Historical Efforts on R & M Integration into Engineering Curricula

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ABSTRACT

Many approaches are being tried to incorporate reliability and maintainability principles and techniques into engineering education at both the undergraduate and graduate levels. The United States Air Force has been vitally interested in all graduate engineers becoming knowledgeable of R&M so they will be able to readily include R&M in their designs. R&M must be designed into new systems as they evolve through the complete design process, and not be attempted as an extra addition or afterthought. Only by having the designer be proficient in the principles and tools of R&M can the final design be successful. The only way for all the designers to have the knowledge of R&M is to include R&M in the design courses within the academic environment. The time is here for R&M education to be included in every engineers education. This does not imply that the education must be increased, or that some items must be eliminated to make room for the R&M principles in design. What is implied is the measurement of the design is not adequate until the success of the design (R&M) is determined. R&M education of engineering designers is absolutely necessary for the future if quality products are to meet the requirements to satisfy customers.

1. INTRODUCTION

Historical efforts at engineering education have neglected the subject matter regarding reliability and maintainability for the preponderance of engineering graduates. My personal experience (Aeronautical engineering in the 1950's) had nothing about reliability and maintainability with the possible exception of learning to include tolerances on dimensions in my engineering drawing class. Tight tolerances would preclude the "tolerance build-up" problem as pieces of the design were joined together. This would help make the final design more successful.

In recent years, there has been a growing knowledge that reliability and maintainability are design parameters that must be incorporated into the design by the initial designer, and not are items which can be added to the design by a group of specialists after the design has been finalized. This sounds easy, but the designers were never taught the principles of R&M in their respective educational courses. For the future, designers need to be educated regarding R&M being mandatory design parameters, and their education must include analysis and tools for the future designers to be capable of including R&M in their designs.

2. USAF R&M 2000 EDUCATION

A major push for R&M throughout the Air Force was made with the creation of R&M 2000 in 1983. An office of a special assistant for R&M was created in the Pentagon to guide and oversee the activities. One of their first endeavors was to attempt to change the education of engineers within the Air Force. Shortly thereafter, the focus on education was expanded beyond that internal to the Air Force, since it was realized that the majority of the designs employed by the Air Force were actually designed by engineers in the commercial marketplace, and they must know and understand reliability and maintainability if they are to incorporate it into designs for Air Force use. Activities were generated and funded to the limited extent non-governmental education can be funded from within the Air Force. The activities included an investigation of the tools for including R&M into the design of systems using computer aided design (CAD). Another activity was the education of engineering educators, who could in turn teach their respective students about R&M in the design process. The activities even included experimental integration of R&M education into design curricula. Much of the total activities of the Air Force office of the Special Assistant for R&M was devoted to the educational activities, as it was recognized that this was an area of extremely high return on the investment.

3. GRADUATE ENGINEERING EDUCATION

The Air Force Institute of Technology (AFIT) is the graduate school of the Air Force, and the school of engineering alone graduates over 200 Master's Degrees and a few Doctorate Degrees per year. Very early in the R&M 2000 initiative, AFIT was asked by the Special Assistant for R&M what could be done in a timely manner to add R&M to each of our graduating engineers degree plans. The answer was not easy. AFIT supports more than a dozen degree plans and options, each with highly coordinated prerequisites. Adding any courses would change the pattern of other courses, which would in turn seriously jeopardize the remaining schedules of prerequisites. The conclusion as to what could be done quickly, was to extend a selected group of engineering graduates to take a specialty sequence of R&M courses. This could be done for students about to graduate who were finishing their last quarter of classes, which were scheduled such that change was impossible if they were to graduate on time.

January 1992 is the seventh year of the program to add a quarter onto selected students graduating with an advanced engineering degree. This education is referred to as Professional Specialized Education (PSE), implying

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this is graduate education at the post master's degree level. Approximately 30 students per year have undergone this PSE program. The intent is not to make reliability engineers of the students, but to add R&M knowledge to each individual that should be useable in the future design activities.

4. R&M DESIGN TOOLS

As many believe future designs will be largely accomplished at a computer aided design (CAD) terminal, one possible way to aid the incorporation of R&M into the design world would be to include R&M tools into the CAD activities. The Air Force Human Resources Directorate of the Armstrong Laboratory funded an effort to investigate RAMCAD (R & M in Computer Aided Design) in academia. The effort held several meetings from coast to coast attempting to blend a knowledge of what activities were being tried, and what was their respective success or failure. The utility of the tools is a function of their versatility to various design alternatives, and their ease of use. A tool that works only on a limited type of designs will not contribute except in the relatively few cases that meet the design criteria. A tool with complexity that requires expertise will not be utilized by the average designer, and consequently only is beneficial when a design warrants true expert design. The program was not continued to the maximum possible fruition due to limitation of funding, but the concept of putting tools in the hands of future designers was clearly demonstrated.

5. EDUCATING ENGINEERING EDUCATORS

The education of future engineers is in the hands of engineering educators, who normally teach updated versions of the material they themselves were taught only a few years before. If the educators have never been exposed to R&M, then it is highly unlikely that they will in turn introduce subject matter they have not studied on their own. Their are exceptions to this generic rule, but by and large, new and different material is rarely introduced into existing courses without a major catalyst. The Air Force Special Assistant for R&M funded an effort to introduce R&M to engineering educators who would take the information back to their respective schools and attempt to include R&M in their design classes. The courses were held at AFIT with approximately 30 educators each for the summers of 1987 and 1988. The program attracted educators from many departments from a variety of schools. An interesting aspect of the program was the complete integration of all educators in the total program. The mechanical engineering educators were educated to electronic design, and the electrical engineering educators were introduced to mechanical design. This was accomplished because electronic failures are normally mechanical in nature, and the complicated mechanical designs of the future will rarely be achieved without computer control and monitoring, consequently the mechanical designs will include electronics and the electronic designs will need to consider mechanical failure modes. This combination of R&M for the total spectrum for all of the educators proved highly beneficial.

One measure of the success of the program is the continued interest in R&M by those attending the

workshops. Many of those attending have introduced R&M into their design courses, or have performed research into adding R&M into the design experience. By practically all measures these two workshops for engineering educators were very successful. However, as the Air Force budget views the workshops, they were not directly vital to the immediate need of declining defense funds, consequently no more funds could be made available, and the workshops were not continued.

6. UNDERGRADUATE ENGINEERING EDUCATION

The United States Air Force Academy (USAF) is the undergraduate school of the Air Force, and has introduced the concepts of R&M in their engineering programs as well as the importance of reliability and maintainability for all of their students. For several years, the Rome Laboratories at Griffiss AFB, NY has maintained a summer program for USAFA faculty and students to further their studies and research in R&M activities. Real educators and real students working on real Air Force problems. It sounds to real to be academic, but it is happening.

As most of the designs utilized by the Air Force are the result of engineering education other than the USAFA, Rome Air Development Center funded a research project for incorporating R&M into a complete engineering curricula at an undergraduate school. Florida Institute of Technology was selected because of their vital interest and willingness to pursue this for their total electronic engineering program. The size and type of school made conversion of curricula possible where other schools might find it seemingly impossible. It probably did not hurt that the head of the electrical engineering department had attended one of the R&M workshops for engineering educators at AFIT. It also was highly likely to be helpful that one of the major employers of their graduates was also vitally interested in having their new recruits be exposed to R&M during the educational process. The pieces for opportunity fit together very well.

The success of this experiment has been proven. One measure of success would be the intent of the school to return to status quo after the funding of the experiment expired. There are no plans to return to the "before" status. They like what they see. Their customers (recruiters) like what they see. The results have been presented to a collective group of electrical engineering department heads from other schools in the area. They were introduced to the concepts of reliability, maintainability and testability through an instructional guidance program. They were shown how these areas of interest could be incorporated into the mainstream of engineering design. The demonstration shows the integration of R&M into the engineering design curricula can be accomplished without eliminating the requirements of the Accreditation Board for Engineering and Technology (ABET).

7. COMMITTEE FOR R&M IN ENGINEERING CURRICULA

The above examples represent a few of many activities from a variety of Air Force organizations and clearly demonstrate the interest of the Air Force into the incorporation of R&M principles and technology into engineering curricula. What was decided within the Air

Force was that some of the activities might be disjointed, or at least appear to be less than fully integrated, consequently a committee to oversee the various activities was formed to coordinate across organizational lines. As a taxpayer I like seeing that we establish a system of cooperation rather than duplication. As a person who has seen how small details can be presented in less than favorable light by the media, I like knowing that there is an effort to make certain there is no appearance of duplication of effort. As a citizen I like knowing that there are many organizations in the Air Force that are vitally interested in the future of R&M in Engineering education, even when the defense budget is so severely limited that additional research funds may be precluded from completing and enhancing specific projects.

8. OTHER ACTIVITIES

The majority of this paper has related to what the Air Force and other governmental agencies have done to accomplish desires for improved R&M. It would be a complete oversight to imply that other institutions have not been advocates and educators in this area for several years. Mentioning any schools specifically leads to problems associated with omissions, regardless of the consequences some must be mentioned; the University of Arizona has maintained a most significant program for many years towards the production of reliability engineers. These are the specialists of the profession and graduates of this program should be capable of introducing R&M into design. More recently, the University of Maryland has a large and growing graduate effort in R&M research and education following the influence of Dr. Michael Pecht. The annual R&M Symposium has held special workshops for the last three years related to R&M education for educators. These have been led by Dr. John Boles from the University of South Carolina. The American Society of Engineering Educators has held sessions in R&M education during their annual summer meetings. Other significant activities continue but become too numerous to mention.

9. THE FUTURE

The desire for quality in goods and services throughout the world mandates improvements in design methodologies. The future designers will be required to be educated in R&M to compete and win the competition. Industry would like to get designers who know and comprehend how to design better items. Unfortunately, the desires of senior technical managers rarely get translated to the recruiters who go to college campuses to recruit engineers. If recruiters do not ask for R&M, then many educators do not think industry is interested, and there is no overwhelming pressure to change. When industry starts hiring only R&M educated engineering designers, then the schools and ABET will proceed to make it a requirement. Until R&M is required in the engineering curricula, the best you can do is to ask for the R&M education, and to pay a premium for designers with R&M knowledge. Sometimes you should buy the best to beat the rest (of your competition).

BIOGRAPHY

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Ben Williams is the Director of the Air Force Center of excellence for Reliability/Maintainability/Quality, coordinating education and research in R/M/Q for both management and engineering. His academic credentials include a BS in Aeronautical Engineering from Texas A&M, a PhD in Operations Research from the University of Texas at Austin, and post doctoral education at Harvard through the Senior Executive Fellows program. Original research areas include aircraft structural repair, reliability analysis, maintenance interval determination, system safety, diagnostics, and turbine engine durability. He is a member of AIAA, ORSA, TIMS, SSS, and represents SOLE on the Board of Directors of the annual R&M Symposium. His lectures on reliability, maintenance, and logistics have been attended by representatives from commercial and governmental organizations from more than fifty countries.