Comparative Study of Reliability growth Models

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Abstract—The development test system design is not usually effective nor efficient to improve reliability based on. Alternative it is essential to design in reliability. The model estimates that the timescale for the detection reliability is essential to the development for the reliability of the design, process is designed to target the objective will be achieved. Various models have been developed for the testing of the reliability test development, but very little attention has been given to the development of design reliability.

Reliability growth model, planning, design and operation of the system are an important consideration. The reliability of modern discipline has its origins in the military and space technology. Again due to the competition in this market, resources and budgets and the increasing complexity of the system is the increased competition. Modern electrical systems and urban transport system failures cost of repair or maintenance or replacement of parts that goes beyond the cost of high impact. Products and services to customers for the inconvenience and lost productivity, crime has decreased, costs are much higher than the cost of urgent repairs.

Product reliability at every stage of production should be managed. Research, product design, development, manufacture and marketing at every stage of development model focused on reliability.

Keywords- *Software reliability growth model, NHPP, Testing effort, optimal software release policy, mean value function..*

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I. INTRODUCTION

In general, the first pattern produced during the development of new complex systems design, manufacturing and engineering constraints will include. Because of these shortcomings, an early version of the device achieved initial credibility or reliability of the system could be less than expected. Orders to identify and overcome these short comings, the prototype test program are subject to often difficult. During testing, the problem areas are identified and appropriate corrective actions are taken. The product must pass the test and appropriate corrective action should be implemented in order to reach this goal. "Reliability is increased.". Reliability problems finding and development through successive stages of product reliability as well as increased monitoring of the structured process called due to changes in the design and manufacturing process of a product (component, subsystem or system) over a period of time to improve. A reliability growth program, including testing by reliability problems finding corrective actions and monitor the reliability of the products increased during the test phase of a well-organized process.

Reliability targets generally are associated with a reliability growth program. One goal of the program is more credibility. There's a separate failures and unscheduled maintenance operations, resulting in catastrophic failure due to those failures associated with the mission aborted, or associated with the target could be a reliable target. Other reliability targets that are related to security may be associated with the failure mode. Reliability growth analysis (RGA) quantification and standards (or matrix) concerns itself with time to assess the reliability of products in development through successive stages of product reliability growth monitoring. Reliability growth management planning reliability and credibility of the realization of the development process is to address through controlling.

System, subsystem or at major unit level can evaluate the reliability of the development taking place. A comprehensive program for the system, subsystem or at major unit level testing can operate two general approaches: an integrated and dedicated. Most development programs for reasons other than the testing that takes place reliability. Integrated reliability using existing test development to highlight the reliability problems and corrective actions to include. The development of a test program for testing the reliability dedicated to highlight the reliability troubles, including corrective action and generally, is focused on the achievement of a reliability goal. The lower level of the test, the primary focus of such an engine, the water pump and the lower level test, which can be dedicated or integrated as a unit to improve the reliability of the system, the design may seem like the place during the early part of the stage. Later dedicated prototype system and subsystem reliability development, testing, integrated reliability growth test or may be subject to both. Credibility to the initial design and development of the latest applications to use the method to expand customer service. As a function of time and resources in planning and reliability of an item with the reliability growth management concerns the management of growth.

Corrective and preventive actions to increase reliability of the failures and design, equipment, operation and production processes rely on the experience gained from testing. Reliability growth test and set design concept to highlight the weakness during the test period and the first full-scale production by performing the appropriate corrective action is implemented. Reliability growth failure modes are addressed. A problem such as a seal leakage may be more than one cause. Each problem set due to a different failure modes and, if necessary, corrective action separately. As a result there can be many failure modes and corrective actions designed to address this as a seal can leak. Formal methods and products associated with the maintenance and support are part of the manual system design and may need to be improved. Reliability growth is a component, subsystem or system reliability permanent improvements that result from changes in product design and manufacturing process is due. Rework, Repair and temporary fixes reliability does not constitute development.

Operators and maintenance personnel training plays a major role in improving the situation. Equipment, operators and maintenance personnel become more familiar with the routine use. This is called net training. Net Training is an ongoing process that fewer mistakes as reliability, operation and maintenance of equipment is used and is being used more effectively to improve since. In the early stages of the learning rate will increase and then level off. When familiarity is achieved, can generate natural learning lessons learned and good governance and has written and formal institutional system design methods and manuals that are the implementation of a permanent technical guidance to improve maintenance reliability or even with the modification of special training, it is a part of the development process reliability. Natural learning is not an individual attribute and a reliability growth.

The reliability of the technology development is not only theoretical. Reliability growth such corrective action, the success of reforms, reliability needs, the initial stages credibility, reliability, and competitive factors, such as money management techniques to take .For relates to such factors as a management team to take corrective action failures during the test takes 90%, with the same design and test information and take corrective action on only 65% of the team management failures during testing may begin. The same basic design with different management strategies can get different reliability values. The relative effectiveness of corrective action if corrective action is initially reliability goal of Tools & Equipment 1 / 10th of a 400% reliability, refinement was given at the beginning of the test, compared to the initial reliability, this is not as important as 50% reliability in the system at the start of the initial treatment goal was a half reliability

II. COMPARISON OF TWO MODELS FOR MANAGING RELIABILITY GROWTH DURING PRODUCT DESIGN

II.I GROWTH MODEL FORMULATION

II.I (A) MODIFIED POWER LAW MODEL

The modified power law (MPL) model objective to carry planning decision in the design phase. it suppose design reliability modifications are applied successfully to decrease a failure mode or to decrease its probability of occurrence, and needs information about the time from the starting of design to occurrence of the development, this model can measure the number, or the magnitude of modifications in the real design to increases its reliability from that initially assessed to its target value. These assumptions of a power law are justified by the fact that the early improvements will be those that contribute most to the reliability improvement. The actual reliability values achieved in the course of the design are plotted corresponding to the design time when they were realized and compared to the model. This model is use to plan the strategies necessary for reliability improvement of a design during the available time period from the initial design revision until the design is completed and released for production the model can the formulated as follows the initial product reliability for the predetermined product operational life at time T is denoted by R0 (T). Assuming that the distribution of the time to failure exponentially distributed then the initial hazard rate of that product is

$$\lambda a0= - In[R0(T)]/T.........(1)$$

Under the assumption that growth in reliability follows a power function, the product hazard rate decreases as modification are made. We can represent the hazard rate after a period of design time t as a function of the accumulated number of modification made by t, d(t). Therefore, we can express the hazard rate of the product at time t during the design period as

$$\lambda a(t)=\lambda a0[1+d(t)]\text{-}\alpha D............(2)$$

Assuming the number of design modification is a function of time distributed linearly over the design

$$d(t)=Dt/tD............(3)$$

Where D is the number of modification that will be made during specified design period tD and αD is the reliability growth rate resultant from fault mitigation the hazard rate as a function of design time becomes

$$\lambda a(t)= \lambda a0(1+Dt / tD) -\alpha D .....(4)$$

Denoting the product reliability goal by RG(T), then the goal hazard rate at the end of design period tD, is

$$\lambda aG\ (tD) = -\ln[RG(T)]\ /\ T ....(5)$$

Equating goal and projection from initial reliabilities gives

$$\lambda aG(tD) = \lambda a0(1+DtD\ /\ t_D\ )-\alpha D= -\ In\ [Ro(T)]\ /\ T\ x\ (1+D)-\alpha D.............(6)$$

Substituting λaG(tD) in to the expression for goal reliability and solving for D Gives

$$D = \exp[-In(In[RG(T)]\ /\ \ln\ [R0(T)\ /\ \alpha D] - 1..........(7)$$

Solving the same equation for the growth rate, expressed as a function of the design modification initial and goal reliability, gives

$$\alpha D= In(In[Ro(T)]\ /In\ [RG(T)\ /\ In\ (1+D)..........(8)$$

During the design period, the product reliability at operational time T can be expressed as a function of design time t (the reliability growth model in the time period from 0 to tD) as follows :

$$R(\ t\ ,\ T\ ) = \exp(\ -\ \lambda a(t)\ T)..........(9)$$

Substituting the expression for the average failure rate, the modified power low model for the design phase 0<t<tD, is derived as follows:

$$R\ (t,T) = \exp\ [-\lambda a0T(1+Dt\ /\ tD)-\alpha D]=\exp[In[Ro(T)]\ /T(1+Dt/t_D)-\alpha DT]\qquad ....(10)$$

In the above equation, expressing D in terms of initial and goal reliability, the reliability growth as a function of time in design period, available for design improvements becomes

$$R(t,T) = R_0(T)\left\{[t_D]^{-1}\left[t_D + t\left(\frac{\ln[R_G(T)]}{\ln[R_0(T)]}\right)^{\frac{-1}{\propto_D}} - t\right]\right\}^{-\propto_D} .... (11)$$

II.I (b) MODIFIED IBM MODEL

This modification of the IBM –Rosner reliability growth model (MIBM) was initially motivated by the analysis of test data. This version is adopted for supporting planning decisions during the product design phase. The model is based on a Bayesian approach the combines a prior distribution for the number of design weaknesses in the new product design with empirical data for the reliability of similar product design to produce posterior distribution for estimating the reliability of the new product design like the IBM –rosner model, this model assumes a fixed number of weaknesses or potential faults are inherent in the product design and that within the period between design modifications the rate at which failures occur is constant. It is further assumed that modifications to the design to remove weaknesses are perfect.

In this model we additionally decompose the inherent failure rate of product design in to appropriate systematic classes ,such as build environment , and degradation in such a way that groups of like faults are together for example , major faults of the same types with low rates of occurrence or minor faults of the same types with high rates of occurrence . We also include a non-systematic failure category to represents those noise failures, such as no founds that cannot be attributed to a particular cause. This allows us to modify the reliability growth profile as the systematic failure rate changes when design modifications are implemented, while always taking in to account the impact of noise failures on the estimated reliability at a given time.

The non-systematic failures are supposed to obtain at a constant rate (λNS) and can be evaluated using data from homogenous product designs. The systematic failures are estimated via expert judgment about the design deficiency and the failure rates related with fault classes from engineering experience.

To evaluate the effect of systematic failures on the reliability of the product design, all potential design weaknesses (D) should be defined and may be assigned to one of K fault classes as suitable. The chance of every design weakness within every fault class resulting in failure during the specified age of the product should be evaluated for example, engineering judgment. Method for defining design weaknesses and evaluating their probability of resulting in failure

The expected number of design weaknesses in fault class k (η_k) likely to output in failure if the design is not improved can be calculated using.

$$\eta_k = \sum_{j=1}^{D_k} P_{kj} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where η_k expected number of design weaknesses in fault class k, Dk is is the total number of design weaknesses expected in fault class k and Pkj is the probability of the Jth design weaknesses in fault class k being realized. This calculation is depending on the assumption that the number of design weaknesses for each fault class is a Poisson random variable.

Systematic failure rates can be estimated for each fault class using empirical or generic data on relevant existing product designs of similar complexity.

It is given that the input data have been indentified, and the estimator of the reliability of the initial product design can be found. This is the product of the reliabilities of the non-systematic & the systematic failures. The rate of the former is the product of the prior distribution for the no. of design weaknesses and the empirical value for the systematic failures. Hence the reliability of the initial product design can be written as:

$$R_I(T) = \exp\{-[\lambda_{NS}T + \sum_{k=1}^{k} \eta k(1 - e^{-\lambda_k T})]\} \ldots\ldots (2)$$

Given that modifications will be executed to remove design weaknesses, the reliability of the product design will increase. Therefore, to take into account the rate of reliability growth (αD). The reliability of the modified product design at time T is given by

$$R(t, T) = \exp\{-[\lambda_{NS}T + \sum_{k=1}^{k} \eta k e^{-\alpha Dt}(1 - e^{-\lambda_k T})]\} \ldots (3)$$

To estimate the rate of growth, exchange the goal reliability (RG(T)) and the specified time of the design period (tD) with R(T) and time index T on the growth rate (αD), respectively, in the previous equation. Rearranging gives

$$\propto_D = \frac{\ln\left[\frac{\sum_{k=1}^{K} \eta k\left(1-e^{-\lambda_k T}\right)}{-\ln\left[R_G(T)\right]-\lambda_{NS}T}\right]}{t_D} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

If a growth rate has been estimated or evaluated then, similarly, an estimate of the expected time to achieve the target reliability is given by

$$t_G = \frac{\ln\left[\frac{\sum_{k=1}^{K} \eta k\left(1-e^{-\lambda_k T}\right)}{-\ln\left[R_G(T)\right]-\lambda_{NS}T}\right]}{\propto_D} \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

III (a) ASSUMPTIONS AND MODEL FORMULATIONS

The MPL supposed to fixed number of design modifications (D) that will be conducted over design time period (t_D). The MIBM differs so far as the number of design modification is assumed unknown a priori, but modeled as a Poisson random variable with a known mean.

Both modeling approaches use subjective assessments to help inference regarding the number of design improvements that will be made. The MPL requires a point position of the improvements while the MIBM needs a prior distribution, defining the uncertainty associated with the number of faults that outcome within the design

Every model makes different assumptions concerning the rate at which this improvement is performed. The MPL suppose that improvements are evenly spaced via design stage, while the MIBM suppose that it is more likely to conduct improvements early in design and they become fewer as time progresses.

Both models satisfied that the hazard rate decreases more substantially in early design by supposing a power law and common spaced improvements; the MPL state that earlier improvements have a bigger impact on the hazard rate then later. The MIBM concentrate more on the underlying fault, whereby it is supposed that every fault within a class contributes to the overall hazard rate of the design. By supposing more improvements in early design, the MIBM captures the decreasing rate of failures.

Both models assume that when design is aborted or terminated, the product has a stable hazard rate. However in the MPL, this hazard rate assumed known, while in the MIBM it is composed of an unknown number of underlying faults for which we are in possession of a prior distribution. As such this latter model while not defined the time to failure with an exponential distribution but model the time to failure throw an average of exponential distributions but models the time to failure an average of exponential distribution weighted against the prior distributions.

In theory neither model straightforward considers defective fault mitigation, or the introduction of new fault throughout design. However re-assessing the input parameter D or the MPL and re-eliciting the prior distribution for MIBM can address this and permit the models to be updated. In practice the analyst may evaluate the impact of the modifications in this way since changes often lead to more complex designs and hence greater potential for decrease reliability. Therefore, the assumption that reliability must modify is not a constraint when applying these models dynamically through the design cycle.

III (b) DATA REQUIREMENTS AND MODEL OUTPUTS

Both models need a straightforward description of the target reliability and an initial estimate of the reliability. Using these as inputs they explain the relationship between the number of design improvements or changes and effectiveness of the design stages. The MIBM requires as input a mean number of faults within the initial design and therefore the effectiveness of design time in mitigating faults is an output; choose to achieve the goal reliability. However, with the MPL the number of modifications drives the reliability enhancement and is find out by supposing an effectiveness parameter, which would be characteristic of the product and the anticipated type's improvements. The data used to occupy, the models are based upon failure events on components and assemblies provided by their manufacturer's age test data, from accelerated test on components with unknown reliability as well as historical data from same products of the some complexity. Such data will provide either failure rates as input for the fault tree, or related analysis for MPL or the failure rates or intensities in the MIBM. Expert engineering judgment succeed in both the selection and treatment of the an aforementioned data to ensure suitable classes and types of failure event are considered, but more importantly in gauging the presuppositions of the design team to obtain and quantify the potential design weaknesses.

Each model can be supported using a spreadsheet and can deliver an important guide to increase profiling in design practice. Both models have formulations that are instinctive to project management teams. The MIBM needs more inputs, is grounded in a stochastic process theory and so needs slightly deeper understanding to modify. However, it can formally account for uncertainty in reliability increases through a prior distribution, which can be modified mathematically through Bayesian methods or through re-elicitation, during design. All through not shown in this example, the MIBM will support the generation of interval approximates. The MPL has an easier formulation that is instinctive and integrates with standard reliability techniques used in the design phase. However, it is only able to support point estimates of reliability growth.

IV. SUMMARY AND CONCLUSIONS

The option of model depends on the growth process being modeled. Key driver are the type of system being designed and the project management of the growth process. When the design action are understood in advance project workloads can be managed evenly leading to foreseeable and equally spaced improvements, each of which having same effect on the reliability of the item ,then the MPL would be the more suitable model. On the other hand, the MIBM would be more appreciate for more uncertain condition, where the reliability improvement of a design is driven by the removal of errors, which are as yet unknown, and only through further investigation of the design will be identify. These conditions have less foreseeable workload and fewer improvements are likely later on the project. Informal evidence from industrial applications of this model purpose they are useful in supporting reflection upon the potential weaknesses of the design and the impact of improvements on its reliability through analysis thereby permitting reliability engineering to obtain the attributes of a design engineering discipline. The models are simple in comparison with the complexity of the problems they describe. However, this simplicity permits them to provide an experience for use by managers tracking reliability growth in design.

Growth modeling in the design can be confirmed by comparing the output with observations from test and use. This is a defective verification since the evidence collected through test to confirm or disprove the presence of potential weaknesses, and to flag additional, unexpected problem, only provides partial observations given that only one design option is being examined. In addition, there is a time lag from months to years between modeling and the generation of observations about the reliability of the system design data collected through test and use. However, such verification is must as it permit feedback to be given to the analyst and engineers to re-calibrate the model and their understanding of that family of designs.

V. DUANE V / S Crow / AMSAA Model Comments

1. Duane model is a deterministic model and the crow / AMSAA model Stoch model. Suppose reliability growth and development model Duane Crow / AMSAA models declined as well and allow for consistent reliability (NHPP)
2. Overview Duane development model is based on a regression equation. AMSAA stochastic point of view of the development model is developed.

In general, AMSAA development model the word "credibility" does not use. The criterion "reliability growth" as MTBF or failure rate is actually "MTBF Growth" uses. But assuming that you use your product MTBF of age can use to transfer an approximation equation for reliability, failure is distributed faster time (t) = exp (-1 / MTBF * T). At the end of his trial here MTBF is instantaneous.

Test phases: the "design phases" or after the test as each design revision can be thought.

3. "Duane development model" on the X-axis and Y-axis on the cumulative time by plotting cumulative MTBF. AMSAA development model, cumulative failures against the cumulative time (x) plotting.
4. Duane crow- AMSAA model development model and are most often used reliability growth model. The fact that both their relationship and the logarithm of the cumulative MTBF underlying the observed linear relationship between cumulative test times comes to make use of. However, Duane model MTBF whether observed changes over time due to random error between stages is quite different from what can be seen to the test does not provide a capability. Crow- AMSAA model allows for such assessments. In addition, growth in data a crow-AMSAA hypothesis test to determine the presence allows for the development of processes (Beta 1 indicate a low MTBF <1 indicates that there is an increase in MTBF, beta = 1 MTBF and indicates the continuous beta>). Additionally, the Duane model crow- AMSAA model looks at the process as a determinant, as the reliability of the development process to consider potential.
5. MTBF a "simplified" model is considered credibility (this assumes a constant failure rate), since it is still a valid measure of reliability growth? It is used to track the development of other belief reliability / model would be difficult?
6. Reliability growth, as the names implies measure and assess reliability metrics used and tracked These phases improve the reliability of a product or process that deals with the assessment. One such metric is a "reliability growth" scenario; US model and improve MTBF metric as it is appropriate to allow such experiment.
7. MTBF (mean each distribution is a) any distribution that's going to be used for a measurement of credibility, (beta = 2 points).
8. In general, there is a simple rule that your goal should be based on a certain metric Beta adds this value is not given. Metric that you can use depending on your requirements and application needs to be better MTBF metrics are considered. However, MTBF reliability growth widely .with that said, the failure of the normal cumulative number versus time plot to tell you is not going to reach your goal is. Unless of course your

goal or the cumulative number of failures in terms of cumulative MTBF. Cumulative MTBF can be calculated by using the T / n, where n cumulative number of failures at time t, however, the cumulative MTBF reliability growth in the immediate time being considered instead, since most you wants to know where you are now. At a specific time from a reliability goal for reliability MTBF equation that Harry has been told to go, assuming a constant failure rate (exponential distribution) use.

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