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The Status and Prospects of Reliability Technology - Part 1

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Editor's Note: The following is the first of a two-part theoretical statistical article that, in part 2, proposes using "diffusion" models for reliability prediction. (One such model is the Birnbaum-Saunders distribution, which Mann, Schafer and Singpurwalla describe in their book as a fatigue-life model that can provide "a probabilistic interpretation of Miner's rule.") We are publishing Dr. Strelnikov's article as an opinion piece and to provide some insight into East European and Russian reliability work, specifically his thesis about diffusion models. We seldom include theoretical pieces in the Journal but are making an exception in this case. We welcome our readers' comments on the opinions expressed.

This article provides a survey of reliability problems that are the subject of research and an analysis of why many of today's "solutions" are inadequate. It presents new methods for solving reliability problems more effectively.

Introduction

The theory of reliability is comparatively new, appearing as an applied mathematical science in the last 50-60 years of the 1900s. It was developed when large and complex systems began to emerge in the military and commercial sectors. These include missile systems, national and international communication systems, information computer systems, and transportation systems.

All reliability research is directed to:

- Estimating and predicting the reliability of items during design (a priori methods).
- Experimentally estimating the reliability measures (i.e., verification of the design level of reliability) based on the results of testing or operation (a posteriori methods).
- Providing a predetermined level of reliability by optimizing the preventive maintenance strategy, correctly assessing the amount of spares, etc. (the optimization problem).

Traditionally, the theory and practice of mechanical and electronic reliability were developed separately. Existing methods of dealing with the reliability of systems and equipment in Russia and abroad are unsatisfactory given the requirements and level of production technology. In surveying the status of reliability research technology for the last few years [1, 2], we find that researchers often express disappointment in the frequent and large divergence between predicted and obtained values of reliability measures. Also, more and more firms are eliminating their reliability departments.

In this article, the author explores the deficiencies in reliability research and discusses new and novel probabilistic-physical methods that make it possible to attack basic problems in reliability on a new level, compared with traditional methods.

The Status of Reliability Research

Basic problems in reliability of machines and equipment (i.e., establishing the regularities in the occurrence of failure and evaluation of quantitative measures of reliability) may be solved in two different ways. Currently, most practitioners use an approach based on probabilistic concepts (a strictly probabilistic theory). In this method, failures are treated as abstract random events and the status of an item is reduced to one of two states: good and failed. The method of determining the item's reliability then consists of the following steps. First, on the basis of testing or operation, the statistics of item failure is derived. Then, using known statistical criteria of truth (chi-square and others), the most suitable

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model of statistical distribution of random quantities (exponential, normal, Weibull, lognormal, etc.) is selected and used as the theoretical model of the distribution of the reliability performance probabilities (model of reliability). The model serves as the basis for all quantitative measures of reliability. The estimate of a system's reliability is derived by calculating the probability of the up states of all the system elements. It should be noted that the primary statistical methods of estimating reliability included in basic methods and standards are ineffective for newly-designed, very high reliability or one-of-a-kind, items, or whenever the statistics of failures are scant or unavailable. In addition, the absence of a connection between the reliability measures and the physical characteristics of the items and external conditions of operation makes it impossible to effectively control the design to provide the necessary level of reliability.

Strictly probabilistic conceptions of reliability were recognized as insufficient early in the development of reliability as a science. Academician B.V. Gnedenko, exploring more effective theories of reliability, noted in the foreword to work [3] that "inclusion in the theory of reliability of the physical conceptions about wear processes undoubtedly is necessary to promote broader application of reliability theory and practice." In the works of B.C. Sotskov [4], R. Haviland [5], and other researchers, it is suggested that a combination of the probability approach with "deep understanding of the physical nature of the processes affecting the item" is the best direction for further development of reliability theory and techniques. These works pioneered the study of the reliability and strength of items considering mechanical-physical-chemical characteristics of the latter and the conditions of their operation and storage. Thus, unlike the strictly probabilistic approach, the second way of determining quantitative measures of reliability is based on studying mechanical-physical-chemical properties and some physical parameters of items, characterizing the technical state of the latter, using probabilistic methods.

The method of establishing quantitative measures of reliability on the basis of studying physical parameters that characterize the technical state of items, involves defining kinetic regularities of the degradation processes (constructing mathematical models of the degradation processes) and determining the analytical relationship of these regularities to reliability measures. Currently, it is possible to choose from the two approaches to the solution of reliability problems on the basis of studying kinetics and dynamics of failures.

In studying the reliability of the electronic equipment items, the most widespread method is the so-called method of "physics of failures" (physical), which is based on determining analytical relationships between reliability measures and the rate of physical-chemical processes derived from deterministic kinetic equations. These kinetic equations are usually linear or exponential, or are based on the Arrhenius, etc. The underlying assumption is that deterministic relationships describe averaged effects and include average values. The method then makes it possible to establish the relation between some main measures of reliability (the expectation of the operating time to failure or rate of failures) and the physical properties or physical parameters of items and the conditions of their operation. In turn, the deterministic approach of the physical theory of reliability has two directions: phenomenological [6] that employs the regularities of the physical-chemical processes, and regression [7] that involves the experimental establishment of the relation between the mechanical-physical parameters and loading conditions and reliability measures. It is important to note that in the past few years, because of inadequate predictions on the basis of failure rate, interest in the "physics of failure" [8] has grown. From a methodological standpoint, it is the next logical step in the development of the reliability theory for electronic parts (the third after 1965).

The development of physical (causal) theory of reliability, i.e., identification of the failure mechanisms and their influence on the item's reliability, allows effective improvements to be made to production processes and eventually the item's reliability. But the pure physical (deterministic) approach does not permit the absolute values of the probabilistic reliability measures, particularly, the distribution of time to failure, to be directly determined. That is, the regularities of the failure distribution are not directly related to the physical characteristics of the items. It should be noted that with such an approach, the models either simulate some prevailing processes of component degradation, or the numerous coefficients are obtained for specific testing conditions. The generalization of the results thus obtained even to a similar object but for different test conditions may yield only a rough estimate. Undoubtedly, further development of the "physics of failures" will improve the estimation of the reliability of electronic components, but it will not contribute to solving the problem of predicting the reliability of electronic systems.

Selecting a Theoretical Model of Reliability

After reviewing the works on reliability from the past several years, one can conclude that the main body of the work is devoted to formulating and solving all kinds of optimization problems and to the problems of developing confidence intervals for the reliability measures from testing or operation. Many works are devoted to improving the exponential model using all kinds of empirical coefficients. Recognizing that some positive improvements have resulted from these studies, it is necessary to note that the problem of selecting a theoretical model of reliability still receives little attention.

It is known that in the case of practically all reliability problems, the choice of the theoretical model of reliability (functions of the distribution of the operating time to failure) determines the accuracy of the estimations. In this case, the methodical errors conditioned by the theoretical model may render the results of no practical value in addressing the issue of optimization.

The number of the commonly used theoretical models of reliability is not large. The most used one-parameter model is the exponential distribution. For two-parameter models, the Weibull and lognormal distributions are frequently used. Other popular models are the Gaussian, gamma- and alpha-distributions. The exponential distribution is generally used in the case of the reliability of electronic devices and systems, and the two-parameter models are used for mechanical items. Note that all calculations, as well as optimization reliability problems, are generally solved using the one-parameter exponential distribution, since the use of the more adequate two-parameter models for obtaining accurate solutions is associated with insuperable mathematical difficulties. For this reason, the one-parameter exponential distribution is often used to solve the reliability problems even for mechanical items, where it is not recommended.

Reasons for Inadequate Reliability Estimates

The major problem in making reliability estimates is the inappropriate use of the one-parameter exponential distribution. On the one hand, the use of the exponential model simplifies the estimation problem; on the other hand, the essential constraints of the model lead to obtaining very approximate results. Some conclusions, based on using the exponential model, are not sensible at best and faulty at worst. For example, the exponential distribution fails to account for aging and wear, and necessarily excludes factors such as material selection in manufacturing or preventive maintenance processes in operation. The exponential distribution has a maximum density of failures (rate of failures) at the instant of start-up (switching on); that is, it corresponds to low technology and quality of manufacturing. In other words, the worse the equipment performs, the more suitable the exponential distribution is for describing the reliability. All the moments of the exponential distribution are constant values, beginning with the second one (the coefficient of variation always equals to unity, the coefficient of asymmetry to two, and the coefficient of excess to nine). The latter testifies that the researchers deal actually with the expectation, i.e., the time to failure is, in fact not considered to be a stochastic value. The drawbacks of the one-parameter exponential model become particularly evident when it is applied to long-term predictions. Thus, the predictions of the mean life for high-reliability electronic items or of gamma-percentage life for very small levels of failure probability differ 50-100 times and more from the predictions made using more adequate two-parameter models [9].

Experimentally assessing reliability is known to be an obligatory stage and actually the main way of determining the actual level of reliability achieved in the processes of designing and lot production of the items. Compliance tests generally of limited duration are the most widely used ($t_u << T_0$, where t_u is the duration of the test, T_0 is the controlled value of the mean operating time to failure). Since by its formal properties the exponential law allows the largest quantity of failures during the initial period of operation, the real level of reliability of the tested items turns out to be lower than the controlled one. Presently, typical test plans lead to overrating the real reliability level (mean operating time) by 2 or more times for items of the PC, TV-set type and others. For high-reliability items such as integral microcircuits, semiconductor devices, etc., the prediction of the mean life is overrated by 50 times or more [10].

When using the exponential distribution, a very rough assumption must be made about the constancy of the failure rate because the real value of the failure rate within the operating time interval being considered changes (increases) several times. This is one of the causes of the enormous methodical error of the calculation of the reliability of systems on the basis of the failure rate of the elements (lambda-method). It has been determined [10-12] that estimating the mean operating time to failure of systems using the exponential distribution (lambda-method) yields $\sqrt{n}$ times underestimated values, where n is the number of elements in the system connected in series from a reliability perspective. Therefore, practical application of the exponential distribution in predicting, for instance, the mean operating time to failure leads to an essential *overrating* of the reliability of individual elements (devices with small quantity of elements) and also to an essential *underrating* of the reliability of large systems (over 10^5 elements). These errors, which may have different signs (overrating or underrating), have been the source of distrust in the estimates made using the exponential distribution. In this regard, a British engineer called the lambda-method the method of "wet finger", i.e., "wet your finger and raise it in the air" [13].

In a number of works of foreign specialists [8, 13] it is justly noted that the widely used standard MIL-HDBK-217 is based on the use of the exponential distribution and cannot provide predictions of reliability with a guaranteed accuracy. It is more likely to be used as an instrument in the evaluation and comparison of new designs.

Use of the exponential model has been sharply criticized for a long time [14-15]. Yet up to now, this much-criticized model was used due to the absence of a suitable alternative that would allow solving the main problems of reliability (including the calculation of the reliability of systems) on the engineering level.

It is also important to note the following. The application of "failure rate" as a measure of item reliability performance is associated with the use of the one-parameter exponential distribution. Also, experimentally estimating the failure rate with a given accuracy requires about two times more statistical information than estimating, for instance, mean operating time to failure or the function of the distribution of the operating time (distribution probability density). This is true since "failure rate" is the ratio of two statistics (density and distribution function). Many specialists in their investigations identify "failure rate" (measure of reliability of non-repaired items) with the instantaneous failure intensity (measure of reliability of repaired items). Such identification is true only with the use of the exponential distribution, when the theoretical failure rate and the instantaneous failure intensity of the item coincide. But in reality the empirical (true) characteristics of the compared measures (failure rate and instantaneous failure intensity) have quite different regularities in time [10]. It has been found [10, 16 and 17] that the empirical "failure rate" has a non-monotonic character multi-coinciding with the density distribution curve, but differing from the traditional presentation in the form of "bath-tub curve" that is more typical of "instantaneous failure intensity". In view of the aforementioned, "failure rate" seems to be an inconvenient characteristic for the investigation of the reliability of items. The operating time distribution function (distribution density) or integral characteristics of the mean-operating-time type are more efficient in the reliability studies. The latter recommendations are not observed in the present-day theory and practice of reliability again due to a wide use of the exponential distribution.

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About the Author

Dr. Valery Strelnikov works at the Institute of Mathematical Machines and Systems of the National Academy of Sciences of Ukraine (Kiev), where he is the Head of the Science Department, the Institute's Deputy Director; and Head of the Department for Theory of Dependability and Efficiency of Computers Technique.

In addition to his responsibilities at the Institute, Dr. Strelnikov serves as the Chief Deputy of the Technical Committee of Gosstandard of Ukraine for Standardization, TC-68 "Dependability of technique." He is also the Chief of Body Certification for Technologies and Computers Technique, and the Chief of Accredited Laboratory Test of Computers Technique.

Dr. Strelnikov received his Doctor of Technical Sciences in 1990. The theme of his doctoral dissertation was "The Probabilistic-Physical Methods of Researching of Dependability of Computers Technique." He has published more than 100 scientific works and inventions. More than 10 standards (GOST, DSTU) were developed based on his scientific work.

Dr. Strelnikov was born in Sludianka of the Irkutsk region, Russia. He is married and has two sons. He and his wife reside in Kiev, the Ukraine.

Smoke Alarms - Preventive Maintenance

In Press Release # 01-020, dated October 26, 2000, the US Consumer Protection Safety Commission (CPSC) warned that smoke alarms in about 16 million homes are not operational. The Press Release was timed to coincide with the end of Daylight Savings Time. It has become standard practice to check the operation of smoke alarms and replace the batteries at the beginning and end of Daylight Savings Time.

Although about 90 percent of US households have smoke alarms installed, a CPSC survey found that the smoke alarms in 20 percent of those households — about 16 million — were not working, mostly because the battery was dead or missing.

In the US, fire is the second leading cause of accidental death in the home. Nearly 3,200 people die in residential fires each year, and more than 390,000 residential fires are serious enough to be reported to fire departments. "Smoke alarms can save lives, but they won't work if they are not maintained," said CPSC Chairman Ann Brown. "They should be tested monthly, and the batteries should be replaced at least once a year or when they make a 'chirping' sound."

According to the CPSC, consumers should test their smoke alarms monthly to ensure that they are working properly. Consumers may also want to upgrade their alarms if they were purchased prior to 1995, when long-life smoke alarms with 10-

year batteries became available to consumers. Even long-life alarms, however, should be tested once a month.

The CPSC recommends that consumers purchase smoke alarms that meet the requirements of the Underwriters Laboratories' (UL) standard. They further recommend that an alarm be installed on each level of a home outside sleeping areas and inside bedrooms.

The CPSC protects the public from unreasonable risks of injury or death from 15,000 types of consumer products under the agency's jurisdiction. To report a dangerous product or a product-related injury, call CPSC's hotline at (800) 638-2772 or CPSC's teletypewriter at (800) 638-8270, or visit CPSC's web site at <http://www.cpsc.gov/talk.html>. For information on CPSC's fax-on-demand service, call the numbers indicated or visit the web site at <http://cpsc.gov/about/who.html>. To order a press release through fax-on-demand, call (301) 504-0051 from the handset of your fax machine and enter the release number. Consumers can obtain this release and recall information at CPSC's web site at <http://www.cpsc.gov>.

Industry News

CrossTalk Focuses on COTS

The September 2000 issue of CrossTalk, The Journal of Defense Software Engineering, focused on commercial off-the-shelf (COTS) products. Although the emphasis was on COTS software, one article addressed implementing COTS open systems technology in the Airborne Warning and Control System, a system made up of hardware and software. In one article, Paul Maritz, vice president of Microsoft's Developer Group, presents his views on COTS software.

Other articles in the issue cover a myriad of topics related to COTS, including logistics support and functional testing.

Ian Knowles Receives the Order of the British Empire

[Editor's Note: This article was reprinted from the Ministry of Defense (MOD) CODERM Newsletter with the kind permission of the WLS 2b, MOD. Ian is well known to many in the US reliability community and was a regular participant in the SAE G-11 and the annual RAMS. All of his American friends congratulate Ian on this well-deserved honor.]

Comings and Goings (or even Gongs!)

What is the connection between a member *of Dire Straits and someone who practices psychosexual medicine?* The answer is Ian Knowles. Ian was appointed an OBE [Order of the British Empire] in the New Year Honour lists and, in the Times Newspaper, his name was sandwiched between the two recipients above.

Ian is the 5th engineer in his family: his great-great-grandfather was a mill engineer in Lancashire, regarded as a "wizard" since he could use a slide-rule.

Although Ian obtained good "O" and "A" levels, an impoverished County Council meant that he could not take up his place at Manchester University. Therefore he got a job as an engineering apprentice with De Havilland Aircraft Company at Lostock, and after working all day would cycle to Salford Technical College to qualify for a BSc (Eng). This degree came from London University in 1963. More importantly, he felt, he became "apprentice of the year" at De Havilland.

Ian is a member of the IMechE, qualifying under their own examination system rather than with his degree: a dual-redundancy situation!

Ian receives his OBE from Queen Elizabeth
With the kind permission of British Ceremonial Arts, Ltd.

In 1964 he was seconded by the then Hawker Siddeley to Consberg in Norway to work for 6 months on a NATO project. He stayed for 5 years, and became fluent in both Norwegian languages, and learnt to ski well. He decided to return home in 1969 and joined the AEI, working on electron microscopes. When investment in research projects was cut back, he became chairman of the escape committee, tunnelling out in 1971 when he joined the MOD.

He had 15 years in the world of Reliability from which he has never been able to escape. He was the Principal R&M Engineer for the development of R&M engineering policy. He is a "world-known" figure in R&M and has been the lead figure in promoting R&M in MOD, with UK Industry, in NATO, at the SAE, IEEE and other organisations here and abroad.

Ian said he was delighted and honoured to receive his award and that it was a reflection of the work undertaken by the whole R&M community. We wish Ian many congratulations on a well deserved recognition for his work, and both Ian and Anna all the best for the future in Ian's retirement from the "service".

Reliability Web Sites

For an extensive list of sites covering topics related to reliability, maintainability, quality, and supportability, visit the RAC's own web site at <http://rac.iitri.org/>. At the main page of the RAC web site, simply click on "Related Web Sites."

For each site, the URL and a short explanation are given. Visitors to our site can obtain lists of web sites for the following categories.

- *List of All Related Web Sites*
- *General DoD & Government Resources*
- *General Search Engines*
- *Maintainability Resources*
- *Quantitative Data Sources*
- *Quantitative Reliability-Related Resources*
- *Reliability-Related Professional Societies*
- *Resources Related to Automatic Test Systems*
- *Resources Related to Quality*
- *Resources Related to Software*
- *Resources Related to Structural Integrity*
- *Test Laboratories*

Joint Advanced Health and Usage Monitoring System

Part of most reliability-centered maintenance programs is some form of monitoring to assess the condition, or "health", of a system, subsystem, or assembly. Often, the monitoring is done in "real time" and the data collected can be used not only to identify required maintenance but also to allow the operators to take action to avoid a catastrophic failure.

One system for which such monitoring has proved valuable is the helicopter. The environment of a helicopter presents numerous challenges. Vibration and structural loading are just two problems that can compromise helicopter safety and reliability, and ultimately affordability and readiness. The Helicopter Usage and Monitoring System (HUMS) is being used by many agencies to:

- Monitor parameters such as rotor track and balance, engine performance and health, gearbox and drive train health, and structural usage
- Track fatigue life
- Provide information for maintenance trending.

The Joint Advanced Health and Usage Monitoring System (JAHUMS) is a DoD-sponsored Advanced Concept Technology Demonstration (ACTD) to demonstrate advanced HUMS technologies and an open systems approach to HUMS deployment. The JAHUMS ACTD is currently developing five technology modules to be integrated into the Integrated Mechanical Diagnostics (IMD) HUMS for the SH-60 aircraft, a joint Stage I prototype demonstration under the Office of the Secretary of Defense's (OSD) Joint Dual Use Program Office Commercial Operations and Support Savings Initiative (COSSI). The IMD project is managed for the Government by a joint integrated project team from the Naval Air Systems Command, representing the H-53 Helicopters Program Office (PMA-261) and the Multi-Mission Helicopters Program Office (PMA-299). The technology modules from JAHUMS will provide new functionality and new technology for the HUMS.

Open systems and technology insertion for HUMS involve both business and technical practices. The business issues involve the clear definition of roles, responsibilities, liabilities, and compensation throughout the HUMS life cycle. The technical issues affect the way that system engineering, component development, and system integration must be performed. Open standards will encourage the development of system components by multiple sources. Successfully integrating the system, however, requires an effective systems engineering effort, a well-defined integration and verification process, and life-cycle support to ensure that the system is adequately integrated into the end-users' systems and processes. Critical to the process is a systematic approach to developing open architectures and standards so that all stakeholders' objectives are satisfied.

To learn more about IMD HUMS for the SH-60 aircraft, visit the Helicopter Integrated Mechanical Diagnostics (IMD) Health & Usage Monitoring System (HUMS) home page at <http://pma261.navair.navy.mil/>. For more information on the JAHUMS, contact Dr. David Haas at (301) 227-1397.

Reliability and Maintainability Snippets

Improving Engine Durability – A collaborative government-industry effort is developing a high-speed pyrometer to measure and monitor the surface temperatures of jet engine blades with a ceramic coating. The new instrument will enable jet engines to be operated at higher combustion temperatures, increasing efficiency while improving durability and lowering emissions. The participants are the Ohio Aerospace Institute, Air Force Laboratory (Wright-Patterson AFB), Arnold Engineering and Development Center (Arnold AFB), NASA Glenn Research Center, Pratt & Whitney, General Electric, and Rolls-Royce.

New Welding Technique Improves Reliability – A friction stir welding process, developed by the Welding Institute in the United Kingdom, reportedly eliminates cracks and porosity, problems induced by traditional welding techniques. Conventional welding requires that the metal be melted. In the new technique, a high-speed tool generates heat through friction, plasticizing the metal. The result is a high-strength weld.

Checking for Stealth – A new technique ensures that structural repairs to the Air Force's F-117A have not compromised the aircraft's stealth characteristics. The heart of the technique is a holographic, three-dimensional radar camera. Developed by DOE's Pacific Northwest National Laboratory, a prototype of the hand-held camera operating in the Ku band at 12-18 GHz has been built and demonstrated. A second camera, operating in the X band at 8 to 12 GHz is now in development.

Extending Life of Engine Components – An aircraft engine repair technique developed by Morgan Advanced Ceramics' WESGO Metals Division will restore the efficiency and extend the life of cold-section compressors and super-alloy-hot section components. The repair technique is called PreSintered, or PSP.

New DoD Uprating Policy

The Department of Defense has issued a new policy on using components where they will be operated at temperatures outside the manufacturer's specified temperature range (a practice referred to as "uprating"). Uprating is sometimes necessary and acceptable, but can, if used improperly or without a thorough understanding of the risks, compromise reliability and performance. For that reason, the RAC has chosen to reproduce the policy letter here in its entirety.

SUBJECT: Using Components Outside Manufacturers' Specified Temperature Ranges

The Under Secretary for Acquisition and Technology advised diligence in pursuit of the integration of commercial products into our weapon systems to be certain that we do not invalidate technical requirements by misapplying commercial components. Microelectronic components are an area of particular concern. As we pursue greater weapon system capability, we find that some advanced technologies are available only in commercial temperature range parts. Further, the Department and industry alike are facing problems with obtaining legacy parts rated for extended temperature ranges. Original Equipment Manufacturers (OEMs) are increasingly looking at the option of using components in temperature ranges wider than those specified by component manufacturers. This practice is known as uprating.

Component manufacturers generally oppose uprating and will only guarantee parts when they are used according to their specifications. But increasingly, OEMs and program offices are finding that there is no alternative. Little guidance exists on how to do uprating in a way that considers and minimizes risk. Two guideline documents have been developed in an attempt to manage this practice. The first guide, "Avionics Industry: Guide for Using Components Outside Manufacturers' Specified Temperature Ranges," was developed by an Avionics Working Group (AWG) of the International Electrotechnical Commission Quality Assessment System for Electronic Components (IECQ). This guide offers practical advice on how to document and control the processes by which equipment contractors uprate components for use outside component manufacturers' specified temperature ranges.

The second guide, "Parts Requirements and Application" was developed by the Navy and is now a Defense Standardization Program Guide SD-18. This manual offers extensive information to help guide the selection, design, procurement, and assessment of parts used in military systems.

It is critical that we do not jeopardize performance of our weapon systems for the sake of insignificant cost savings. However, it is equally critical to ensure that we can support legacy systems, and in new design, to avail ourselves of the best technology the commercial world has to offer. Both of these goals will occasionally mean using components beyond their specified ranges. When that is necessary, please ensure that your program offices and buying activities exercise care to minimize risk and manage such "out-of-spec" application. Making them aware of these two guidelines will help them to base their selection and parts management decisions on well conceived, structured plans.

Dr. Mulville, NASA Associate Deputy Administrator Addresses SAE G-11

Dr. Daniel R. Mulville, Associate Deputy Administrator of National Aeronautics and Space Administration (NASA) delivered the keynote speech at the SAE G-11 Reliability, Maintainability, Supportability, and Logistics (RMSL) Division meeting on October 23, 2000 in Reno, Nevada.

Dr. Mulville focused his speech on past, present, and future NASA programs; the need, development, and application of probabilistic analysis and tools for these programs; and opportunities for working together with industry, universities, and other government agencies.

Dr. Mulville stressed the need to do a better job of assessing risk. He said that NASA is moving from deterministic to probabilistic analysis, tools, and capabilities. NASA already conducts a number of probabilistic analyses when we launch a payload in space. For example, they conducted such analyses to ensure the highest safety standards for launches involving a nuclear payload, such as Cassini and Galileo.

As NASA looks to the future Mission to Europa, Dr. Mulville said that the probability is high that nuclear materials will be used. It is thus imperative that NASA conducts probabilistic analyses to ensure a safety level of less than one fatality over fifty years. In addition, NASA must design a suitable containment system and diligently apply the Quantitative Risk Assessment System (QRAS – developed for the Shuttle Safety Program). QRAS is based on event trees and fault trees.

To address recent satellite failures and problems in maintenance and operation of the Shuttle, Dr. Mulville said that two activities have been reinstated with involvement of industry, universities, and other government agencies. These are:

- Advanced Engineering Environment – Implement internal Design Centers at NASA JPL (Jet Propulsion Lab) and at NASA Goddard. Link NASA with universities and industry for specific products. Explore opportunities for NASA to engage with industry.
- Design for Safety – Focus on robust design, consider all risk elements as part of the design, and quantify and assess risk. Consider contingencies and robustness for contingencies as part of the simulation from concept to final operations.

Dr. Mulville concluded that NASA is headed in the right direction. He emphasized that NASA is in the business of taking risk, to "go where no one has gone before." The NASA Administrator is providing the vision and leadership needed to meet the challenges faced by NASA.

After his address, Dr. Mulville presented the SAE G-11 Division Probabilistic Methods awards.

For information on G-11, contact Gina Saxton at SAE International. By phone: (724) 776-4841, Ext: 7319 or E-mail: <ginaf@sae.org>.

Z1 Dependability Subcommittee Seeking New Members

The strategic goal of ANSI Accredited Standards Committee (ASC) Z1 is to enable US commerce and industry to compete effectively in national and international markets through the use of voluntary standards. ANSI ASC Z1 supports this goal by providing leadership and coordination in the timely development and adoption of US national standards that are responsive to user needs, and cost-effective both during development and in use. ANSI ASC Z1 is responsible for generic, national standards related to:

- Quality systems and quality management
- Environmental management
- The application of statistical techniques
- Dependability

Dependability is the responsibility of the Z1 Dependability Subcommittee (DSC). The Z1 DSC parallels the US Technical Advisory Group (TAG) to the International Electrotechnical Commission (IEC) Technical Committee (TC) 56 – Dependability. The Z1 DSC focuses on national issues related to dependability; the US TAG to TC56 focuses on international issues.

Dependability, as defined by the IEC TC56, is the collective term used to describe availability performance and the factors influencing availability: reliability performance, maintainability performance, and maintenance support performance. Although the term is not widely used within the United States, the Z1 DSC has adopted it due to its relationship to the US TAG to IEC TC56.

The Z1 DSC, like all the Z1 Subcommittees, is an accredited standards body, and has the following areas of responsibility:

- Develop National Standards on dependability
- Propose standards on dependability for adoption as National Standards
- Submit standards on dependability to ANSI for acceptance as American National Standards
- Periodically review published standards on dependability

Although the subcommittee has the authority to develop National Standards on dependability, its main focus has been on coordinating and working with other Standard Development Organizations (SDOs) to facilitate the development of useful National Standards on dependability. Since the demise of many of the military RMS standards, several SDOs have developed or are considering parallel standards development efforts. It is the view of the Dependability Subcommittee that duplicate standards are neither in the best interest of any individual SDO nor that of US business and industry.

Over the past few years, corporate support of many professional societies and organizations has decreased. As a result, groups such as the Z1 DSC have lost members. The Z1 DSC must have a balanced membership that reflects the needs and concerns of a wide range of US business and industry. The Z1 DSC invites all interested persons working in dependability-related areas to become members. Of course, the important considerations in joining any such group is to know the purpose of the group and the responsibilities of membership. The purpose of the Z1 dependability subcommitte has already been discussed. What then are the responsibilities of membership?

The sole mandatory requirement of membership is active participation. Active participation means that members should review and comment on all draft standards sent to them by the Chair of the Z1 Dependability Subcommittee. When projects are identified, members should contribute their time and talent to making the projects successful. Since it is difficult, both from a financial and schedule perspective, for many people to travel frequently, nearly all communication and the subcommittee's work is conducted via the Internet. So members must have access to the Internet.

The US Standards Group (the Z1 and TAGs associated with environmental, quality, dependability, and statistics) has a web site. The URL for the web site is <http://standardsgroup.asq.org/members/docdist/docdist.htm>. Each subcommittee has a page on the Public and Members Only side of the web site.

Two meetings are held each year jointly with the US TAG to TC56 and concurrently with meetings of the American Society of Quality (ASQ) Standards Group (ASQ administers several of the US TAGs and the Z1). Meeting attendance is not mandatory but is encouraged.

How to Join

Membership is open to all as a common national forum, although in striving for balance, membership may be denied if a particular industry is over-represented on the committee. Membership is free, but members must pay any expenses associated with attending meetings. A Membership Application must be completed and applicants must submit a biography (½-page maximum with the application. The biography should include qualifications (degrees, experience, etc.), industry represented, and special interests (i.e., maintainability, human reliability, etc.).

Membership application forms can be requested from Patricia Kopp at <pkopp@asq.org>.

For more information on Z1 and the Dependability Subcommittee, refer to the US Standards Group web site or contact the Chair of the Dependability Subcommittee, Ned H. Criscimagna, at (301) 918-1526, <ncriscimagna@iitri.org>.

New ISO President

The International Organization for Standardization (ISO) has announced that Mr. Mário Gilberto Cortopassi from Brazil took office as the organization's new President on January 1, 2001. Mr. Cortopassi will serve a two-year term.

Mr. Cortopassi is a successful industrialist. His formal training is as a chemist, and he has gained a wealth of experience in the textile and synthetic fiber industries. He has been actively involved in standardization for over 30 years.

Mr. Cortopassi stated in his inaugural message that international standards are more necessary than ever to "facilitate business, encourage free trade, and foster progress in society." He singled out standardization, metrology, testing, conformity assessment, and certification as key instruments in achieving business success in a global market.

The new President cited ISO's success in responding to market-driven requirements by modernizing its own processes to deliver standards in a timely and efficient manner. Mr. Cortopassi called for even stronger support for ISO from its constituent members, pointing out that ISO's success greatly contributes to the efficiency of the global marketplace, which in turn extends prosperity to all nations.

Statistical Analysis of Reliability Data, Part 1: Random Variables, Distributions, Parameters, and Data

By: Jorge Luis Romeu, IIT Research Institute

Introduction

Sometimes, engineers have problems understanding the basis for the statistical procedures they need when analyzing reliability data. But this is not surprising. In many engineering curriculums, the study of statistics is limited to one or two courses (3 to 4 credit hours). These courses are usually theoretical, do not address data analysis, and cover a wide range of statistical techniques. Finally, other engineering courses emphasize the physical (deterministic) rather than the stochastic laws governing the processes under analysis.

This article is the first of a series written to provide engineers with a practical understanding of statistical analysis of reliability data. This article discusses random variables, statistical distributions and their parameters, and data collection issues, including the special problem of outlier (or extreme value) detection and treatment. The second article addresses parameter estimation and hypothesis testing, emphasizing goodness of fit procedures used to identify and select suitable distributions from a given set of data. In the third article, the concepts from the first two articles will be applied to reliability estimation and assessment problems. The fourth article discusses data collection and data quality problems.

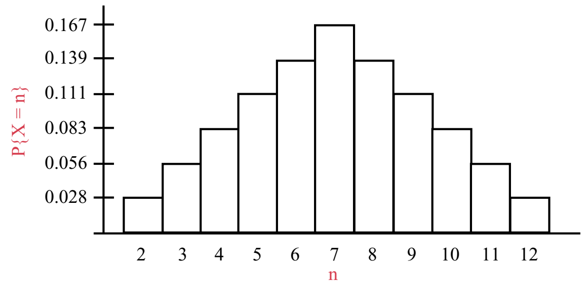
Statistical Distributions

Statistics deals with the study of phenomena and processes that (1) yield more than one outcome, and (2) occur in a random fashion [1, 2, 3, 4, 6]. Results of the random processes under observation are called random variables (RV) and are denoted with a capital letter, say X. Specific outcomes (denoted in lower case) are called "events" and the set of all possible RV outcomes is called the "sampling space". For example, from the process of rolling two dice and taking their sum, we observe X, the random variable "sum of both dice". Similarly, from the process of life testing we observe X, the random variable "life of the device". In the dice example, the sampling space consists of integers 2 through 12. An event $(X = n)$ is rolling a given sum and it occurs with a probability $(P\{X = n\})$ (Figure 1). For the life testing example, the sampling space consists of all positive values of time and an event $\{X < t\}$ is observing a life of less than t units (Figure 2).

The graphical pattern of occurrence of such random outcomes (e.g., Figures 1 and 2) provides an intuitive way to understand the meaning of the statistical distribution of an RV. The abscissa of such graphs represent the sampling space of X (all possible outcomes) and the ordinate represents a value proportional to the frequency of occurrences of the outcomes. Such graphs represent the probability density function (pdf) when the sampling space of X is continuous (Figure 2) or the mass function when it is discrete (Figure 1). The area under the curve of the mass/density function is one. The Cumulative Distribution Function (CDF) of an RV is non-decreasing, has a value between zero and one, and is defined for both the mass and density functions as:

$F(a) = P\{X \leq a\}$ where "a" is any feasible value in the sampling space of X.

Hence, all random variables have a distribution, uniquely described by one or more parameters.



DICE	1	2	3	4	5	6
1	2	3	4	5	6	7
2	3	4	5	6	7	8
3	4	5	6	7	8	9
4	5	6	7	8	9	10
5	6	7	8	9	10	11
6	7	8	9	10	11	12

x is the Sum of Two Honest Dice

P{X = n} is the probability of two honest dice adding up to a particular value, n

x	P{X = n}
2	0.028
3	0.056
4	0.083
5	0.111
6	0.139
7	0.167
8	0.139
9	0.111
10	0.083
11	0.056
12	0.028

Figure 1. Dice graphical pattern

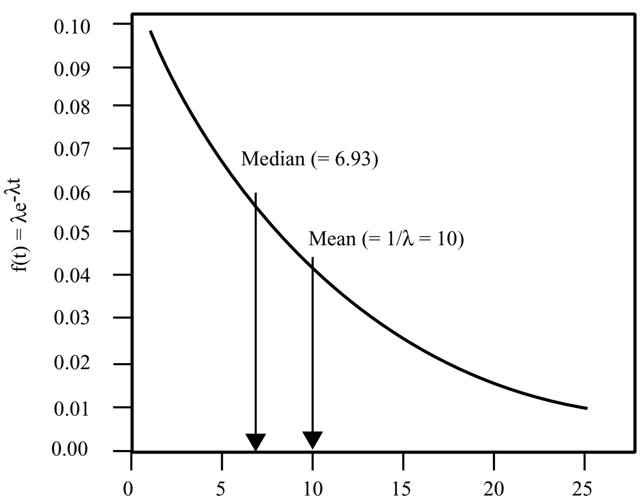


Figure 2. Exponential distribution with mean of 10

The mass/density functions provide an objective, precise way to describe the probability mechanism governing the random process that produces them. For example, contrast the (graphical) flat pattern from rolling an honest die, where the occurrence of any of its six sides is equally likely, with that of the sum of two dice (Figure 1), where a sum of 7 is more likely than that of 12, or with the decreasing pattern of the exponential (Figure 2). Such patterns (distributions) can be numerically described by a set of fixed numbers called parameters. In the sum of two dice example, the set (1/36, 2/36, 3/36, ... 1/36) of frequencies associated with the possible sums, uniquely describe its distribution (pattern). In the exponential case, the mean describes it.

Statistics is about investigating those distributions and parameters. In this series of articles both quantitative and qualitative RVs are addressed. Quantitative RVs are numerical and exhibit mathematical properties of order and distance. These RV are said to have a "stronger" measurement scale level, which allows the implementation of certain statistical methods, not always appropriate for qualitative variables [5]. Qualitative RVs (e.g., attributes such as pass/fail) are categorical or can be ordered at best.

Statistical distributions can be discrete or continuous, according to whether their corresponding RV sampling space is discrete or continuous. The result of rolling a die is an example of a discrete RV; the life of a device is an example of a continuous RV. Their corresponding graphical patterns yield step or continuous mass/density functions. The probabilities for individual outcomes (e.g., rolling a sum of 2 or observing 3 failures in the field) can be calculated for discrete RVs. The probabilities of ranges (e.g., that a device life is longer than ten hours or between three and ten hours) can be calculated for continuous RVs. For example, the probability of "rolling a sum of three or less" (denoted $P\{X \leq 3\}$) is obtained by adding the discrete mass function; the probability of "observing a life of less than three hours" (denoted $P\{X < 3\}$) is obtained by integrating the continuous pdf. These examples illustrate the one-to-one relationship between the distributions and their corresponding mass/density functions.

In addition to being discrete or continuous, distributions can be symmetric or skewed, according to whether their mass/density functions are or are not symmetric with respect to one point in their sampling space. Distributions can also be unimodal or multimodal, or have no mode, according to whether their mass/density functions have one or more (local) maximums (modes). The distribution of the RV "sum of two dice" in Figure 1, is an example of a symmetric, unimodal distribution. Its mean and mode are both 7, about which the distribution is symmetric. The exponential distribution, in turn, is skewed to the right and has no mode (peak).

As may be surmised, the number of statistical distributions that can arise is infinite, posing a difficult practical problem. To deal with it, well known and thoroughly studied "families" of statistical distributions that are easy to manipulate and fit different patterns and have a small and easy to interpret number of parameters, have been developed. Two examples of discrete families of distributions (and their respective parameters) are the Binomial (with parameters n, number of trials and p, probability of success at any trial) and the Poisson (with rate of occurrence λ). Two examples of continuous distributions are the Normal (with mean μ and standard deviation σ) and the exponential (with mean $1/\lambda$).

Often, the exact distribution of a random process under study is unknown but can be satisfactorily approximated by one of these well-known distribution families, by finding suitable combinations of parameters. If we can live with the difference between the exact probability of any event and its approximation, then we will work with the latter as if it were its exact distribution. Much statistical work is spent in (1) selecting a specifically well-suited family of distributions, (2) verifying that such selection is correct, (3) estimating adequate parameters, and (4) deriving probabilistic results with them.

The previous discussion shows that it is important to fully understand the concepts of RVs, their distributions and their corresponding parameters, because they provide an objective and precise way of describing a random phenomenon under study. Applying these concepts to a data set provides practical and useful, probabilistic statements on "events" of interest, such as "what is the Reliability of the device, if its mission time is ten hours?" Conversely, a pre-specified probability (e.g., Reliability = 0.99) may be required by designers or the procurement office, as the performance measure of a device. Therefore, samples of such devices may be drawn and tested for compliance with these requirements.

Distribution Parameters

Parameters are population-fixed values that uniquely characterize and help describe the distribution of a RV (e.g., λ in the exponential distribution). Parameters allow the graphing of the RV specific mass/density function (outcome patterns). The location, dispersion, shape, scale, and threshold parameters, all of which are widely used in Reliability applications, will be discussed.

Location parameters respond to the question "Where is the distribution?" A particularly useful subset of the location parameter is given by the three measures of central tendency: mean, median and mode. The mean is the outcome located at the center of gravity of the mass/density function graph. The median is the outcome such that half the population scores below (or above) it. The mode is the value where the mass/density function peaks (most frequent outcome). Mean and median are unique but multiple modes may coexist (in a multimodal distribution). If a distribution is symmetric and unimodal (e.g., Normal) then the mean, median and mode coincide. If it is skewed (e.g., exponential), they will differ.

If a distribution is skewed (non-symmetric), then one tail is longer than the other is, and the mean is less important than the median and mode. For example, the mean of the RV "household income" may have little meaning if the population consists of several billionaires and millions of landless peasants (it provides little information about the situation). In such a case, (1) the median income level is such that half the population income lies above and below it, and (2) the modal income level is that which is most frequent and around which there is some population clustering. The latter two parameters provide more useful and meaningful information about the population income. In addition, if we add (subtract) a few billionaires to the population, the mean will be affected, whereas mode and median will be much more resilient to such changes. Such resilience is referred to as the "robustness" of a parameter and is considered a good quality.

Other location parameters of interest are the quartiles and the percentiles. A percentile is an outcome value within the sampling space of the RV such that a given percent of the population scores a result less than or equal to such outcome. For example, by definition the median is the fiftieth percentile (because 50% of the population scores less than or equal to it). Other important percentiles are the lower (1^{st}) and upper (3^{rd}) quartiles. They define values where 25% of the population (75% of the population) are less than or equal to such quartiles. Between the 1^{st} and the 3^{rd} quartiles lie half of the population closest to the center (median). The "Characteristic Life" of the Weibull distribution is an example of a percentile (63.2%) with a well-known engineering interpretation.

Dispersion parameters respond to the question "How does the random process vary about some location parameter?" Some well-known dispersion parameters are variance, range, and Interquartile Range (IQR). The standard deviation is the square root of the variance. In a Normal distribution, the standard deviation yields the distance from the mean to the abscissa of the inflection point of the density function. The range is the difference between maximum and minimum outcomes. The IQR is the difference between the upper and lower quartiles.

Dispersion parameters are used to characterize or compare population variability. And variability is always associated with risk in statistics. If, for example, the means of two positive RV are the same, their variances can be compared directly. But if the means differ, then an indirect dispersion parameter, such as the Coefficient of Variation (the ratio of the standard deviation to the mean, for a positive RV) is used. Also, as distributions depart from symmetry, the IQR is more useful than the variance for the same reasons that the median and mode are more useful than the mean.

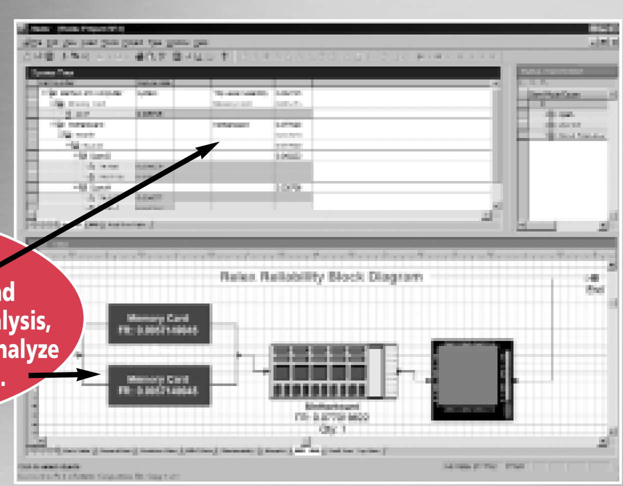
By varying the shape and scale parameter, a specific family of distributions can describe a specific population (i.e., by obtaining a good fit or approximation to the exact RV distribution). A Weibull, for example, can approximate a Normal or exactly describe the exponential by adjusting its shape parameter. Other useful parameters include the threshold parameter, which provides a lower bound for the RV range of possible values. The Weibull [4] is a good example of such a three-parameter distribution. It is also worth noticing that, in most distributions, the mean and variance are no longer density function parameters (e.g., Normal) but are obtained as a function of the shape and scale.

Finally, Skewness and Kurtosis are two parameters that describe a distribution's degree of (dis)symmetry and peakedness. Parameters help visualize the outcome patterns of an RV, which allows us to better understand them.

Extreme Values or Outliers

Data analysis begins with identifying a suitable family of distributions, and its corresponding set of parameters, that accurately characterizes the random phenomenon under study. We then can analyze the distribution behavior, especially in the tails, where the real "action" takes place. For it is in the distribution tails where a distinct behavior really occurs, a fact particularly important in hypothesis testing. Hypothesis testing allows us to ascertain whether an unusually high or low observation may have a reasonable probability of occurrence, or whether such an unusual observation constitutes a "rare event" under the current model assumptions, signaling out a possible anomaly (e.g., some assumptions made are wrong).

(Continued on page 14)



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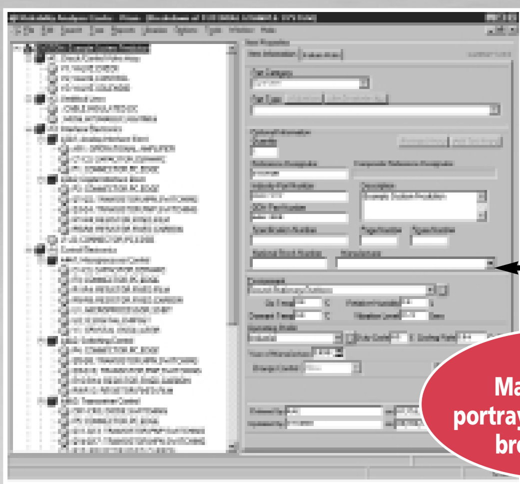

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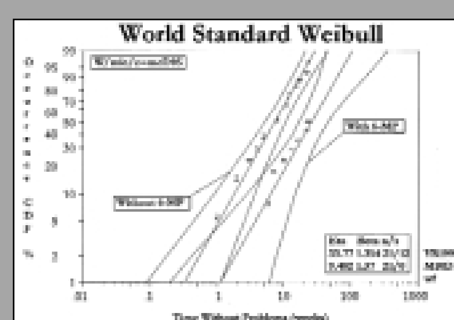

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Statistical Analysis of Reliability Data (continued from page 11)

An "outlier" or "rare event" is defined as an observation (in the tails of the RV range) that occurs with a very small probability. It is incorrect to believe that an outlier is always an erroneous observation or that it should be automatically removed from the sample. In the dice example, the sum 12 occurs with probability 1/36=0.028 but may occur at any trial with that probability. We may perform the dice experiment three times in a row and roll three sums of 12 (an event that occurs with probability 2.14 x 10^{-5}, very small but not zero). As another example, if the life of a device is exponentially distributed with a mean (i.e., $1/\lambda$) of 100 hours, we may observe one device that lasts more than 500 hours, although the probability of such an event is only 0.0067.

These "outlying" events seldom occur, but they can, and sometimes do! They may provide grounds for us to believe that (1) the dice are loaded or that the actual mean life of the device is more than 100 hours or (2) that we have been extremely lucky or unlucky and have observed a "rare event". The occurrence of low-probability results raises a red flag but does not ensure foul play. What statistics provides is a useful and scientific context in which to analyze them.

For example, in a particular life test we may observe that a large number of otherwise acceptable devices fail. We observe that in all previous life tests (say 99) of the same device, we did not observe such a high number of failures. Such a result is a "rare event" (occurs once in 100 times), and we may be tempted to automatically discard it as an "anomaly" and assume the information provided is erroneous. But we may well be discarding very useful information. It may happen that, say, an unusual combination of humidity, temperature and pressure, that only occurs once in a 100 times, greatly affects the failure mechanism of the device. And it may be that the life test in which we have observed such large number of failures was conducted precisely under such unusual conditions. If instead of discarding these unusual test results as "outliers" we submit them to further lab and statistical analyses, we may be able to discover the real reasons behind them.

On the other hand, rare events and outlying observations often result from clerical errors or some other unrelated circumstances. Such cases do warrant discarding the unusual observation because it no longer "represents" the population under analysis. Only in this case is it proper to remove such elements from the data set.

Data Collection

We've discussed "observations" of events, data points obtained by gathering information from the population of interest or under study. Such data constitute the life and blood of statistical analysis. Hence, the next few paragraphs focus on the important subject of data collection.

We collect a sample of data from an entire population to study it and do not have the time or means to look at it in its entirety. But we want our data analysis results to be valid for the entire population and not just the sample. To extend our analyses results from sample to population (called "extrapolation" in statistical terms), the sample must meet several criteria.

The sample must be *representative* of the population. Hence, the sample must be randomly drawn from the entire population of interest and sample elements must be independent. A draw is *random* when every element has the same probability of being selected. Two draws are *independent* if one result does not, in any way, affect the other.

Finally, data collection is very expensive and time consuming. On the one hand, we strive to get as much data (information) as we can afford. The more information we obtain (larger sample), the smaller the margin of error and the more precise the estimates. On the other hand, time and budget constraints force us to work with samples much smaller than we might desire. Good statistics helps us to extract as much information as possible from these samples or to define the optimal sample size to meet our requirements.

Conclusions and Summarization

Statistical analysis is more than just the mechanical application of a set of fixed procedures and equations. In fact, many statistical procedures and equations result from the systematization of the process of scientific experimentation, developed under certain statistical assumptions and conditions. If such underlying assumptions and conditions (e.g., normality, independence, homogeneity of variances, etc.) are not met, then the analysis results obtained from the statistical procedures used are not valid or will have a different statistical interpretation (i.e., different probabilities of occurrence).

This article and those that follow in the series provide additional insight into the statistical thinking process. By applying statistical thinking to their analysis, engineers will improve their use of statistics as a reliability analysis tool and will extract greater benefits from their data analysis work.

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Calls for Papers

A Call for Papers has been issued for the 2001 Military & Aerospace/Avionics COTS Conference, Exhibition, and Seminar. The conference will be held at the Renaissance Portsmouth Hotel and Waterfront Conference Center in Norfolk, VA on August 14-17, 2001.

This conference, for the past thirteen years, has been dedicated to issues related to the quality, availability, reliability, and cost effectiveness of microelectronic technology and its insertion into high performance, affordable systems. Commercial-off-the-shelf (COTS) issues include the application of non-military plastic encapsulated microcircuits (PEMs) on commercially produced printed circuit boards and assemblies used in these systems. Discussion will include recent developments in and future directions of microelectronic technology. The conference will continue to highlight the insertion of commercial technology, i.e., plastic encapsulated packaging and low cost assemblies, into military, aerospace and avionics equipment.

Prospective authors are requested to submit five (5) copies of a one-page abstract to the Conference Chairman by May 1, 2001 for review by the Program Committee. Abstracts must include, for each author, the name of the author; the author's affiliation; and the author's complete address, E-mail, and fax and telephone numbers. Abstracts will be selected on the basis of technical merit, supporting test results, and overall suitability. Notification of paper acceptance or rejection will be mailed by May 15, 2001. The Conference Chairman is:

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The Call For Papers & Tutorials may also be accessed in full on the worldwide web at: <http://www.rams.org>.

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New Guidance for Using Performance-Based Standards

The Pentagon has released a new guidebook that helps procurement officers buy services using performance-based standards. In 1999, the Defense Department spent as much money on services as it did on new supplies and systems. The guidebook (the 59-page document in PDF is at <http://www.acq.osd.mil/ar/doc/pbsaguide010201.pdf>) is the result of efforts led by former Under Secretary of Defense for Acquisition, Technology and Logistics Jacques Gansler to introduce performance-based contracting into the military services' acquisition processes.

Under performance-based contracts, agencies describe to contractors the end results needed by the government. Deciding on how best to meet those requirements is left to the contractor. "DoD has developed this guidebook as a cooperative effort… to help the acquisition team, and any other stakeholder, better understand the basic principles of performance-based services acquisition," wrote Gansler in a Jan. 2 letter accompanying the new guidebook.

The guidebook walks procurement professionals through the entire acquisition process, from crafting work statements to establishing performance standards. It also clarifies how to build incentives into contracts to encourage vendors to exceed performance standards. A 1998 study by the Office of Management and Budget found that agencies were slow to award performance-based contracts because procurement officers weren't familiar with the process.

Last April, Gansler ordered the Pentagon to make half of its service contracts performance-based by 2005. He then directed the military departments and the Defense Logistics Agency to develop a training course for procurement officers on the performance-based process. By making Defense's service acquisition policies transparent, the guidebook should also prove useful for contractors, said Allan Burman, a procurement expert and the president of Jefferson Solutions, which provided input on the guidebook. "It aids the move toward a partnership [between government and customers]. Both are focused on achieving the best outcomes," Burman said.

Non-Government Standards Adopted

On 14 December 2000, the Department of Defense (DoD) has adopted the following two non-Government standards:

- EIA Engineering Bulletin SSB-1, "Guidelines for Using Plastic Encapsulated Microcircuits and Semiconductors in Military, Aerospace and Other Rugged Applications"
- EIA Engineering Bulletin GEB1, "Diminishing Manufacturing Sources and Material Shortages (DMSMS) Management Practices"

Adoption is an expression of acceptance of a non-Government standard (NGS) for repetitive use by the DoD. The main criteria for adoption of a NGS is whether it meets the DoD needs, and if it will be used by DoD users either in direct procurement, as a reference in another document, or as a design or reference guide. While it is not mandatory for a NGS to be adopted to be used, adoption is strongly encouraged to provide for document visibility, ensure document availability to DoD personnel, and identify a DoD technical focal point. The adoption notices are available from the ASSIST Data Base <http://astimage.daps.dla.mil/>.

Larry Crow New Chair of IEST Fellows Committee

Dr. Larry Crow has been elected as the Chair of the Fellows Committee of the Institute of Environmental Sciences and Technology (IEST). Larry is an IEST fellow and an appointed member of the seven-person IEST Fellows Committee. Each year the committee elects a chair from those board members in their last year of appointment. Larry was elected as the chair for 2001. He will be responsible for coordinating the Fellow grade nominations, reviews, voting, and notification of results to the IEST president. New Fellows are recognized at the IEST Annual Technical Meetings in May.

Dr. Larry Crow represents IEST as a member of the Board of Directors (BOD) for the Annual Reliability, Availability, Maintainability (RAMS) Symposium. There are seven professional societies that sponsor RAMS, one of which is IEST. With his membership on the RAMS BOD, IITRI is recognized as a RAMS Participating Organization.

Dr. Larry Crow joined the IITRI/RAC team in 2000. Larry has a long and distinguished career in the field of reliability and related fields. While with the US Army, he developed the AMSAA-Crow reliability growth model.

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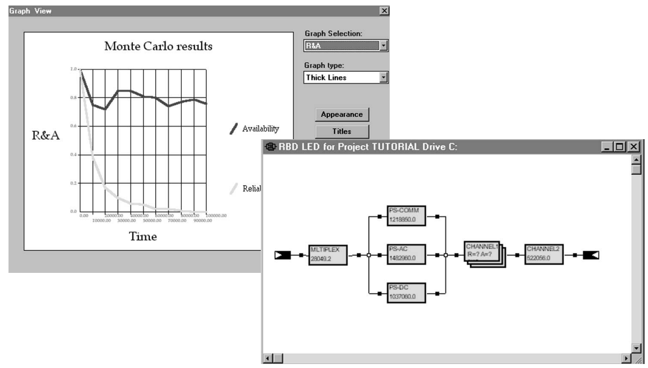

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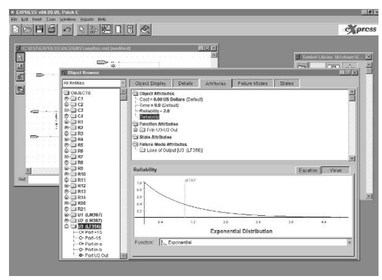

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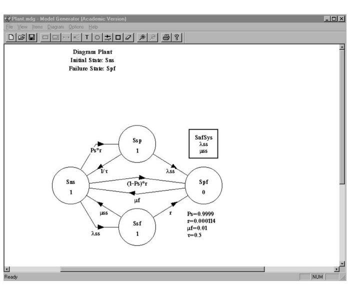

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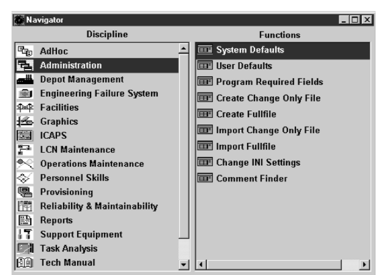

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Considering Becoming a CRE?

By: Ned. H. Criscimagna, Reliability Analysis Center

The American Society for Quality (ASQ) offers certification in several areas, one being reliability. To become a Certified Reliability Engineer (CRE), an individual must:

- Have eight years of on-the-job experience in one or more of the areas of the CRE Body of Knowledge, with a minimum of three years in a decision-making position. If an applicant has completed a degree* from a college, university, or technical school with accreditation accepted by ASQ, part of the eight-year experience requirement will be waived.
- Show proof of professionalism.
- Pass a written examination that consists of multiple choice questions that measure comprehension of the Body of Knowledge. The Reliability Engineer examination is a one-part, 150-question, four-hour exam and is offered in the English language only.

The Body of Knowledge and a study guide can be found at <http://www.asq.org/standcert/certification/cre.html>. In addition, courses and certification review material are available from several sources. Many companies that offer correspondence courses and review material advertise in Quality Progress, the journal of ASQ. In addition, classroom review courses are available from Sections of ASQ, many universities, community colleges, and consulting firms. A search of the web will find a good if not complete selection of sources of courses and review materials.

*Degrees or diplomas from educational institutions outside the United States must be equivalent to degrees from US educational institutions.

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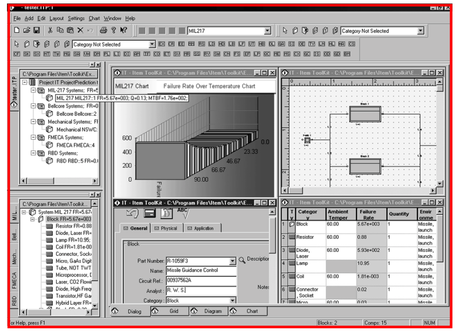

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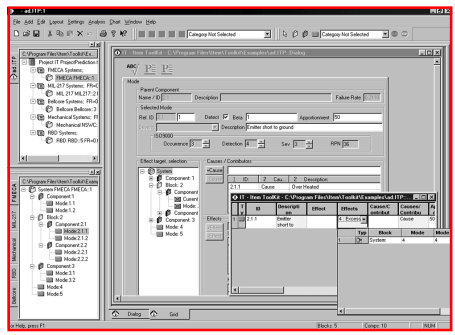

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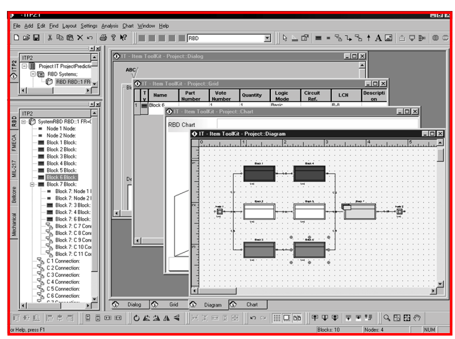

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Fax: (505) 872-0022
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Also visit our Calendar web page at <http://rac.iitri.org/cgi-rac/Areas?0>

From the Editor

The Start of a New Millennium

Although most of the hoopla about a new millennium came a year ago, I align myself with those who consider 2001 as the first year of the second millennium of the Common Era. Rather than renew any arguments about when the millennium did or did not begin, I want to do some crystal ball gazing regarding on the future challenges and promises for the R&M community over the next ten years.

Trying to see even one year into the future, let alone ten, is difficult. Most of us could not have forecast many of the events of the past year or two. Technology, human ingenuity and frailty, and chance conspire to confound even the most gifted prognosticator. Nevertheless, let's polish up the crystal ball and give it a whirl.

Areas of Concern

In previous editorials, I have identified areas of concern. The one to which I give greatest priority is management support of the reliability discipline. Recent problems as well as recent interest in reliability by new industrial sectors lead me to hope that if the pendulum has indeed swung too much to one side, it's swinging back to center. I think we'll see more demand for reliability engineers, or, more precisely, engineers with a working knowledge of reliability. Reliability requirements will become more sophisticated and will require that we have better methods for assessing and verifying reliability.

New technologies, such as Micro Electro-Mechanical Machines (MEMs) will pose new challenges for the reliability engineer. The incredibly small scale on which these machines operate means that materials behave differently than they do at the macro scale. New failure modes and mechanisms will present themselves. New analytical tools may be needed to design for and evaluate reliability. From a maintainability and supportability perspective, standardization of MEMs will be a critical issue.

Software reliability or software quality (for those who argue that software reliability has no meaning) will continue to be a crucial element of new systems. An ever-increasing portion of system functions relies on software, which means that software complexity and size is increasing at an astonishing rate. Our society is becoming much more dependent on our capability to design, build, and test reliable software. As even the most mundane of home appliances becomes software-intensive, failure-free software performance is becoming essential.

Ned H. Criscimagna

The reliability of space-based systems has always received a justifiable level of attention. Recent failures of NASA missions have called into question the "faster, better, cheaper" mantra of recent years. At the same time, I see no reason why "faster, better, cheaper" cannot exist side-by-side with high reliability. The way to achieve this coexistence is to not get too cheap, rush too fast, or try to make too big a leap at one time. If one takes a long-range view of costs, an effective reliability program reduces operating and support costs, and warranty costs, while increasing productivity and reducing risk.

Finally, given the world community's reliance on communications, the reliability of communications-related systems (e.g., computer networks, telecommunication systems, and satellite communications) must be a major focus of those who design, build, and operate such systems. Sound integration is probably the biggest challenge in achieving acceptable levels of availability for these systems.

Areas of Opportunity

Now I may be accused of taking an easy way out to finish this editorial, but I believe that the same areas that are of concern offer the most opportunities. Whether you are a grizzled veteran or a newcomer to the reliability community, the areas of concern should motivate you more than they intimidate you. Not only is the opportunity for innovation, creative thinking, and a break from tradition greater than ever before, never has it been more important to capitalize on the opportunity.

The same opportunities and challenges I've cited for the reliability community await those who work in maintainability, quality, and supportability. As we look to the next decade, we see the promises of a fully staffed international space station, MEMs that eliminate invasive surgical methods, cars with anti-collision devices, and super-fast computers with gigs of storage that we carry in our pocket. All of us who work in the RMQS disciplines can play a role in bringing these promises to practical and effective fruition. Has there ever been a better time to be alive!

Correction: In the last issue of the RAC Journal, an error appeared in "Tutorial: Test Risks, Confidence and OC Curves." The author stated on page 16, right column, that "the risk of accepting a worse rate than .05 will be lower than 12%, and defect rates higher than .05 will be accepted more often than 12% of the times they are tested to the same criteria." "Higher" should have been "better" since a higher defect rate is a worse rate not a better one, and a sample with a worse rate is less likely to pass. We apologize for the error. *The Editor.*

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