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A Discussion of Software Reliability Modeling Problems

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Introduction

A quarter of a century has passed since the first software reliability model appeared. Many dozens more, of various types, have been developed since. And many practitioners still disagree on the practical uses of models in software managing, staffing, costing and release activities. The present article examines this situation, discusses some of its causes and suggests some approaches to improve it.

This author believes that the current user dissatisfaction stems from the manner in which reliability, as a concept, is applied to the software environment and on how the related models have evolved. This paper, therefore, begins by providing an overview of the characteristics of software reliability models and of their development efforts. This is followed by a discussion of the assumptions underlying software reliability models and other related problems. Finally, some suggestions on how to improve the situation are provided.

Software Reliability

Broadly speaking, reliability is the probability of satisfactory operation of a system or device, under specific conditions, for a specific time. In software systems, the concept of reliability is complicated by several factors. An operator and a hardware subsystem are always associated with the software. Hence, documentation, training, and interface problems can (directly or indirectly) induce software failures, thus becoming part of the reliability assessment process.

It is also important to understand the origins of the concept of software reliability. It evolved as a result of the increasing use of embedded software in already existing hardware systems. Hardware reliability had been successfully developed and understood since the early 50's. Hence, it was only natural that the same type of hardware professionals (e.g. systems and electrical engineers) would develop the first software models by extending and adapting their previously successful hardware ones. But the hardware modeling techniques, as we will later see, did not always work well in the software environment.

This lack of model portability occurred due to some basic differences between the two environments. It is true that, in general, both hardware and software reliability models can be broadly divided into three categories: Structural (theoretical), Part Count (component) and Black Box (empirical). Examples of theoretical hardware/software models are few and usually are of systems of minor complexity (independent series, parallel component). Of the second type, we find MIL-HDBK-217 models for hardware, and models based on software science or cyclomatic complexity for software. Black Box models, usually time-driven, include the Army Materiel and Systems Analysis Activity (AMSAA) model for hardware, and Jelinski-Moranda, Musa, Goel-Okumoto, etc. for software. Also included are other types of empirical models based on time series, input domain, seeding, etc.

However, this author finds one substantial difference between the two modeling activities.

After its development stage, hardware is mass-produced and the resulting industrial product is used in relatively similar environments. For example, after the prototype has been developed and tested, a military helicopter is mass-produced and flown by similarly trained pilots in attack and rescue missions.

Software, on the other hand, always remains a "prototype" on its own, of which exact copies are made and used by a wide variety of people with very different interests and applications. For example, a matrix-inversion software may be used by a high school student to solve a 2x2 system of linear equations or by a Ph.D. candidate to invert thousands of multivariate correlation matrices in a simulation study.

The modeling stage is, therefore, permanent for the (prototype) software product. Hence, its characteristics and problems have a more significant impact in this environment than in the hardware one, as we will see next.

Modeling Problems

A major problem encountered in the software reliability modeling activity arises from the involvement of two different groups of individuals, modelers and practitioners, each having a different product and process in mind and seeking a different result. The fundamental differences between these two groups make the existing software reliability models a professional success for many modelers but unsatisfactory working tools for many practitioners.

Modelers are usually researchers or academicians while most practitioners are software developers. Academicians and researchers rely on publishing papers, which are peer reviewed and assessed for their theoretical value by other academicians and researchers, to obtain their tenure, promotion or doctorates. To publish their work, modelers use sophisticated statistical theories that require strict (and sometimes unrealistic or unjustified) underlying assumptions.

Practitioners (managers, developers) on the other hand, need to staff, cost, and release software products. Practitioners work with programmers, under time constraints and must rely on insufficient and sometimes deficient information. Software practitioners need models and approaches that are feasible (implemented without incurring exorbitant costs or excessive burden) and practical (can be used to staff, cost, release the software, etc.).

Theoretical models are based on many mathematically driven software assumptions that, in practice, do not hold or are weak. In addition, many models of the Black Box (e.g. time-based) class fail to capture several other important factors that affect software reliability.

In general, modelers achieve their goals but practitioners (whose needs are not met) remain unsatisfied. For, even when the software reliability models developed have indeed helped users in their work, they have not completely solved their practical problems in a satisfactory manner.

Such dichotomy of interests is, in the opinion of this author, the source of most of the problems encountered in software reliability modeling. For models that have been based on theoretical assumptions, many times far removed from reality, cannot produce accurate results. This is not to say that other problems, such as defining software reliability, agreeing on software metrics, etc. do not complicate the matter even further. We will, in the following pages, discuss some of the major discrepancies that arise from the mentioned dichotomy between software theory and practice.

Validity of Software Reliability Model Assumptions

Some software reliability model assumptions do not hold or are weak because they have a purely theoretical (mathematical) origin. Note that not all model assumptions are invalid all the time or in all the models. Some (Black Box) model assumptions and related topics and the reasons for their possible lack of validity are:

- *Definition and Criticality of Failures:* In many cases, failures are user dependent and poorly defined. This makes their identification in the field also difficult.
- *Definition of Time Units:* Include calendar time, execution time, etc., which may differ substantially or may not always be accurately recorded. Some models (Musa) have found ways to deal with this by converting units from one time domain to another. The assumption also implies that testing intensity is time homogeneous.
- *Fixed Number of Faults:* Assumes that no additional faults are introduced and that every debugging attempt is successful. Some models (e.g. imperfect debugging of Goel) attempt to address these issues.
- *All Faults Have the Same Failure Rate:* This implies that all faults have the same probability of occurrence. But failure probability is in fact associated with input domain and user profile. Hence, all failures are not equally likely. For example, a software failure occurs only when a specific input is given. But some users may provide such input very frequently. For this user, the program will have a high failure rate. Another consequence of failures not being equally likely is that reliability will be affected by the order in which faults are discovered. Say two different testing teams have uncovered two different sequences of "n" faults. They may obtain two different reliability estimates (and this is complicated by the specific user profile).
- *All Software Faults are Always Exposed:* Faults are encountered only if that part of the software

where they reside is exercised. If there is a fault that prevents the execution of some part of the software until it is removed, the faults that exist downstream, in that part of the code, are not exposed until the initial one is uncovered and removed.

- *Faults are Immediately Removed:* Testing will not usually be stopped once a fault is uncovered. Adaptive procedures (removing/ patching part of the code; restricting the input) will be used to continue the testing, while the fault is uncovered and fixed.
- *Only One Failure at a Time Occurs:* This is a required Poisson Process assumption and not all software necessarily complies with it. There may occur multiple failures simultaneously (and not all faults will be corrected before restarting the testing).
- *Testing is Homogeneous:* Testing effort is not always the same; personnel may vary as well as time dedicated to it and to other concurrent functions. In addition, if a critical fault is uncovered or a deadline approaches, testing may become more intensive.
- *Failure Rate is (only) Proportional to Error Content:* There are many other factors, such as user profile, complexity of the problem, language, programming experience, etc.
- *Number of Failures in Disjoint Intervals is Independent:* This is also another key Poisson Process assumption. There is a finite number of faults in the software, which are sequentially removed. If we encounter and remove a large number of faults in one interval, then in the next time interval there will be less faults to find, and vice versa. Hence, the number of faults uncovered in two disjoint, adjacent time intervals is affected by the number of faults previously uncovered.
- *Times Between Failures are Independent:* Since the number of failures encountered in disjoint intervals is not independent, this associated assumption is not true either.
- *Testing Proceeds Only After a Fault is Removed (corrected):* This is an ideal situation that does not occur in practice. Adaptive procedures are used to proceed with testing.
- *All the Code is Tested, All the Time:* Some testing may occur before all the code is completed. Then, if a fault is encountered and located in a given module, this fault may be removed or patched (adaptive procedure) to proceed with the testing.
- *Run Time versus Think Time:* Run (test) time models penalize development strategies that spend more desk (think) time analyzing the program than in testing. Calendar time captures both of these activities (think and run times) but this time measurement is weak.
- *Specific Prior Distribution:* Some modelers have attempted to deal with the reality of different failure rates for different faults by assuming a prior distribution and then using a Bayesian model for the reliability. The form of such a prior is selected for mathematical reasons, in order to obtain a closed form solution for the corresponding posterior.
- *Reliability Growth Continues with Additional Testing Time:* It is implicitly assumed that, as test time proceeds, new faults will be uncovered and removed. Hence, the software reliability will increase. This precludes the introduction of new faults as well as the increase in program complexity by the maintenance operation.
- *Seeded Faults Have the Same Failure Rate as Indigenous:* In this approach to software reliability, the developer intentionally introduces a number of faults in the program (e.g. fault "seeding"). Then the testing team "uncovers" some of them during testing, along with other "indigenous" faults (not seeded, but actual programming ones). Based on the number of indigenous and seeded faults uncovered, an estimate of total number of program faults is obtained. This estimation approach assumes that the complexity and location of seeded faults are the same as the complexity and program location of the indigenous faults. This is not necessarily so.
- *Software Input and User Profiles are Known and Representative:* Some software reliability models use input domain profiles, which are difficult to establish. Then, some users exercise some parts of the code more than others do, establishing a particular user profile. Estimating such profiles constitutes a complex statistical problem, involving multivariate parameter estimation and goodness of fit tests. In addition, these profiles are user dependent, requiring one for each different user.
- *Failure Data Collection is Accurate:* In software development, the basic activity is to develop good code. Data collection is usually a peripheral activity that programmers are assigned, in addition to their work. Data collection forms (problem reports, etc.) are complicated and data elements such as exact times, etc. may not be recorded accurately.

In addition, other issues associated with software development and model use, impact software reliability model assessment. Some of them are:

- *Software Doesn't Wear Out with Time:* This has always been a key difference between software and hardware reliability. Hardware devices "age". Software also "ages" – just in a different way! As time proceeds and software maintenance occurs, new functions, modules, hardware, capabilities, are added/modified. Its complexity increases to the point, that it becomes more economic to "retire" it than to continue maintaining it. This process is, conceptually, akin to hardware "aging" processes.

- *Development Phases and Fault Exposure:* In different software development phases, different types of faults are uncovered. Hence, combining failure data from different phases for model input may be detrimental to the overall software reliability estimation.
- *Experimentation:* Many software development experiments undertaken to assess software reliability models and methods have been implemented using very specific problems and subjects. This situation poses restrictions on the extrapolation of results. The experimental subjects are usually students or pre-selected professional teams. The problems are usually theoretical, or replications of available real life ones. Neither has been randomly selected and may be far from representative. Experimental results are still useful and provide valuable insight, but care should be exercised in their interpretation and especially in extrapolation.
- *Additional Factors Not Accounted For:* Most software models are affected by project requirements, software environment and documentation, user profile, programmer and management experience, and other factors not accounted for in the model. Their contribution to the unreliability of the software program is therefore not reflected in the model results.
- *Initial Reliability Estimations:* In some software models, initial estimates are a function of (1) the processor speed, (2) programming language used (via expansion rates) and (3) error exposure rate. Program size cancels out and does not constitute a factor at this early time. Other previously mentioned factors that also affect software complexity and reliability are not included in this initial estimation.
- *Fault Exposure Ratios:* These ratios, used for initial estimation, were obtained several years ago. In a rapidly advancing area such as software programming, where new languages, new environments (e.g. visual) and technologies are coming out every day, such fault exposure ratios may no longer be representative. In addition, they were obtained from specific environments and projects of the past and may not represent the projects and new application areas of today.
- *Language Exposure Ratios:* These ratios are subject to the criticism made of fault exposure ratios. In addition, new programming languages (e.g. Java) have appeared recently for which accurate language exposure ratios may not yet be available.
- *Having a Large Pool of Software Reliability Models from Which to Choose:* This constitutes an additional and serious problem. Since no single model has been completely established, software developers must choose one. For example, the developer may try fitting several models and then choose the most accurate among them, based on past behavior. However, can one be sure that past behavior always guarantees a model's correct future behavior? Model selection is not an easy task.

Some Suggestions to Improve Software Reliability Modeling

Software reliability models are used to assess the end result of the software development process. This final result (program) is a function of at least three broad factors: people, project and environment. The people include programmers, management, testers, etc. The project is represented by its characteristics: size, complexity, requirements, functions, interfaces, etc. The environment includes all the characteristics of the software development shop: management style, software tools, methods, etc. This author believes that, in addition to using and improving the software reliability models, resources should also be dedicated to obtaining a better understanding of one's own software organization (strengths and weaknesses) and to improve it by training its people and readjusting its methods.

In-depth forensic analysis of an organization's past work will reveal its strong and weak points. It will also provide for assessing key components of the three factors mentioned in the previous paragraph. This author also proposes that error prevention, rather than correction, be emphasized. Organizational improvements based on the results of forensic analysis may provide substantial mid and long-range software reliability gains. The development by the Software Engineering Institute of the Capability Maturity Model (SEI/CMM), with its five-level classification of software shops (from basic practices to continuous, quantitative improvement process) is a tacit recognition of the urgent need for organizational improvements.

It is known that about 70% of software faults result from problems introduced during the requirements definition and design phases (including software reuse problems). Dedicating more time and staff to better understanding, stating and conveying to programmers the special requirements and design issues of each project will pay off at the end. Better training, software tools and programmer and resource time management may also contribute to reducing programming stress and thus software errors.

Finally, forensic analysis may also show that improvements are needed for important concepts such as fault avoidance and prevention techniques (tools, training), fault tolerance (recovery blocks, n-version programming), fault detection/correction (walkthroughs).

Conclusions

This author recognizes the excellent work of many software reliability model developers. He has worked with some of them in industry and academia and respects their many talents and achievements. There are ample examples in the software engineering literature that show how software reliability models, directly and indirectly, have:

- Improved the software estimation, assessment, prediction, etc. processes
- Improved the understanding of the software development process
- Contributed to the development of new software engineering tools and techniques

However, it is also unquestionable that the problems discussed in this article affect model efficiency and accuracy and are at the heart of the dissatisfaction of some model users. For, in general, software reliability models are based upon:

- Poor (few, weak measurement scale) data
- Weak (invalid, incomplete, unrealistic) assumptions
- Incomplete (lacking many important) factors

Therefore, current software reliability models can only provide an approximation of the results that we want and need. All things considered, however, and under the circumstances discussed in this article this is the best they can do, at this time. Therefore, this author also proposes that the models be improved. This can be accomplished by seriously revisiting the modeling problems discussed in this paper. By approaching the stated model-developer versus model-practitioner dichotomy in a constructive manner, all parties may agree to:

- Not ask or expect unrealistic results from software reliability models
- Have practitioners work more closely with software model developers
- Provide an incentive for adapting (as opposed to developing new) models
- Assess each software organization's strengths and weaknesses
- Improve, correspondingly, each organization (programming/ processes)
- Strive for error prevention rather than error correction
- Then, use a software reliability model, judiciously, to assess improvement.

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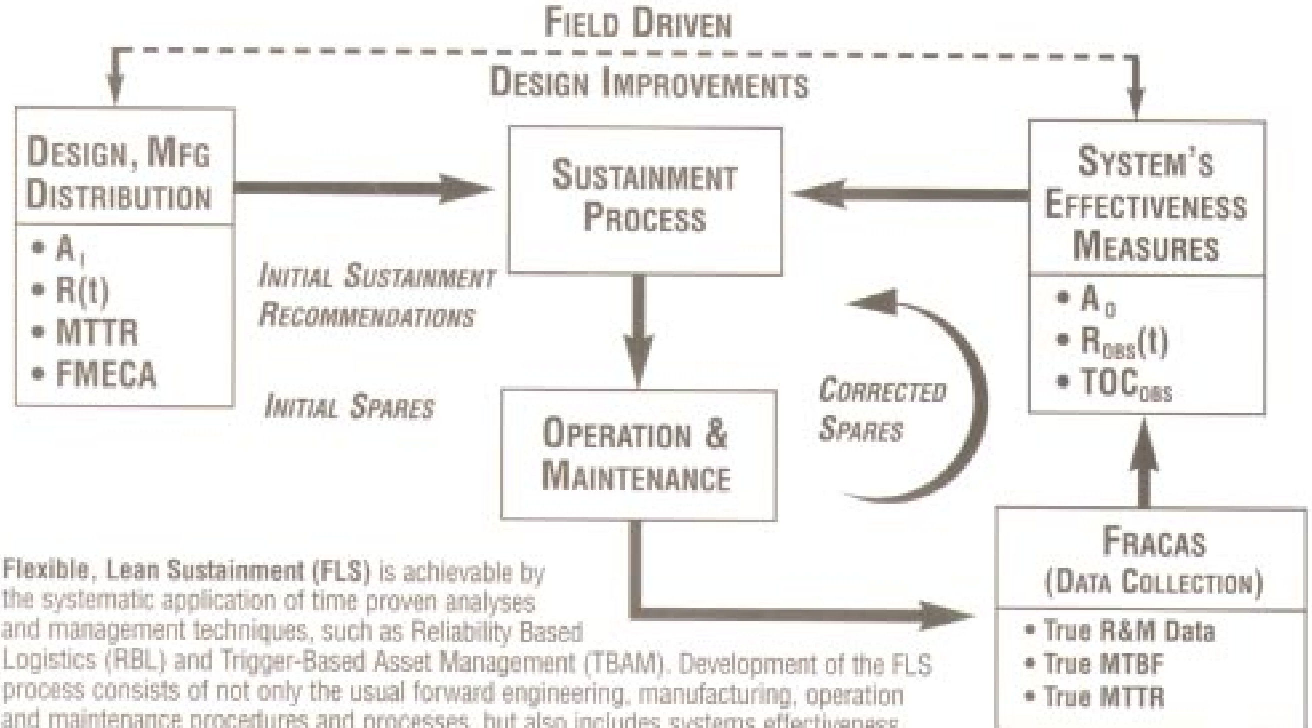

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Tutorial: Testing for MTBF

By: *Anthony Coppola, Reliability Analysis Center*

Tests for failure rate or its reciprocal, mean time between failures (MTBF), are based on the risks of accepting a value defined as undesirable (the consumer's risk) and of rejecting a value defined as desirable (the producer's risk). These risks are computed using the Poisson distribution, which provides the probability that any given number of failures will occur during the designated test time.

$$P_n = \frac{a^n e^{-a}}{n!} \tag{1}$$

where:

P_n = probability of n events occurring in some defined circumstances

a = expected number of events

For reliability testing, the expected number of events is the number of failures in a given test time. Since reliability tests define a maximum number of failures for acceptance, we will need the cumulative Poisson:

$$P(\text{n or fewer}) = \sum_{x=0}^{n} \frac{a^x e^{-a}}{x!} \tag{2}$$

where:

n = maximum number of failures allowed

a = expected number of failures

x = number of events

The consumer's risk (i.e., the probability that a product with a failure rate considered unacceptable would be accepted.) is determined by calculating the probability of no more than the allowable number of failures occurring using the expected number of failures of the most reliable unit that is still considered unacceptable. The expected number is calculated from the failure distribution parameters of a product considered just unacceptable, the number of products on test, and the test time.

For example, if a group of products having a failure distribution described by a Weibull function are put on test, the expected number of failures is:

$$a = m(t/\theta)^{\beta} \tag{3}$$

where:

a = expected number of failures

m = number of units on test

t = test time on one unit

θ = characteristic life (the time at which 63% of products will have failed)

β = shape parameter (when β < 1.0, failures occur at an decreasing rate with time: when β > 1.0, failures occur at an increasing rate with time.)

Note: use of this equation assumes that testing starts at t = 0 for all units (none operate before the test) and that each unit is operated for the same test time (except those that fail before time = t).

For example, suppose we wish to test a product that experience indicates will have a Weibull distribution of failures with β = 2. We decide we want to reject it if its characteristic life (θ) is no better than 100 hours, and will accept no more than a 10% risk of a product with this life passing the test. We can test 20 units (m) for 50 hours (t) each. How many failures can we allow?

Our expected number of failures (a) would be:

$$a = m(t/\theta)^{\beta} = 20(50/100)^2 = 20(.5)^2 = 20(.25) = 5.0$$

Hence, the probability of accepting a product with the life we want to reject is:

$$P = \sum_{x=0}^{n} \frac{a^x e^{-a}}{x!} = \sum_{x=0}^{n} = \frac{5^x e^{-5}}{x!} = \sum_{x=0}^{n} = \frac{5^x (.0067)}{x!}$$

For n = 0:

$$P = \frac{5^0(.0067)}{0!} = \frac{1(.0067)}{1} = .0067$$

For n = 1:

$$P = \frac{5^0(.0067)}{0!} + \frac{5^1(.0067)}{1!} = .0067 + \frac{5(.0067)}{1}$$

$$= .0067 + .0335 = .0402$$

For n = 2:

$$P = \frac{5^0(.0067)}{0!} + \frac{5^1(.0067)}{1!} + \frac{5^2(.0067)}{2!}$$

$$= .0402 + \frac{25(.0067)}{2}$$

$$= .0402 + \frac{.1675}{2} = .0402 + 0.0838 = .124$$

Hence, we can allow one failure, but not two, if we wish to keep the consumer's risk below 10%.

What of the producer's risk? It is the probability that a product with a failure rate considered acceptable (one we do not wish to reject) would be rejected. It is found by solving Equation 2 using the characteristic life considered acceptable, with the given test time and allowable number of failures, which we calculated earlier. The result is the probability of the acceptable product passing the test. One minus this result is the probability that the product will fail the test and, hence, be rejected, which is the producer's risk.

For example, suppose we decided that the product that we are testing should have a characteristic life of 500 hours. What is the risk that the test we devised will reject a product actually achieving this norm?

Since θ = 500 hours, the expected number of failures for 20 units running 50 hours each would be:

$$a = m(t/\theta)^{\beta} = 20(50/500)^2 = 20(.1)^2 = 20(.01) = 0.2$$

The probability of this product having no more than one failure during the test is:

$$P = \sum_{x=0}^{1} \frac{a^x e^{-a}}{x!} = \frac{(.2)^0 e^{-.2}}{0!} + \frac{(.2)^1 e^{-.2}}{1!}$$

$$P = .8187 + .1637 = .98$$

A product with the desirable life will therefore pass the test 98% of the time, or, equivalently, will have a 2% risk of rejection (producer's risk = .02).

Note that if we tested only one unit and allowed no failures, Equation 2 reduces to:

$$P = \frac{\left[(t/\theta)^{\beta}\right]^0}{0!} = e^{-(t/\theta)^{\beta}} \qquad (4)$$

Equation 4 is the expression for the reliability of a product with a Weibull distribution of failures, as should be expected (reliability = probability of no failures in a given operating time).

When a constant failure rate is assumed (β = 1.0), it is not even necessary for all units on test to have equal operating times. For this case, the probability of passing the test is determined by the formula:

$$P = \sum_{x=0}^{n} \frac{e^{-\lambda t}(\lambda t)^x}{x!} \qquad (5)$$

where:

λ = failure rate (λ= 1/θ; note that in this case, θ is also the mean time between failure)
n = number of failures allowed
t = total test time among all units tested

For determining the consumer's risk, λ is set equal to the best failure rate we feel is unacceptable. For the producer's risk, λ is set to a value we do not wish to reject.

However, for products assumed to possess a constant failure rate, there is no need to solve the equations. Tabulations of tests have been made citing the total operating hours and number of allowable failures for selected values of the producer's risk, the consumer's risk and the discrimination ratio (i.e. the ratio of acceptable MTBF/unacceptable MTBF). For "fixed length" tests, the units on test are operated until the acceptable number of failures is exceeded (reject decision) or the total operating hours among the units on test equals the test duration (accept decision). Table 1 is one such tabulation, which clearly shows the effects of different risks and discrimination ratios on test duration and acceptable number of failures.

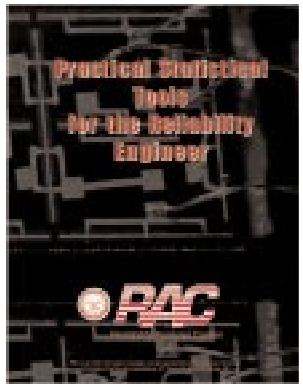
To reduce the test time required to reach decisions, "probability ratio sequential tests" have been devised. These tests assume a constant failure rate and require us to define an MTBF we want to reject with a certain confidence (or, equivalently, one for which we have defined an acceptable consumer's risk) and an MTBF we want to accept with a certain confidence. For these tests, the probability that an observed number of failures in an

Table 1: Fixed Length Test Plans

Decision Risks		Discrimination Ratio	Test Duration (multiples of "bad" MTBF)	Allowable Failures
Producer's	Consumer's			
10%	10%	1.5	45.0	36
10%	20%	1.5	29.9	25
20%	20%	1.5	21.5	17
10%	10%	2.0	18.8	13
10%	20%	2.0	12.4	9
20%	20%	2.0	7.8	5
10%	10%	3.0	9.3	5
10%	20%	3.0	5.4	3
20%	20%	3.0	4.3	2
30%	30%	1.5	8.0	6
30%	30%	2.0	3.7	2
30%	30%	3.0	1.1	0

elapsed test time would have occurred if the product had the undesirable MTBF is divided by the probability that the same number of failures would have occurred if the product had the desirable MTBF. If this ratio is sufficiently small, the product is accepted. If it is sufficiently large, the product is rejected ("Sufficiently" is defined by a formula based on predefined producer's and consumer's risks). If neither criterion is satisfied, the test continues. See MIL-HDBK-781, *Reliability Test Methods, Plans, and Environments for Engineering Development, Qualification, and Production*, for further details.

A new RAC text, "Practical Statistical Tools for the Reliability Engineer," provides basic training in probability, statistics and distributions, followed by detailed discussions of the application of these concepts to measuring reliability, demonstrating reliability, reliability growth testing, sampling, statistical quality control, and improving processes. Statistical techniques are the most valuable tools of the reliability engineer. However, there is a dearth of statistical textbooks that are both pertinent to reliability applications and easy to understand. The discussions are detailed to the extent that practical use can be made of tools, and the limitations to each tool is clearly defined to keep a novice from misapplication. The text is designed to be as user-friendly as possible.



PRISM - A New Tool from RAC

As reported earlier, the Reliability Analysis Center has developed a new methodology, and an associated software tool called PRISM, for estimating the failure rate of electronic systems. This methodology includes new component reliability prediction models developed by RAC called RACRates, and means for assessing the reliability of systems due to non-component variables.

The PRISM methodology is structured to allow the user the ability to estimate the reliability of a system in the early design stages when little is known about the system. For example, early in the development phase of a system, a reliability estimate can be made based on a generic parts list, using default values for operational profiles and stresses. When additional information becomes available, the model allows the incremental addition of data.

PRISM provides the capability to assess the reliability of electronic systems. It is not intended to be the "standard" prediction methodology, and like any methodology, it can be misused if applied carelessly. It does not consider the effect of redundancy or perform FMEAs. The intent of PRISM is to provide the data necessary to feed these analyses.

The methodology allows modifying a base reliability estimate with process grading factors for the following failure causes: parts, design, manufacturing, system management, wearout, induced and no defect found. These process grades correspond to the degree to which actions have been taken to mitigate the occurrence of system failure due to these failure categories. Once the base estimate is modified with the process grades, the reliability estimate is further modified by empirical data taken throughout system development and testing. This modification is accomplished using Bayesian techniques that apply the appropriate weights for the different data elements.

Advantages of this new methodology are that it uses all available information to form the best estimate of field reliability, is tailorable, has quantifiable confidence bounds, and has sensitivity to the predominant system reliability drivers.

The new model adopts a broader scope to predicting reliability. It factors in all available reliability data as it becomes available on the program. It thus integrates test and analysis data, which provides a better prediction foundation and a means of estimating variances from different reliability measures.

PRISM is unique in that, as a single integrated tool, it:

- Includes a failure rate model for a system
- Includes component reliability models with acceleration factors (or pi factors) to estimate the effect on failure rate of various stress and component variables
- Allows an initial estimate of failure rate to be developed using a combination of the new "RACRate" failure rate models developed by RAC, the empirical field failure rate data contained in the RAC databases, or user-defined failure rates entered directly by the user
- Allows the initial estimate of failure rate to be adjusted for process grading factors, infant mortality characteristics, reliability growth characteristics, and environmental stresses
- Includes a factor for assessing the reliability growth characteristics of a system
- Accounts for infant mortality
- Includes a predictive software reliability model that does not require empirical data
- Allows the predicted failure rate to be combined with empirical data using a Bayesian approach

For further information contact D. Dylis at (315) 339-7055 or to download DEMO version of PRISM visit our RAC web site at http://rac.iitri.org/PRISM.

Calls for Papers

The 5th High Assurance Systems Engineering Symposium (HASE 2000)

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The home page for HASE 2000 is http://www.high-assurance.org/. Papers to the HASE 2000 conference can be submitted via snail mail or through the electronic submission page. To send papers via snail mail, please mail a hard copy of your paper to the following postal address:

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Military & Aerospace/Avionics COTS Conference, Exhibition & Seminar

August 22-25, Fort Collins, CO
Sponsored by the Johns Hopkins University Applied Physics Laboratory, Laurel, MD, Naval Surface Warfare Center, Crane, IN & Jet Propulsion Laboratory, Pasadena, CA.

This conference is dedicated to issues assuring the highest 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 of recent developments and future directions will assure relevance of material. The conference will continue to highlight the insertion of commercial technology, i.e., plastic encapsulated packaging and low cost assemblies, into military, aerospace and avionic equipment.

Prospective authors should submit five (5) copies of a one-page abstract by May 1, 2000 for review by the Program Committee. Abstracts must include author's name(s), affiliation and complete address, E-mail, fax & telephone number. Abstracts will be selected on the basis of technical merit, supporting test results & overall suitability. Send abstracts to:

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Edward B. Hakim
The Center for Commercial Component Insertion (C3I, Inc)
2412 Emerson Avenue
Spring Lake, NJ 07762
Telephone & Fax: (732) 449-4729
E-mail: ebhakim@bellatlantic.net

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START Selected Topics in Assurance Related Technologies

Volume 7, Number 1

Sustained Maintenance Planning

Table of Contents

Introduction

Readiness is the ability of forces or equipment to deliver designed outputs without unacceptable delay. While “readiness” is associated more with combat forces, it can also be used to describe how well an enterprise is poised to impact or respond to commercial marketplaces. The term comprises human resources and equipment (weapons systems, e.g.) among its many elements. *Affordable* readiness is that level of readiness that can be sustained within some budget or at minimum life-cycle cost. The discussion here is about the support necessary to keep equipment ready (a contribution to overall readiness) at an affordable cost. Affordable readiness encompasses four separate but related ways to look at support for weapons systems or industrial machinery:

- Total Cost of Ownership
- Sustained Maintenance Planning
- Flexible Sustainment
- Rightsourcing

That is, total cost of ownership, or life-cycle cost, cannot be minimized unless:

- maintenance planning is continually reviewed for system optimization (sustained planning);
- performance-based specifications and metrics are used to adjust existing support concepts and operations; and
- innovative procurement strategies are used to find the best sources of supply, labor, and materials to support the system.

This START sheet addresses the concept of Sustained Maintenance Planning (SMP). (The RAC has also published a closely related sheet on Flexible Sustainment.)

Background and Concept

Innovative maintenance planning and execution can extend the useful life of a system. Maintenance management’s functions are to cost effectively maintain the system to achieve mission objectives, with minimal downtime, and to introduce upgrade and modification programs that improve operational capability as required. To accomplish this, maintenance managers must plan for and execute preventive and corrective maintenance that is based on an in-depth understanding of how the system is performing when compared to design limitations. When done correctly, the useful life of a system can be extended safely and operational readiness and system effectiveness are more affordable.

In an era of fierce competition for scarce resources, it is no longer sufficient or competitive to develop a maintenance plan during development, and then implement that plan without change over the life of a system. That happened - still does, in commercial industry – all too often when development and production (build) organizations transferred systems with static maintenance plans to owners unprepared to do the required sustaining engineering. Fortunately, modern, proven concepts (e.g., Just-In-Time logistics, Integrated Product Teams, seamless transition, etc.) in addition to powerful communications media and computer-based information systems and analytical tools enhance the capability to do dynamic and iterative maintenance planning. Such planning, and its judicious execution, optimize the use of scarce resources and make readiness more affordable.

To maximize the benefits of applying these concepts, the U.S. Navy’s Naval Aviation Systems Command (NAVAIR) identified key processes that are known collectively as Sustained Maintenance Planning (SMP). SMP is defined as:

“An iterative process that ensures the highest affordable aviation weapons system reliability by using the broad range of aviation metrics to analyze effectiveness and performance of each weapons system’s maintenance programs, continually improve maintenance documentation and recommend improvements across the entire spectrum of ILS elements”

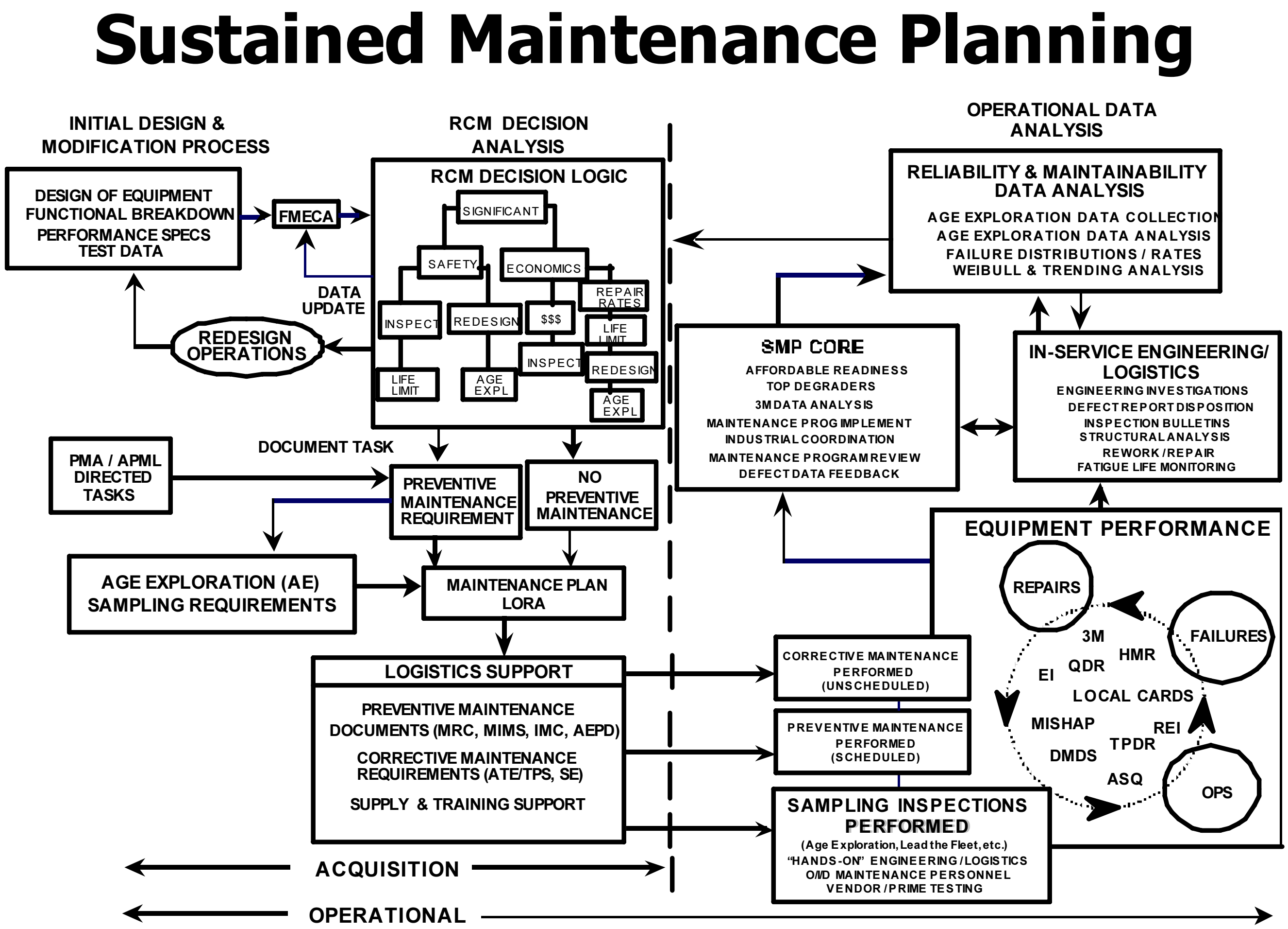

Figure 1. The Sustained Maintenance Planning Process

The goals of SMP are to:

- have a set of iterative processes that use maintenance metrics to evaluate the effectiveness of a maintenance plan in achieving desired availability;
- have a life-cycle process for establishing and adjusting Preventive Maintenance (PM) requirements for all levels of maintenance; and
- ensure the desired levels of reliability are obtained for a system, either through actual or near-achievement of inherent reliability, or through the identification of the most significant candidates for redesign.

High field reliability, coupled with optimized maintenance, translates directly into *affordable readiness.*

SMP Components

Figure 1 shows the SMP process, and is similar to Figure 6-16 in the Management Manual Draft NAVAIR 00-25-406, Design Interface Maintenance Planning. The figure shows Sustained Maintenance Planning as "In Service Support Planning." Figure 1 depicts SMP as an overarching *closed-loop process that encompasses continual review of established maintenance plans* to ensure the most cost-effective maintenance is being performed on fielded systems. The two key components of SMP are:

- Reliability-Centered Maintenance
- Age Exploration

Reliability-Centered Maintenance (RCM) is an extensive process unto itself, and applies to all levels of maintenance. It is well defined in another Management Manual, NAVAIR 00-25-403, Guidelines for the Naval Aviation Reliability-Centered Maintenance Process. RCM is readily adaptable to any system, industrial ones included, having mission or output requirements over some system life (life cycle). Essentially, RCM is a process that can be used to first establish and then adjust maintenance procedures and activities based on projected and observed fielded system performance. That performance can be characterized through the analysis of expected and actual system or component failures, and tracking the trends over time to determine maintenance plan effectiveness. Also, reliability can be improved by implementing results of engineering activities such as a Failure Modes, Effects, and Criticality Analysis (FMECA). Proposed solutions and changes to maintenance plans should routinely be subjected to the rigors of cost-effectiveness analysis.

Age Exploration (AE) is the second key component of Sustained Maintenance Planning. AE tasks can range from reviews of usage or failure data (e.g., Navy's 3-M, Air Force's 66-1) to actual inspections or tests to monitor age-related phenomena such as wearout, fatigue, longer response times, and degradation caused by exposure or storage. Ideally, AE tasks would be limited to the durations needed to collect sufficient data and update RCM analyses.

The key to both RCM and AE is a commitment to apply the significant resources that may be required to collect and analyze performance data. It follows that only with such a commitment can SMP be meaningful and successful.

Closing the loop in Figure 1, AE program results are integrated into and with RCM activities, which in turn are used to refine maintenance plans and improve their cost-effectiveness. Reiterating these activities over the life of a system and implementing the resulting solutions cost-effectively are the essence of **Sustained Maintenance Planning**.

Implementing SMP

As shown in Figure 1, implementing SMP actually begins early with the initial design activities of the early Acquisition Phase during Design Interface. It is then that the initial FMEA's are accomplished, maintenance concepts are developed, critical performance parameters are defined, and data gathering and data analysis schemes are formulated. The ability to **sustain** that initial **maintenance planning** and refine maintenance plans as required, throughout the life of a system, depends on an adequate resource commitment to gather and analyze data cost-effectively and intelligently throughout the life of the system.

For Further Study

Web Sites. Additional information on SMP can be obtained from the following web sites. In addition, many of the publications in the list that follows can be downloaded from these sites.

a. http://www.deskbook.osd.mil

b. http://www.nalda.navy.mil/rcm/403/403desc.htm

c. http://www.nalda.navy.mil

d. http://www.nalda.navy.mil/3.6/coo/

e. http://www.acq-ref.navy.mil/

Publications

a. Joint Aeronautical Commanders' Group. Flexible Sustainment Guide, Change 2. December, 1998.

b. Naval Air Systems Command. Draft NAVAIR 00-25-406, Management Manual, Design Interface Maintenance Planning. Washington, D.C.: Commander, NAVAIR, January, 1999.

c. Naval Air Systems Command. Maintenance Trade Cost Guidebook. Washington, D.C.: Cost Department, NAVAIR-4.2, October, 1998.

d. Naval Air Systems Command. Joint Service Guide for Post Production Support Planning. Patuxent River, MD: Logistics Policy and Processes, AIR-3.6.1.1, October, 1997.

e. Naval Air Systems Command. NAVAIR 00-25-403, Management Manual, Guidelines for the Naval Aviation Reliability-Centered Maintenance Process. Washington, D.C.: Commander, NAVAIR, October, 1966.

f. Naval Air Systems Command. Contracting for Supportability Guide. Patuxent River, MD: Logistics Policy and Processes, AIR-3.6.1.1, October, 1997.

Other START Sheets Available

RAC's Selected Topics in Assurance Related Technologies (START) sheets are intended to get you started in knowledge of a particular subject of immediate interest in reliability, maintainability, supportability and quality.

- 94-1 ISO 9000
- 95-1 Plastic Encapsulated Microcircuits (PEMs)
- 95-2 Parts Management Plan
- 96-1 Creating Robust Designs
- 96-2 Impacts on Reliability of Recent Changes in DoD Acquisition Reform Policies
- 96-3 Reliability on the World Wide Web
- 97-1 Quality Function Deployment
- 97-2 Reliability Prediction
- 97-3 Reliability Design for Affordability
- 98-1 Information Analysis Centers
- 98-2 Cost as an Independent Variable (CAIV)
- 98-3 Applying Software Reliability Engineering (SRE) to Build Reliable Software
- 98-4 Commercial Off-the-Shelf Equipment and Non-Developmental Items
- 99-1 Single Process Initiative
- 99-2 Performance-Based Requirements (PBRs)
- 99-3 Reliability Growth
- 99-4 Accelerated Testing
- 99-5 Six-Sigma Programs

These START sheets are available on-line at http://rac.iitri.org/DATA/START.

About the Author

Stephen G. Dizek is a Senior Engineer with IIT Research Institute, where he has worked on projects related to Reliability, Cost-Benefits Analysis, and Decision Support. Before joining IITRI, he worked in industry as Reliability and Sustaining Engineering Manager for design, build, and fielding of precision, automated, robot-based materials handling systems. Earlier, he spent 15 years with Dynamics Research Corporation (DRC) and The Analytic Sciences Corporation (TASC) as Manager and Technical Director for weapons systems projects on reliability, warranty, logistics, risk analysis, decision support, and the development and implementation of sequential Bayesian techniques for assessing dormant systems. Prior to that, a 22-year United States Air Force career included acquisition assignments to Electronic Systems Division, the MINUTEMAN SPO at the Space and Missile Systems Organization, and Aeronautical Systems Division.

Mr. Dizek holds a BS in Mathematics (minor in Mechanical Engineering) from the University of Massachusetts, an MS in Systems Engineering (Reliability) from the Air Force Institute of Technology (AFIT), and an MS from the University of Southern California in Systems Management. He is a resident graduate of the United States Naval War College's School of Naval Command and Staff, and earned graduate-level certificates from AFIT in Systems Software Engineering and Systems Software Acquisition. He has presented numerous papers at RAMS, SOLE, NAECON, and NES / ICA symposia, workshops, and chapter meetings, and guest-lectured at AFIT, DSMC, and TASC.

For further information on RAC START Sheets contact the:
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Rome, NY 13440-6916
Toll Free: (888) RAC-USER
Fax: (315) 337-9932
or visit our web site at:
http://rac.iitri.org

About the Reliability Analysis Center

The Reliability Analysis Center is a Department of Defense Information Analysis Center (IAC). RAC serves as a government and industry focal point for efforts to improve the reliability, maintainability, supportability and quality of manufactured components and systems. To this end, RAC collects, analyzes, archives in computerized databases, and publishes data concerning the quality and reliability of equipments and systems, as well as the microcircuit, discrete semiconductor, and electromechanical and mechanical components that comprise them. RAC also evaluates and publishes information on engineering techniques and methods. Information is distributed through data compilations, application guides, data products and programs on computer media, public and private training courses, and consulting services. Located in Rome, NY, the Reliability Analysis Center is sponsored by the Defense Technical Information Center (DTIC). Since its inception in 1968, the RAC has been operated by IIT Research Institute (IITRI). Technical management of the RAC is provided by the U.S. Air Force's Research Laboratory Information Directorate (formerly Rome Laboratory).

Industry News

SAE and IMechE to Publish Journal on Engine Research

The Society of Automotive Engineers (SAE) and the UK-based Institution of Mechanical Engineers (IMechE) have agreed to cooperatively publish the Quarterly International Journal of Engine Research. The inaugural issue was scheduled for release in March 2000.

Featuring original papers on experimental and analytical studies of engine technology, the journal is meant to be a premier source of reference information on all aspects of engines used in a wide variety of transportation modes. Topics will include combustion engine performance, emissions control, fuel spray technology, electronic engine controls, and other key subjects.

SAE members who are editors of the journal are: Dr. Rolf D. Reitz, Department of Mechanical Engineering, University of Wisconsin, Madison; Dr. Constanti Arcoumanis, Department of Mechanical Engineering, College of Science, Technology, and Medicine, UK; and Professor Takeyuki Kamimoto, Department of Mechanical Engineering, Tokai University, Japan.

Those interested in having articles published in the new journal should contact Vivian Rathke at SAE International for a copy of the author guidelines (call 724-772-7107 or email rathke@sae.org. Subscriptions can be ordered by calling SAE Customer Sales at 724-776-4970 (publications@sae.org). Mention order number JER-2000SUB.

ISO Publishes Draft Interim Version of ISO 9000 Standard

In the January issue of Quality Digest, it was reported that ISO, the International Organization for Standardization, published the draft international standard (DIS) of ISO 9000, ISO 9001 and ISO 9004.

- ISO 9000, Quality Management Systems – Fundamentals and vocabulary. This revision will replace the current vocabulary standard, ISO 8402, and the guidelines for selection and use, ISO 9000-1;
- ISO 9001, Quality Management Systems – Requirements. This revision will replace the current quality assurance models, ISO 9001, ISO 9002 and ISO 9003. It will therefore become the sole ISO 9000 standard for use in third-party certification;
- ISO 9004, Quality Management Systems – Guidelines for performance improvements. This revision will replace the following current guidelines: for quality management and quality system elements, ISO 9004-1; for services, ISO 9004-2; for processed materials, ISO 9004-3; for quality improvement, ISO 9004-4, and the technical corrigendum to that document.

The release of these documents marked the beginning of a five-month period during which they will be circulated to ISO member bodies for review and ballot. Balloting should be completed by the second half of April 2000.

The national standards institutes of 90 countries make up the ISO member bodies. If 75% of the countries vote in favor of the DIS standards by April 25, 2000, the documents will be accepted for further processing as final draft international standards (FDIS). The FDISs will be balloted in the third quarter of 2000. If these drafts pass with 75% of the vote or more, the standards will be published as ISO standards in the last quarter of 2000.

The draft standards are publicly available documents that can be obtained from ISO members (a full list is posted on ISO's Web Site: http://www.iso.ch). For additional information on the revisions to ISO 9000, ISO 9001, and ISO 9004, visit the following Web Site: http://www.iso.ch/9000e/revisionstoc.html.

NIST Announces 1999 Baldrige Award Winners

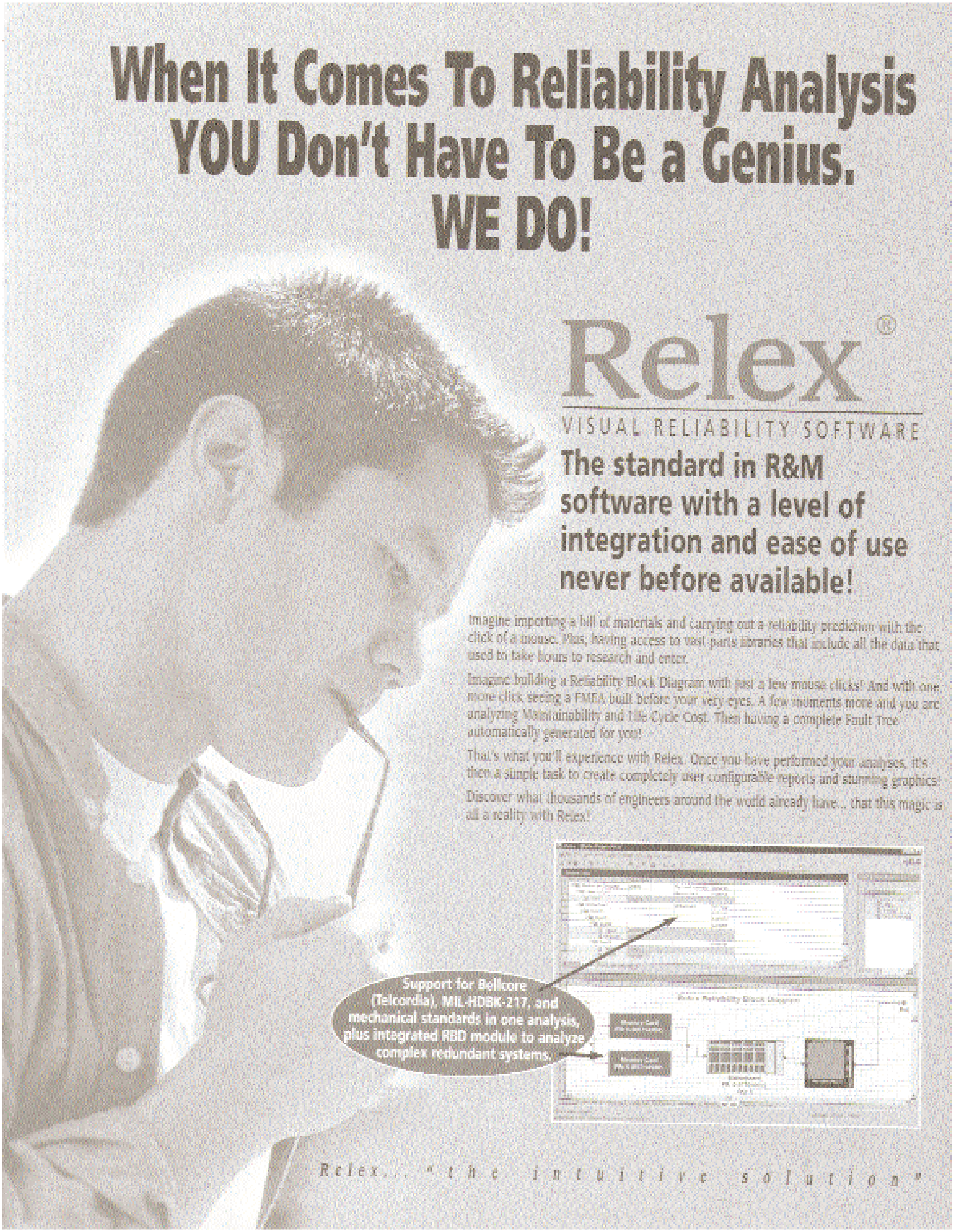
Four companies will receive the Malcolm Baldrige National Quality Award at a ceremony at the Marriott Wardman Hotel in Washington D.C. on March 13-15, 2000. The winners, named by the National Institute of Standards and Technology (NIST), which administers the award, are:

- Manufacturing category: STMicroelectronics Inc. – Region Americas (Carrollton, TX)
- Service category: BI (Minneapolis, MN)
- Service category: Ritz-Carlton Hotel Co. L.L.C. (Atlanta, GA)
- Small-business category: Sunny Fresh Foods (Monticello, MN)

The Malcolm Baldrige National Quality Award was created by Public Law 100-107, signed into law by President Ronald Reagan on August 20, 1987. The Award Program, responsive to the purposes of Public Law 100-107, led to the creation of a new public-private partnership. Principal support for the program comes from the Foundation for the Malcolm Baldrige National Quality Award, established in 1988.

The Award is named for Malcolm Baldrige, who served as Secretary of Commerce from 1981 until his tragic death in a rodeo accident in 1987. His managerial excellence contributed to long-term improvement in efficiency and effectiveness of government. The Secretary of Commerce and the National Institute of Standards and Technology (NIST, formerly the National Bureau of Standards) were given responsibilities to develop and administer the Award with cooperation and financial support from the private sector.

For more information on the Baldrige Award and the 1999 winners, visit the NIST Web Site: http://www.quality.nist.gov/.



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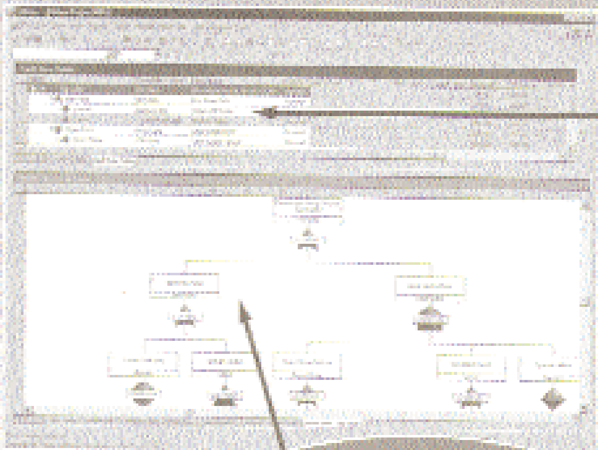

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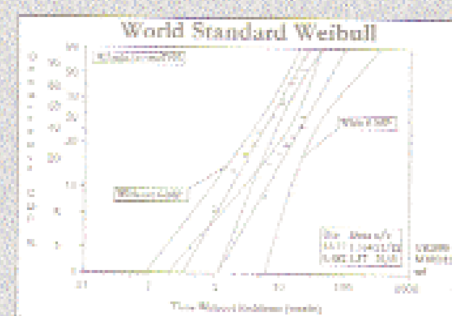

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From the Editor

Those readers who did not receive and read the 4th Quarter issue of the RAC Journal may be surprised to not see Tony Coppola's name in this section. Tony has retired as the Editor of the Journal and I have been given the daunting task of following in his footsteps. Since 1992, Tony worked to make the Journal one of the most respected and valuable publications in the field of reliability and associated disciplines. As important as that work has been, however, it is just one small part of the incredible contribution Tony has made to the reliability community.

When listing the true pioneers in reliability, Tony Coppola's name must be included. For over 40 years, first as a civilian with the US Air Force and then with IIT Research Institute, Tony developed the reliability concepts and tools many of us now take for granted. In 1964, before many of us even knew what reliability or effectiveness meant, Tony served on the Weapons System Effectiveness Industry Advisory Group. His selection for this group was most appropriate – he developed a mathematical model of Systems Effectiveness in 1961 while with the Rome Air Development Center where he worked from 1956 to 1992. In another key effort, he chaired the committee on Artificial Intelligence Applications to Maintenance, a committee of the Institute for Defense Analysis Study on Reliability and Maintainability from June to October 1984.

Tony's technical expertise has always been matched by his good old-fashioned common sense. His talents are many and include an ability to take a complex subject and make it understandable, and a gift for showing how inscrutable theory applies to practical problems. It was natural, then, for Tony to share his expertise through teaching. He served as guest instructor at the USAF Academy in 1973 and 1980; at the USAF Institute of Technology in 1964, 1969, 1974, 1977, and 1978; and at the George Washington University in 1969 and 1980. In addition, he prepared and taught 15 hours of material for a special RAC training course for Eaton Corporation in 1994 and taught both the Design Reliability and Mechanical Reliability RAC Courses in 1993 and 1994.

In addition to passing on his expertise through teaching, Tony has single-handedly created a library of references for the reliability community. His more than 100 publications include Practical Statistical Tools for the Reliability Engineer, RAC STAT, 1999; The TQM Toolkit, RAC TQM, 1993; Report on Artificial Intelligence Applications to Maintenance a 1984 study on reliability and maintainability by the Institute for Defense Analysis; A Reliability and Maintainability Management Manual, with A. Sukert, Air Force Technical Report (AFTR), RADC-TR-79-200, 1979; Bayesian Reliability Testing Made Practical, AFTR, RADC-TR-81-106, 1981; and A Design Guide for Built-In-Test, AFTR, RADC-TR-78-224, 1978.

Tony's contributions have not gone unnoticed. His awards include the Air Force Award for Meritorious Civilian Service (1987), the Air Force Award for Outstanding Civilian Career Service (1992), the IEEE Centennial Medal (1984), and the P.K. McElroy Award for Best Paper (1979 Annual Reliability and Maintainability Symposium). He is a fellow of the IEEE and has been listed in "Who's Who in America" since 1981.

All of us who work in reliability and maintainability owe a debt of gratitude to Tony. Happily, he will be available to the RAC staff on a very limited consulting basis for the immediate future. For me, that is a godsend. As the new editor of the RAC Journal, I will value Tony's guidance and sage advice. But, Tony, I promise to try not to lean on you too much.

Ned Criscimagna

To you, our readers, I pledge my best effort to maintain the level of excellence Tony has achieved in the RAC Journal. To that end, I encourage you to submit articles for the Journal and to respond to articles with letters. For it is through the free and open exchange of ideas and opinions that our body of knowledge grows. So please consider the Journal as a forum for sharing your experiences and research. Readers interested in submitting articles or having ideas for continually improving the Journal can contact me at:

ncriscimagna@iitri.org
301-918-1526

Finally, I know all of his friends and colleagues, and readers of the RAC Journal join me in wishing Tony a long, healthy, and rewarding retirement. And Tony - happy honks!

New RAC Catalog Available

Descriptions and price data for all RAC publications, as well as information on RAC training, consulting services, START sheets, RAC Journal subscriptions, the RAC web site, and the RAC Data Sharing Consortium are provided in the RAC Product catalog. A new issue is now available. To request your free copy, call RAC toll-free at (888) RAC-USER (888-722-8737) or view and print from our web site at http://rac.iitri.org/PRODUCTS/RAC_Catalog.pdf.

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Accelerated Life Testing...

Course Section 2 is devoted to one of the hottest subjects in Reliability Engineering, Accelerated Life Testing. This section provides the theory required to understand, evaluate, and plan accelerated life tests, and instruction in the use of ReliaSoft's ALTA.

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Course Section 3 builds upon previously learned concepts and examines System Reliability, Maintainability and Availability theory and applications. BlockSim, ReliaSoft's latest software for ascertaining and optimizing System Reliability and Maintainability, is utilized.

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Master the Subject

Seminar 2000 Dates & Locations

April 10-14	Tucson, AZ
June 12-16	Minneapolis, MN
August 21-25	Virginia Beach, VA
October 16-20	Tucson, AZ
December 4-8	Reno, NV

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Calendar - Upcoming Events in Reliability

12th Annual Software Technology Conference
April 30-May 4, 2000
Salt Lake City, UT
Contact: Dana Dovenbarger
STC 2000 Conference Manager
OO-ALC/TISEA
7278 4th Street
Hill AFB, UT 84056-5205
Tel: (801) 777-7411
Fax: (801) 775-4932
E-mail: Dana.Dovenbarger@hill.af.mil
On the web: http://www.stc-online.org

54th Meeting of the Society for Machinery Failure Prevention Technology
May 1-4, 2000
Virginia Beach, VA
Contact: Henry C. Pusey
MFPT Society
Haymarket, VA 20169-2420
Tel: (703) 754-2234
Fax: (703) 754-9743
E-mail: hcpusey@ix.netcom.com
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2000 IEEE/IAS Industrial & Commercial Power Systems Technical Conference
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54th Annual Quality Congress and Exposition
May 8-10, 2000
Indianapolis, IN
Contact: American Society for Quality
P.O. Box 3066
Milwaukee, WI 53201-3066
Tel: (800) 248-1946
Fax: (414) 272-1734
On the web: http://aqc.asq.org/

International Conference on Metrology: Trends and Applications in Calibration and Testing Laboratories
May 16-18, 2000
Jerusalem, Israel
Contact: Conference Secretariat
ISAS International Seminars
PO Box 34001
Jerusalem, 91340
Israel
Tel: 972-2-6520574
Fax: 972-2-6520558
E-mail: isas@netvision.net.il

RAC Training Program
June 20-22, 2000
Virginia Beach, VA
Contact: RAC
201 Mill Street
Rome, NY 13440-6916
Tel: (800) 526-4803
Fax: (315) 337-9932
E-mail: npfrimmer@iitri.org
On the web: http://rac.iitri.org/PRODUCTS/course_summaries.html.

35th Annual International Logistics Symposium
August 6-10, 2000
New Orleans, LA
Contact: SOLE
8100 Professional Place
Hyattsville, MD 20785
Tel: (301) 459-8446
Fax: (301) 459-1522
E-mail: solehq@erols.com
On the web: http://www.sole.org

Military & Aerospace/Avionics (COTS) Conference, Exhibition & Seminar
August 22-25, 2000
Fort Collins, CO
Contact: Edward B. Hakim
The C3I
2412 Emerson Ave.
Spring Lake, NJ 07762
Tel: (732) 449-4729
Fax: (732) 449-4729
E-mail: ebhakim@bellatlantic.net

Durability and Damage Tolerance of Aging Aircraft Structure
October 11-13, 2000
Contact: Aerospace Short Courses
The University of Kansas Continuing Education
12600 Quivira Road
Overland Park, KS 66213-2402
Tel: (913) 897-8500
Fax: (913) 897-8540
E-mail: mraymond@ukans.edu
On the web: http://www.kuce.org/aero

ISTFA 2000 26th International Symposium for Testing and Failure Analysis
November 12-16, 2000
Bellvue, WA
Contact: ISTFA Conference Administrator
ASM International
Materials Park, OH 44073-0002
Tel: (440) 338-5151
E-mail: educatn@po.asm-intl.org
On the web: http://www.edfas.org

COMADEM 2000 Condition Monitoring & Diagnostic Engineering Management Congress & Exhibition
December 3-8, 2000
Houston, TX
Contact: Henry C. Pusey
MFPT Society
4193 Sudley Road
Haymarket, VA 20169-2420
Tel: (703) 754-2234
Fax: (703) 754-9743
E-mail: hcpusey@ix.netcom.com
On the web: http://www.mfpt.org

Year 2001 International Symposium on Product Quality and Integrity - Reliability and Maintainability Symposium (RAMS)
January 22-25, 2001
Philadelphia, PA
On the web: http://www.rams.org./

Also visit our Calendar web page at http://rac.iitri.org/cgi-rac/Areas?0

In Progress at RAC

COTS Handbook to be Published

In a project for the Department of Defense, the Reliability Analysis Center and the Naval Surface Warfare Center, Crane Division, collected and summarized information specifically addressing reliability and support issues associated with the integration of commercial products into existing military systems. This collection of information also reflects the expertise and experience that RAC and NSWC have gained in the area of commercial product insertion with the DoD acquisition community.

The information is now being compiled into a handbook that is intended to assist technical personnel in supporting commercial products and, as a result, encourage increased use of commercial products. Included in the handbook will be information on best practices, lessons learned, examples and guidance. The guidance will consist of support planning, configuration management, reliability analysis, and refresh/upgrade assessment and planning. The title of the new handbook will be "Supporting Commercial Products in Military Applications."

New RAC Guide for Reliability-Centered Maintenance (RCM)

The RAC has begun development of a new guide for Reliability-Centered Maintenance (RCM), Practical Application of RCM. John Moubray, an author of note on the subject of RCM has observed that the continuing innovation of systems in all aspects of private and public sector endeavors has meant that reliability and availability have become key issues. This observation is based on the findings of research that show that system failures significantly impact the capability of systems to satisfy customers. Research findings also reveal that system failures have serious safety and environmental consequences.

New developments in maintenance engineering and management have resulted in discarding the past, and now largely discredited, system service and breakdown repair maintenance philosophy. New maintenance practices have included condition monitoring, or condition-based maintenance, design for reliability and maintainability, and the increased use of decision support tools (i.e., hazard studies, criticality analyses, FMEA/FMECA).

RCM has not been addressed in a document comparable to the RAC's Reliability Toolkit. The current version of RCM has been largely developed and refined by the U.S. civil and military aviation engineers and maintenance experts. They have established the "best practices" for Reliability-Centered Maintenance used throughout the aviation industry and DoD. Virtually every major U.S. airline bases their maintenance program on the results of RCM analysis. However, RCM remains relatively unknown outside of aviation.

The new RAC product will build on and expand information existing in the RAC resources, with the objective of providing a single source of information dedicated to the development and implementation of efficient and effective reliability and maintainability programs. Publication is planned for late 2000.

New START Sheets

Two new START Sheets are now available from the RAC. The first addresses Sustained Maintenance Planning and is included in this issue of the RAC Journal. The second sheet addresses the concept of Flexible Sustainment. Sustainment is defined as all of the activities required of an Integrated Weapon System Management (IWSM) single manager in support of operating command customers, to keep a weapon system operational in both peacetime and wartime. Innovative sustainment is required to extend the useful lifetimes of all systems in a global threat environment that is by no means static. The new START sheet provides a good overview of the flexible sustainment concept and good references for further study.

All RAC START sheets can be downloaded from our web page: http://rac.iitri.org/DATA/START

Maintainability Toolkit Nearing Completion

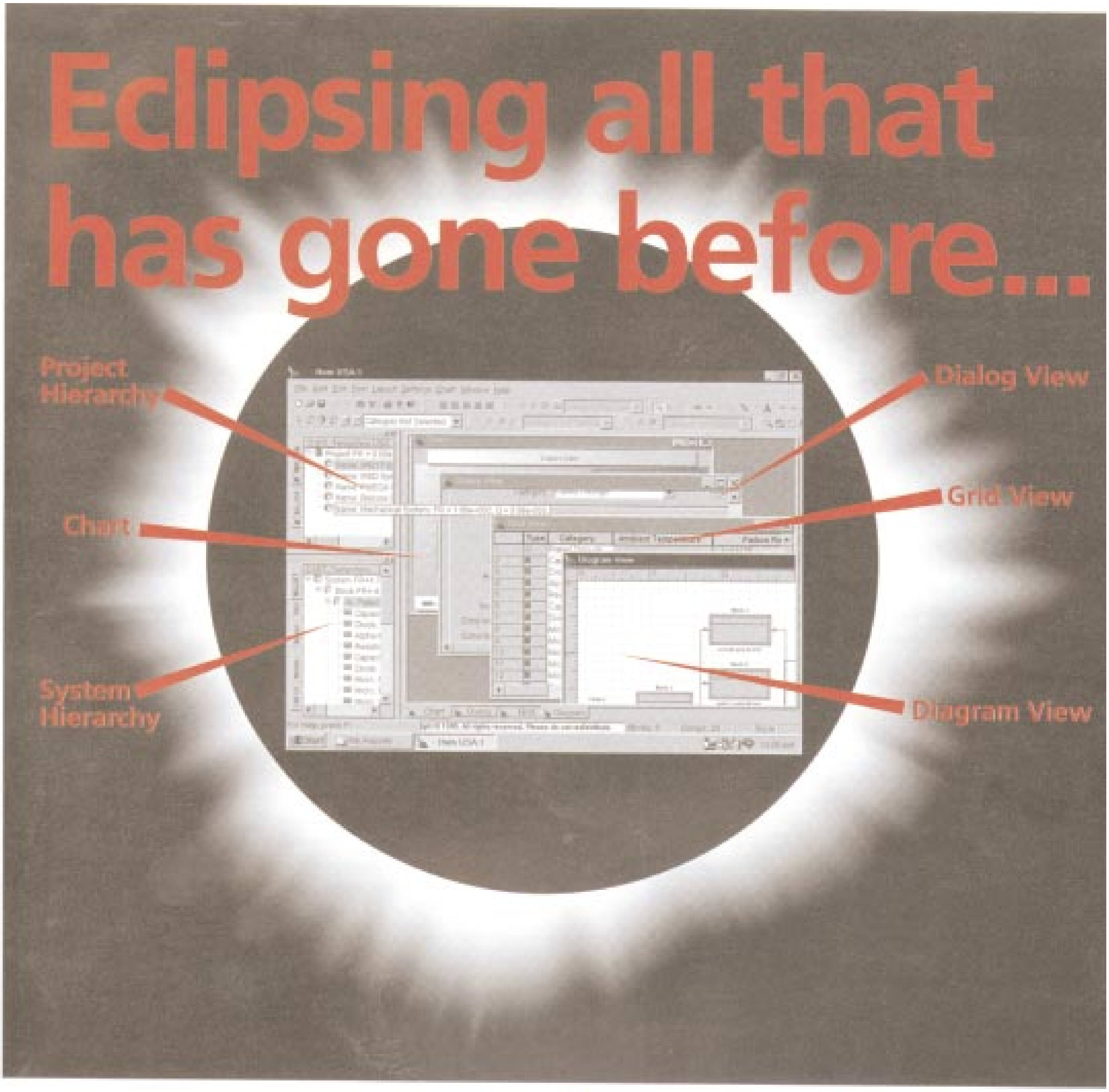
Work is nearing completion on the development of a Maintainability Toolkit, a companion document to the RAC's Reliability Toolkit: Commercial Practices Edition. The new toolkit is a comprehensive guide to maintainability using the same format that has made the Reliability Toolkit such a best seller.

The new toolkit covers a wide range of subjects including:

- The Concept of Maintainability
- Structuring a Maintainability Program
- Source Selection
- Designing for Maintainability
- Maintainability Analysis
- Maintainability Testing
- Maintainability Data Collection and Analysis

The appendices in the Toolkit include information on sources of R&M Education, R&M Software and Acronyms and Abbreviations.

Ned Criscimagna, a Senior Engineer with RAC, is authoring the Maintainability Toolkit.



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RAC Training Program

The Reliability Analysis Center invites you to join us in Virginia Beach, VA, June 20-22, 2000 for courses on the topics of Accelerated Testing, Design Reliability, Mechanical Reliability and System Software Reliability. RAC has been instructing the latest advances in reliability engineering for over twenty-five years. Each of these courses is three days in length and are presented by instructors offering extensive practical experience coupled with deep technical knowledge. Designers, practitioners and managers will become better prepared with the tools and vision to make reliability engineering an integral part of the product development process.

Course Dates:

June 20-22, 2000

Location:

The Virginia Beach Resort Hotel
2800 Shore Drive
Virginia Beach, VA 23451
(757) 481-9000

Course Fee:

Accelerated Testing	$1,695
Design Reliability	$1,095
Mechanical Reliability	$1,095
System Software Reliability	$1,095

Accelerated Testing

This results-oriented course provides both an in-depth introduction to the underlying statistical theory and methods as well as a complete overview and step-by-step guidance on practical applications of the learned theory using ReliaSoft's ALTA, a software tool designed expressly for the analysis of accelerated life test data. Instructed by Mr. Pantelis Vassiliou.

Design Reliability

This intensive overview covers theoretical and practical aspects of reliability engineering with a focus on electrical and electronic parts and systems. Each of the most important elements of a sound reliability program are covered and supported by practical problem solving. Instructed by Norman Fuqua.

Mechanical Reliability

This Mechanical Reliability Training Course is a practical application of fundamental mechanical engineering to system and component reliability. Designed for the practitioner, this course covers the theories of mechanical reliability and demonstrates the supporting mathematical theory. Instructed by Ned Criscimagna.

System Software Reliability

This training course is tailored for reliability engineers, systems engineers, and software engineers and testers. Featuring hands-on software reliability measurement, analyses and design, it is intended for those individuals responsible for measuring, analyzing, designing, automating, implementing or ensuring software reliability for either commercial or government programs. Practical approaches are stressed with many examples included. Instructed by Ann Marie (Leone) Neufelder.

Call us for more information at 1-800-526-4803 or 315-339-7036.
You may also get more details and register on line at our web site at http://rac.iitri.org/PRODUCTS/enrollment_info.html

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