

I found this book to be a good review of reliability and environmental testing – especially for automobiles - in addition to providing motivation for Accelerated Reliability Testing (ART) and Accelerated Durability Testing (ADT).

About the Author

Lev M. Klyatis, Hab. Dr.-Ing., Sc.D, Ph.D, is Senior Consultant at SoHaR, Inc. and a member of the board of directors of the International Association of Arts & Sciences in New York. His vast experience and innovation enabled him to create a new approach for the solution of reliability/durability/maintainability problems. Previously, Dr. Klyatis held posts as a professor, chairman, chair of department, consultant, and lecturer. He holds more than thirty patents worldwide, and is the author of dozens of papers as well as the books Successful Accelerated Testing and Accelerated Quality and Reliability Solutions.

About the Authors

Measures of Effectiveness through Transfer Characteristics of Black Boxes

Jerrell Stracener, Ph.D. is Senior Research Associate in the Southern Methodist University (SMU) AT&T Center for Virtualization with research focus on US defense applications and systems effectiveness.

Previously he was Professor of Practice and Founding Director of the SMU Systems Engineering Program. He taught graduate-level courses in engineering probability and statistics, systems reliability and availability analysis, integrated logistics support (ILS), and performed/directed systems engineering research and supervised PhD student research.

Prior to joining SMU full time Dr. Stracener was employed by LTV/Vought/Northrop Grumman where he conducted/directed systems engineering studies and analysis, and reliability engineering activities and was ILS program manager on some of the nation's most advanced military aircraft programs.

Dr. Stracener was co-founder and leader of the SAE Reliability, Maintainability and Supportability (RMS) Division (G-11) and is an SAE Fellow and an AIAA Associate Fellow. Jerrell served in the U.S. Navy and earned both PhD and MS degrees in Statistics from SMU and a Bachelor of Science in Math from Arlington State College (now the University of Texas at Arlington).

John M. Green is currently a Senior Lecturer in the Systems Engineering Department at the Naval Postgraduate School. His previous positions included Senior Principal Systems Engineer with Raytheon Naval and Maritime Integrated Systems in San Diego where he researched interoperability issues related to Network-Centric Warfare and worked on the architecture for Common Command and Control. Before Raytheon, he was Manager of Advanced Systems at ITT Gilfillan, Van Nuys, CA where he led a team developing concepts for high-power, solid-state radars.

Mr. Green has also worked for Lockheed Martin in Moorestown, NJ where he was Technical Director for the Norwegian Frigate project and System Engineer for the Taiwanese PFG-2 Class Combat System design. In addition, he did research into advanced combat systems for submarines while employed at Electric Boat.

During his military career, Mr. Green served on a variety of ships including a submarine tender, a destroyer, a carrier, and six submarines, rising from Seaman Recruit to Lieutenant Commander.

He holds an MBA and MS in Computer Science from University of New Haven, an MA in International Relations from Salve Regina College, and a BS in Physics from Saginaw Valley State University. He is also a graduate of the Naval War College, College of Command and Staff.

Mr. Green is a Senior Member of IEEE and AIAA. He is also a member of the Military Operations Research Society (MORS); the American Society of Naval Engineers; the Institute for Operations Research and Management Science; the Association of Old Crows, and the International Council on System Engineering.

Glenn S. Tolentino, Ph.D. is a Senior Systems Engineer for the Command and Control Department at Space and Naval Warfare Systems Center located in San Diego, CA. During the past 23 years, Dr. Tolentino has been directly involved as a software and systems engineer in the design, development, integration, and deployment of national level systems in the area of Command, Control, Computers, Communication, and Intelligence Systems. Dr. Tolentino's current research interests include system of systems, complex systems lifecycle, systems reliability, operational readiness, and mission reliability. Dr. Tolentino holds a Bachelor of Science Degree from San Diego State University in Applied Mathematics with an emphasis in Computer Science, Master of Science Degree in Software Engineering and a Ph.D. in Computer Science from Southern Methodist University.

Global Automotive Electronics Faces Reliability Paradox

Cher Ming Tan received the Ph.D. degree in electrical engineering from the University of Toronto in 1992. He joined Nanyang Technological University, Singapore as a Faculty Member since 1996 and joined Chang Gung University, Taiwan in 2014. He has published more than 300 international journal and conference papers and holds twelve patents and one copyright for reliability software. He was the Chair of IEEE Singapore Section, a Senior Member of the American Society for Quality, a Distinguished Lecturer of the IEEE Electron Devices Society on reliability, the Founding Chair of IEEE Nanotechnology Chapter—Singapore Section, Fellow of The Institution of Engineers Singapore, Fellow and an Executive Council Member of Singapore Quality Institute. He is an Editor of the Scientific Report, Editor of IEEE Transactions On Device and Materials Reliability. He is also the Series Editor of Springer Briefs in Reliability. Currently Dr. Tan is the Director of Centre for Reliability Sciences & Technologies, Professor in Department of Electronic Engineering and Institute of Radiation Research, College of Medicine of Chang Gung University, Professor in Department of Mechanical Engineering, Ming Chi University of Technology, and serve a position in Chang Gung Memorial Hospital.

Udit Narula received his B. Tech. degree from Maharshi Dayanand University, Haryana, India, in 2011, and the M. Tech. degree from Amity University, Noida, India, in 2013. He is currently working as a Research Scholar in Centre for Reliability Sciences & Technologies, Chang Gung University and pursuing Ph.D. degree in the Department of Electronic Engineering. His research interests include Graphene-based ULSI Interconnects, Graphene Synthesis methods and Component/System Reliability Analysis and Statistics.

Dipesh Kapoor received his B. Tech. degree from Maharshi Markandeshwar University, Ambala, Haryana, India, in 2012, and the M. Tech. degree from Amity University, Noida, India, in 2014. He is currently working as a Research Scholar in Centre for Reliability Sciences & Technologies, Chang Gung University and pursuing Ph.D. degree in the Department of Electronic Engineering. His research interests include Electromagnetic Interference and compatability (EMI and EMC) and Component/System Reliability Analysis and Statistics.

New Technique Localizes Defects in 3D Chips for Reliability and Failure Analysis

Kristof J.P. Jacobs is a postdoctoral research fellow from KU Leuven at imec. He is part of the reliability group where his research focuses on failure analysis for 3-D technologies. His other research interests include semiconductor material/device characterization and terahertz (THz) technology. He holds a MSc in Electronic Engineering and a Ph.D. in Semiconductor Photonics from the University of Sheffield, UK. His thesis research was conducted on the manufacturability of high current density resonant tunnelling diodes for THz technologies. During his doctorate, he developed new growth, process, and characterization technologies for the realization of compact THz sources in partnership with Rohm Semiconductor, Japan.

Anticipated Climate Change with Implications for the United States

Ms. Katherine Pratt is a leader in the development of environmental logistics as a career field. After 13 years as a logistics professional for major U.S. Corporations, Ms. Pratt founded EnviroLogistics, Inc. Her firm provides business redevelopment, expansion, economic and environmental conversion services to commercial, environmental, and the defense industry sectors. Ms. Pratt is a Coordinator and provides Technical Support to the RMSP Partnership as the Membership Chair and Coordinator of Professional Activities. She was a senior member of the Society of Logistics Engineers (SOLE), a member of the Base Closure Initiative Committee, and a member of the Standing Committee on Environmental Applications. She was also the SOLE Rhode Island Narragansett Chapter Chairwoman. Ms. Pratt has published a variety of logistics and environmental articles. The published works are libraried in 140 libraries.

Colophon

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