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REVIEW OF DARCOM'S USE OF RELIABILITY GROWTH MANAGEMENT TECHNIQ--ETC(U)
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REPORT

REVIEW OF DARCOM'S USE OF RELIABILITY GROWTH MANAGEMENT TECHNIQUES

Prepared by: Dr. Gerhard Reethof, Consultant
Member, Army Scientific
Advisory Panel

Study Requested by: Mr. S.J. Lorber
Director of Quality Assurance
Development and Readiness Command
United States Army
Alexandria, Virginia

Dr. Gerhard Reethof
Professor of Mechanical Engineering
The Pennsylvania State University
University Park PA 16801
Phone: (814) 865-2761

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Background:

The more intensive application of the concepts and techniques of reliability growth management was one of the highlights of a study by the Panel on "Accelerated Development of Reliability" which was presented to the Commanding General of the Army Materiel Command in February of 1972. The "Hope Committee Report" as it became known, resulted in a much accelerated development and application of the reliability growth techniques. The Army Materiel Systems Analysis Agency (AMSAA) assumed a leading role in the development of these techniques by sponsoring two reliability growth symposia. The first was held September 26 and 27, 1972 at Aberdeen Proving Grounds. The second AMSAA reliability growth symposium was held November 12 and 13, 1974, again at Aberdeen Proving Grounds. The first symposium emphasized the fundamental conceptual and mathematical aspects of reliability growth tracking and prediction techniques, whereas the second symposium presented five excellent examples of the application of the reliability growth management methods by Project Management, Contractor, and at various commands. Much credit for the excellent progress made has to go to Mr. Pat Bruno for the vision and encouragement given as well as Dr. Larry Crow for the technical innovation and leadership.

This latest study grew out of several discussions between Mr. S.J. Lorber and myself as we noted the increasing acceptance of the reliability growth management techniques and our joint concern about the proper balance between technical sophistication and the practicalities of everyday application.

On April 2, 1975, Mr. Lorber, representing the Deputy Commanding General, requested that I perform a review of AMC's use of reliability growth management in my capacity as a member of the Army Scientific Panel. The charge presented to me by Mr. Lorber was:

a) Is the reliability growth effort, as currently applied, a worthwhile activity in terms of aiding the decision-making processes and affecting the course of development programs?

b) Specifically, has the reliability growth methodology affected decisions at the technical and managerial level?

c) How can the reliability growth concept application be strengthened and improved?

Because of other commitments, I only started the review at the end of 1975 and conducted two visits in 1976 as follows:

1) Initiation visit to AMC Headquarters 27 January 1976 to meet with S.J. Lorber, Art Nordstrom, Dan Kruvand, Jack Lavery, and Colonel Donovan, DSCRDA.

2) Visit to AMSAA 26 April 1976 to meet with Pat Bruno, Larry Crow, and Jack Lavery, with Colonel Donovan acting as Staff Assistant.

Much information was also obtained at TACOM and AVSCOM in connection with my activities as Chairman of the Product Improvement II Ad Hoc Group. In addition, the Proceedings of the two Reliability Growth Symposia, particularly the second symposium, provided much needed information.

Lastly, long telephone calls were made to BG. W. Hilsman, Project Manager of TACFIRE and TSQ 73, MG Lauer, Project Manager of UTTAS, Mr. R. Whitley, former Project Manager of Dragon, Mr. Salter formerly with the M60 Program and at present working with the Project Manager of MICV, and Colonel R. Phillipp, Project Manager of XM198 project. These candid conversations provided an up-to-date look at the present picture of reliability growth management acceptance, problems, and potential for improvement.

SOME REMARKS ON RELIABILITY GROWTH PROCESSES IN DEVELOPMENT PHASES OF PROGRAMS AND THE PRODUCT IMPROVEMENT OF ITEMS

Reliability growth in a population of items occurs as a result of the correction of deficiencies through redesign and retrofit. In development programs, this is commonly termed the "Test - Fix, Test - Fix" process; for systems in operational service we recognize this process as one aspect of the product improvement cycle. We must recognize a fact of life in the design and development of todays complex, high performance system. Although the developer, either Army or Contractor, will have done his level best to "design" high reliability into the device in a sincere aim to meet the operational reliability goals, the economic and timing constraints as well as the usual departure of new designs from earlier practice resulting from the technical challenges , there will appear a series of unexpected failure modes once the device is put on test, first in the laboratory, and later in the field. True, a number of Product Assurance practices such as failure mode and effects analyses, fault tree analyses, and periodic in-depth design reviews have as their aim the minimization of design oversights, there will still exist a distribution of failure modes with varying failure rates which are waiting to be discovered and corrected by design changes. We can visualize the reliability growth process then as the "erosion" of the failure rates distribution as test hours and later field hours are accumulated. We can visualize this process by depicting such a hypothetical failure rate distribution as shown in Figure 1.

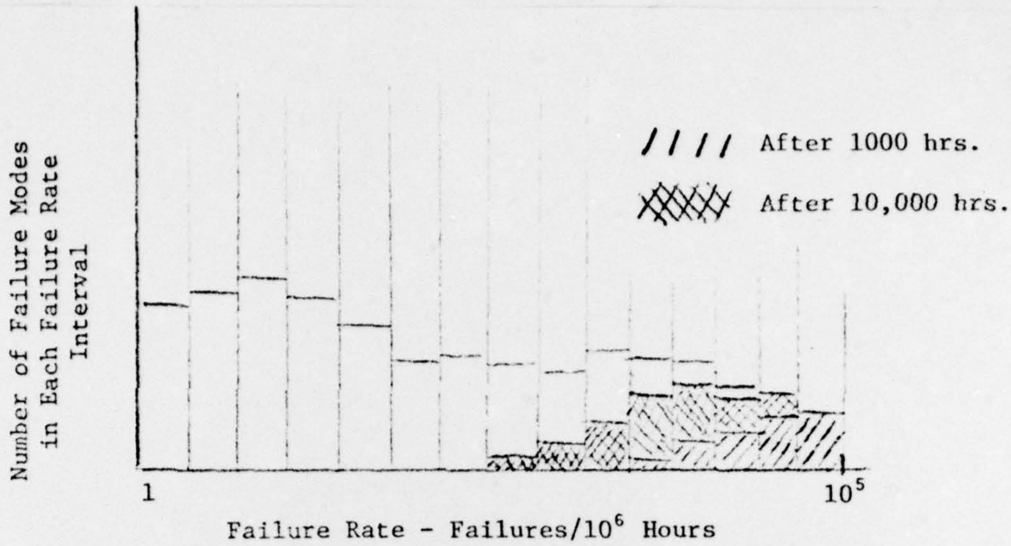

Figure 1

Therefore, for any one specific configuration, the reliability should not be expected to grow during even an extensive series of tests unless, of course, items subsequent to the appearance of particular failures have been retrofitted with the particular corrective features.

The question on how quality control caused problems should be treated has come up. Quality-caused failures should be considered as evidences that the device in question is not representative of the design. Thus manufacturing in fact has not produced a product that meets the design specification. A typical example might be the poor apparent reliability of the DRAGON missile. In this case, an aggressive tightening of quality control with some further organizational changes resulted in a product which finally met the design requirement and performed to expectations.

A very important requirement for the effective tracking of reliability growth is a clear set of definitions of what constitutes mission success and what criteria of measurement are to be used. In essentially all of my discussions with Project Managers, this item of concern was raised as a major factor. Failure definitions were seldom clear and unambiguous, often the key performance factors were not even included. Thus, for an aircraft like UTTAS, MTBF to complete a mission is simply not a sufficient evaluator of the state of the system. Should failure of an indicator light bulb be treated as having the same gravity as failure of an engine bearing?

Thus, additional measures such as the important removal rate, maintenance indicators such as maintenance man-hours per flight hour, and possibly availability, should be developed and tracked. Such additional measures would give the project manager a far better means of evaluating the true effectiveness and rate of growth of his product.

The rate of reliability growth at any one time in a program depends on several factors. I have already mentioned the responsiveness of the program in fixing problems and retrofitting items. Another factor is the test severity. If the severity is high, new failure modes will appear at a higher rate per test hour than would be the case for test conditions that are less severe than for example normal duty. Consideration should, therefore, be given to the establishment of test hour multipliers to account for this well known factor and permit a realistic assessment of development program reliability progress.

We must recognize that an effective reliability growth management program requires an excellent failure and degradation reporting effort as well as a timely analysis of all events and resulting maintenance or corrective actions. Much experience is being gained in this area and these lessons must be transmitted throughout DARCOM.

In conclusion, I get the clear message that reliability growth management is becoming a very useful approach to accelerate the development progress in todays complex weapons systems. The philosophy and techniques are rather new and are understood to varying degrees in different projects.

Reliability growth management is rapidly becoming one of the key drivers in project management, dictating many major decisions on the allocation of resources. As experience is gained and greater insight into the reliability growth processes is obtained, refinements in the technical aspects must be made to further facilitate the decision processes. Thus, resources, on a continuing basis, must be provided to assure the timely and effective development of the techniques and the disemination to the projects via symposia and direct input from the technical focal point; namely, AMSAA.

FINDINGS

1) RELIABILITY GROWTH TECHNOLOGY HAS REACHED A LEVEL OF DEVELOPMENT WHICH IS STATISTICALLY SOUND AND REASONABLY ADEQUATE TO THE TASKS..

Discussion

The so-called AMSAA model of reliability growth appears to be technically sound. However, a continuing effort is needed to further develop confidence bounds for, particularly, truncated tests. Procedures should be developed for small sample sizes so that risks in data interpretation can be identified. Sensitivity of the goodness to fit test used should be established so that deviations of measured data from the model can be interpreted in terms of risks. The question of how to handle deviations from exponential reliability model such as distinct wearout patterns with increasing part age should be addressed.

In summary, development work on the mathematical - statistical aspects of the growth model must continue to incorporate experience which is currently gained. AMSAA is at present not staffed to perform this important function. Dr. Larry Crow, one of the key contributors to reliability growth modeling is not spending any significant amount of time on the further development of the technique. Also, AMSAA must continue to act as teacher, and to some degree, coordinator, between particularly the test agencies such as OTEA and TECOM.

Recommendations

a) An identified, continuing effort should be carried out at AMSAA to further develop and verify the AMSAA Reliability Growth Model. This should be a continuing, planned program with at least one full time bright young engineer working under the direction of Dr. Crow.

b) Charge the AMSAA function with responsibility to assure a coordinated application of reliability growth methodology in various test operations.

c) Consider contracting with a University or one of the DARCOM contractors who are knowledgeable in realiability techniques. to contribute to the development of reliability growth techniques. Possibilities are The University of California at Berkely; the Rand Corporation; the United Technology Center at Sunnyvale, California; Texas A & M; Penn State; Massachusetts Institute of Technology, Nuclear Engineering Department; The University of Arizona at Tucson.

2) THE LEVEL OF UNDERSTANDING OF RELIABILITY GROWTH CONCEPTS AND TECHNIQUES VARIES FROM COMMAND TO COMMAND AND IN PROJECT MANAGER ORGANIZATIONS. IN SOME CASES, THE UNDERSTANDING IS SUPERFICIAL AND HAS RESULTED IN THE SETTING OF UNREALISTIC RELIABILITY OBJECTIVES.

Discussion

Reliability growth management techniques are relatively new and represent inovative thinking in the management of development and product improvement programs. I have detected some rather distressing misconceptions about the basic reliability growth processes among high level managerial and working level technical personnel. On the other hand, I have also met with a profound appreciation of the opportunities of the methods laced with a realistic bit of scepticism on the part of several Project Managers. The power of the method, as well as its limitations, must be clearly understood by the user.

For example, in a particular project, surprise was expressed that no reliability growth was experienced in one particular series of extensive tests involving several items of equipment with no corrective action taken during the test. In another case, the reliability growth projections to introduction into operational service ("the project budgeted growth curve") toward meeting the Material Need document requirements showed a completely unrealistic slope of 2.4. Interestingly, the reliability growth curve slope up through the DT/OT II was a quite realistic 0.752. The only conclusion which the Project Manager should have drawn was that the MN requirements simply could not be achieved with the normal development processes and that a step increase in reliability must be budgeted for by planning on a major review of all failures, indications of design weaknesses and the required design improvements and verification by an extensive test program. Based on the initial low levels of reliability, it was apparent that the MN requirements could simply not be met if the assumption of normal reliability growth rates could be verified as being applicable.

The process of educating the DARCOM community in the application of reliability growth management and tracking techniques must continue, possibly at an accelerated pace. The two symposia appear to have been well conceived and well executed. These should be periodically repeated. In addition, however, workshops should be held at the commands to educate the technical personnel in the fundamentals and the application of the techniques. Of particular importance is the training of project product assurance personnel so that the decision-makers are properly informed.

Recommendations

a) AMSAA should be staffed and funded to prepare and hold periodic workshops at the various commands of DARCOM and the project managers Offices.

b) AMSAA should have the opportunity to periodically assess the technical soundness of the reliability growth techniques application at the various project offices.

c) The test operators, in particular TECOM and OTEA, must be schooled in the statistical techniques needed to properly track reliability growth.

d) Up to date manuals should be prepared which are strictly application-oriented for use of DARCOM personnel. I understand that Dr. Crow has already begun this work but needs additional time to complete the task.

3) FAILURE DEFINITIONS ARE NOT ALWAYS CLEAR IN CONTRACTS WITH CONTRACTORS AND HAVE RESULTED IN MUCH MISUSE OF RELIABILITY DATA AND IN FACT HAVE DETRACTED FROM THE CREDIBILITY OF THE APPROACH AS UNNECESSARY ARGUMENTS ENSURED.

Discussion

The need for clear failure definition and mission definitions must be stressed. These definitions must be developed in the negotiation phases of contracts and included in contractual documents. Scoring conferences must continue to be used by all activities tracking reliability growth. Thus, the Letter of Agreement (LOA) and the subsequent ROC documents must include the appropriate measures of reliability and maintainability.

The reliability of an end item should be expressed in truly operational terms. Thus, mean time between failure may not be a sufficient indicator. For aircraft engines, for example, mean time between power loss, mean time between in-flight shutdown, removal rate, and maintenance man hours per flight hour are used together as criteria. In some situations, availability may, in fact, be an appropriate measure. TRADOC should play an important role in this process.

In my discussions with the Project Managers I found almost universal concern about the need for precise and definitive failure definitions. It would, therefore, be advisable to develop a series of guidelines on the type of failure definitions and their format for various type weapons and systems. The P.M.'s feel that the failure definitions need to be refined as experience is gained with the tracking of reliability growth. There is also concern about differing interpretations of the failure definitions by first the developer and then the user. Their outlook differs as a result of their different basic orientations.

The question of purging the data of failures that are in the process of correction came up several times. It should be made clear that the AMSAA (or Duane) model does not permit purging of data as the result would be injustly biased. Similarly, test data from high stress environmental tests should be carefully screened. If the test condition is truly not representative of operational conditions, then such data may be excluded unless, in the opinion of responsible technical personnel, a potential problem has been uncovered.

Recommendations:

a) Initiate a study by AMSAA, jointly with TRADOC and several Commands, to develop a set of guidelines for the definition of failure criteria and reliability measures.

b) Include carefully developed failure definitions and reliability criteria in LOA and ROC documents.

c) Develop guidelines for the incorporation of reliability measures into contract documents.

4) AS A RESULT OF AMARC AND PREVIOUS REORGANIZATIONS, RELIABILITY TALENT HAS BEEN DIFFUSED TO THE DETRIMENT OF THE EFFECTIVE IMPLEMENTATION OF RELIABILITY GROWTH TECHNOLOGY.

Discussion

Concern has been expressed at both AMSAA and the Quality Assurance Directorate about the deleterious effect of the reorganizations on the staff capabilities of these two key organizations. It is, of course, imperative that a capable cadre be maintained to perform the necessary support functions. I am informed that several very capable young engineers and mathematicians were relocated.

Recommendations

a) Have AMSAA and Quality Assurance present their cases to DARCOM management to assure that the scope of the problem is defined so that corrective action can be taken.

5) RELIABILITY GROWTH MANAGEMENT TECHNIQUES ARE APPLIED OVER THE BROAD FRONT OF DARCOM ACTIVITIES WITH CONSIDERABLE PAYOFF IN INCREASED RATE OF RELIABILITY IMPROVEMENT IN DEVELOPMENT. YET MUCH IMPROVEMENT SHOULD STILL BE ENCOURAGED TO DEVELOP FULL POTENTIAL OF THE METHODS.

Discussion

The reaction to the introduction of the Reliability Growth Management techniques into the project manager's portfolio of managerial tools varies from tremendous enthusiasm to "its been foisted on us and we can live with it." The enthusiastic supporters have stated that the reliability growth technique has been of the key driving factors in the program and has most certainly been a major contributor to rapid reliability improvement. There has been some difficulty in early implementation in a program because of the dearth of a good data base but nonetheless it is generally agreed that reliability growth monitoring is becoming a useful approach. Some of the other difficulties have already been discussed in the previous discussions in this report and the previous findings.

There is simply no doubt that reliability growth management has contributed to reductions in program costs as expressed by UTTAS, Stinger, Shillelagh, SAM-D, TACFIRE, DRAGON, MICV and M60 programs to cite a few specific instances.

I have found, in the negative reactions, that they are based on an incomplete and, at times, erroneous understanding of the fundamental processes and even intents of the approach.

The stage has been set to make broader use of the technique as a management tool for better risk assessment and resource allocation through further education and, in particular, the development of development program simulation techniques. Such stochastic simulations will permit the more effective allocation of resources to maximize reliability and availability achievement.

Recommendations

a) Continue to encourage the use of reliability growth techniques by incorporation into Army Regulations, contractual documents, and specifications.

b) Continue the development of the technique on a continuing basis by collecting expetience on current programs and through use of advanced statistical methods.

c) Provide for effective dissemination of successful practices to new programs.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A review of reliability growth management techniques attempts to answer the questions: Is the reliability growth effort, as currently applied, a worthwhile activity in terms of aiding the decision-making processes and affecting the course of development programs? Specifically, has the reliability growth methodology affected decisions at the technical and managerial level? How can the reliability growth concept application be strengthened and improved?