DESIGN AND PLAN FOR IMPLEMENTATION OF
THE RELIABILITY ENGINEERING AND RESEARCH CENTER

by

Robert Charles Cook

A Thesis Submitted to the Faculty of the
AEROSPACE AND MECHANICAL ENGINEERING DEPARTMENT
In Partial Fulfillment of the Requirements
For the Degree of
MASTER OF SCIENCE
WITH A MAJOR IN MECHANICAL ENGINEERING
In the Graduate College
THE UNIVERSITY OF ARIZONA

1970
STATEMENT BY AUTHOR

This thesis has been submitted in partial fulfillment of requirements for an advanced degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the copyright holder.

SIGNED: Robert Charles Cook

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

DIMITRI B. KECECIIOGLU
Professor of Aerospace and Mechanical Engineering

July 26, 1971 Date
ACKNOWLEDGMENT

The author wishes to express his deepest gratitude to Dr. Dimitri B. Kececioglu, Professor of Aerospace and Mechanical Engineering, who suggested this investigation and devoted generously his time in directing this work to successful completion.

The author is also extremely appreciative of all of the persons delineated in the List of Personnel Contacted who gave generously of their valuable time and provided extensive comments and constructive criticisms. This thesis could not have been completed in the time allowed without their expert and timely assistance.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF TABLES</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF ILLUSTRATIONS</td>
<td>viii</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>ix</td>
</tr>
<tr>
<td>1. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>2. PAST RELIABILITY ENGINEERING AND RESEARCH ACTIVITIES AT THE UNIVERSITY OF ARIZONA</td>
<td>8</td>
</tr>
<tr>
<td>Reliability Engineering Courses and Degree Programs</td>
<td>12</td>
</tr>
<tr>
<td>Reliability Research</td>
<td>12</td>
</tr>
<tr>
<td>Reliability Engineering and Management Institute and Short Course in Modern Design - By Reliability</td>
<td>17</td>
</tr>
<tr>
<td>National Science Foundation Supported Summer Institutes for College Teachers</td>
<td>18</td>
</tr>
<tr>
<td>3. PROJECTIONS OF THE REQUIREMENTS FOR RELIABILITY ENGINEERING AND RESEARCH ACTIVITIES AT THE UNIVERSITY OF ARIZONA</td>
<td>20</td>
</tr>
<tr>
<td>Academic Programs</td>
<td>24</td>
</tr>
<tr>
<td>Reliability Research</td>
<td>26</td>
</tr>
<tr>
<td>Reliability Engineering and Research Activities Other Than Academic Programs and Reliability Research</td>
<td>27</td>
</tr>
<tr>
<td>Requirements for Additional Faculty, Equipment and Facilities Based on Current and Projected Demands</td>
<td>28</td>
</tr>
<tr>
<td>4. THE PLAN AND DESCRIPTION OF THE RELIABILITY ENGINEERING AND RESEARCH CENTER (RERCER) AT THE UNIVERSITY OF ARIZONA</td>
<td>41</td>
</tr>
<tr>
<td>5. CONCLUSIONS</td>
<td>52</td>
</tr>
<tr>
<td>6. RECOMMENDATIONS</td>
<td>55</td>
</tr>
<tr>
<td>APPENDIX A: LIST OF PERSONNEL CONTACTED</td>
<td>57</td>
</tr>
<tr>
<td>APPENDIX B: SIGNIFICANT COMMENTS OF REPRESENTATIVES IN GOVERNMENT AND INDUSTRY</td>
<td>60</td>
</tr>
<tr>
<td>APPENDIX C: LISTING AND DELINEATION OF THE MISSION AND FUNCTIONAL STATEMENTS OF THE RELIABILITY ENGINEERING AND RESEARCH CENTER</td>
<td>70</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>111</td>
</tr>
</tbody>
</table>
### LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Summary of Probable Support of RERCER</td>
<td>2</td>
</tr>
<tr>
<td>II. Tabulation of the Services Considered Most Important by the Personnel Contacted</td>
<td>3</td>
</tr>
<tr>
<td>III. Basic Reliability Courses</td>
<td>13</td>
</tr>
<tr>
<td>IV. Technical Elective Courses Available to the Reliability Engineering Program in Various Departments at The University of Arizona</td>
<td>14</td>
</tr>
<tr>
<td>V. Summary of Probable Academic Program Support</td>
<td>21</td>
</tr>
<tr>
<td>VI. Summary of Probable Reliability Research Support</td>
<td>22</td>
</tr>
<tr>
<td>VII. Summary of Support Indicated in Areas Other Than Academic Programs and Reliability Research</td>
<td>23</td>
</tr>
<tr>
<td>VIII. Summary of Projected Requirements</td>
<td>35</td>
</tr>
<tr>
<td>IX. Summary of Current Deficiencies in the Reliability Engineering Laboratory Facilities</td>
<td>36</td>
</tr>
</tbody>
</table>
## LIST OF ILLUSTRATIONS

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Graduate Students Enrolled in Reliability Engineering Programs at The University of Arizona</td>
<td>9</td>
</tr>
<tr>
<td>2.</td>
<td>Contract Reliability Research Dollars</td>
<td>10</td>
</tr>
<tr>
<td>3.</td>
<td>Number of Reliability Engineering Program Courses</td>
<td>11</td>
</tr>
<tr>
<td>4.</td>
<td>Projection of the Number of Graduate Students Enrolled in Reliability Engineering Programs at The University of Arizona</td>
<td>30</td>
</tr>
<tr>
<td>5.</td>
<td>Projection of the Number of Reliability Program Courses at The University of Arizona</td>
<td>31</td>
</tr>
<tr>
<td>6.</td>
<td>Projection of the Dollar Value of Contract Research at The University of Arizona</td>
<td>32</td>
</tr>
<tr>
<td>7.</td>
<td>Projection of the Number of Faculty Required for Reliability Engineering and Research Programs at The University of Arizona</td>
<td>33</td>
</tr>
<tr>
<td>8.</td>
<td>Projection of Square Feet of Facilities Required for Reliability Engineering and Research Programs</td>
<td>34</td>
</tr>
<tr>
<td>9.</td>
<td>Basic Organizational Structure of The Reliability Engineering and Research Center (RERCER)</td>
<td>45</td>
</tr>
<tr>
<td>10.</td>
<td>Organization of the Directorate of Administration</td>
<td>46</td>
</tr>
<tr>
<td>11.</td>
<td>Organization of the Directorate of Programs</td>
<td>47</td>
</tr>
<tr>
<td>12.</td>
<td>Organization of the Directorate of Operations</td>
<td>48</td>
</tr>
<tr>
<td>13.</td>
<td>Overall Plan of Implementation of The Reliability Engineering and Research Center (RERCER)</td>
<td>51</td>
</tr>
</tbody>
</table>
ABSTRACT

Results of research conducted to determine the requirements of government agencies and private industry for reliability oriented services are presented and discussed. The methods by which academic institutions, government agencies, and private industry provide these services are evaluated. The role of The University of Arizona in providing the required services in recent years is delineated together with the short term requirements for expansion of these services to meet the immediate needs of government agencies and private industry.

Although sufficient requirements exist at this time, it is concluded that by 1975 the establishment of a Reliability Engineering and Research Center will be an absolute necessity. The design and plan of implementation of The Reliability Engineering and Research Center at The University of Arizona to fulfill these requirements is delineated.
CHAPTER 1

INTRODUCTION

The primary research conducted by the author during the preparation of this thesis was to determine the extent of the need for a Reliability Engineering and Research Center and the determination of the functions or services which should be provided by the Center to fulfill the needs of government agencies, private industry and the academic community.

A representative cross section of government agencies, private industry and the academic community was interviewed to determine the probable support for the establishment of a Reliability Engineering and Research Center. Care was taken to interview individuals at all levels of management and to include not only those personnel who are directly responsible for the technical reliability function but also personnel responsible for total management and personnel responsible for related functions such as design. The principal personnel who were contacted are listed in Appendix A. The support which may be expected from this cross section of the potential users of a Reliability Engineering and Research Center is summarized in Table I. These estimates of support were obtained from the personnel contacted in Appendix A. The services which the potential users of a Center consider most necessary and most urgently required are listed in Table II in order of priority.
<table>
<thead>
<tr>
<th>Support indicated by the person contacted</th>
<th>Percent of total persons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Those who would financially support RERCER to the extent that specific services were required and funds were available.</td>
<td>52%</td>
</tr>
<tr>
<td>Those who think RERCER is necessary to fulfill the requirements of the reliability engineering profession but have no plans for financial support at this time.</td>
<td>30%</td>
</tr>
<tr>
<td>Those who provided no statement or no positive statement on the necessity of a Center or anticipated no financial support for the Center.</td>
<td>18%</td>
</tr>
<tr>
<td>Those who do not think a Center is necessary.</td>
<td>0%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

The above summary delineates by category the extent of probable support which was specified by the personnel contacted in Appendix A.
TABLE II

TABULATION OF THE SERVICES CONSIDERED MOST IMPORTANT BY THE PERSONNEL CONTACTED

<table>
<thead>
<tr>
<th>Service</th>
<th>Weighted* Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formal academic degree programs in reliability engineering and related fields</td>
<td>28%</td>
</tr>
<tr>
<td>Reliability research</td>
<td>20%</td>
</tr>
<tr>
<td>Computer program interchange</td>
<td>19%</td>
</tr>
<tr>
<td>Reliability research and literature library</td>
<td>16%</td>
</tr>
<tr>
<td>Test facility interchange program</td>
<td>8%</td>
</tr>
<tr>
<td>Data interchange program</td>
<td>4%</td>
</tr>
<tr>
<td>Consulting and advisory services</td>
<td>3%</td>
</tr>
<tr>
<td>All other services</td>
<td>2%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100%</td>
</tr>
</tbody>
</table>

*The weighted percentages are based on 10 points for the most important, nine points for second most important, etc., and no points are given for a service specified as less than tenth most important. All personnel did not specify a preference and most did not specify 10 or more. Average number of preferences specified is four. One half of the personnel contacted were asked to specify the order of preference of the services which could be provided by a Center.
The necessity for the services of a Reliability Engineering and Research Center has been greatly increased during recent years due to the increase of detailed specification of the reliability requirements in major hardware contracts and subcontracts for the Department of Defense and the National Aeronautics and Space Administration and the increased public awareness of the economic importance of reliable products in the private sector. Liability considerations resulting from accidents caused by products is also becoming an important cost factor. Probably the most important factor is the effect of reliability on direct profits. A general increase in the use of warranties has caused a direct and significant impact to the manufacturer of unreliable products. Defense contractor profits can now vary several hundred percent by factors directly attributable to the incentive clauses for reliable hardware.

The requirements for reliability engineering services and the methods utilized by government and industry to obtain these services has been previously documented by Medford [1],* Lipson, Sheth and Sheldon [2], Zorger [3], Hock [4], Regulinski [5], Kececioglu [6], Birnie [7], Kececioglu and McKinley [8], and Kececioglu [9]. A comprehensive study of the closely allied field of Quality Control Technology in the State of California has been completed by Myers [10].

Interchange of information and facilities has been a constant goal of the various elements which operate in the broad field of

* Numbers in brackets designate literature cited.
reliability engineering and research. The FARADA and IDEP systems have been in use for several years. The American Society for Testing and Materials published a Directory of Testing Laboratories in 1969. Project STORE, "Structures Oriented Retrievable Exchange - Computer Programs and Information", is being utilized by the U. S. Navy. The major armed services have data retrieval systems designed for service wide application. As described in the June 1970 issue of Space Aeronautics, the U. S. Army Aviation Systems Command and the National Aeronautics and Space Administration were able to define a method of joint utilization of facilities at the Ames Research Center. Divisions, groups, subsidiaries, centers, and commands of government agencies and private industry all attempt to some degree to interchange reliability data, reliability computer programs, and information regarding test facilities. Significant examples have been discussed by Naresky [11], Ritch [12], Pollock [13], and Burns [14]. Individual persons, companies, and various government agencies collect and collate relatively limited libraries of reliability literature. It is apparent, however, that current methods involve only portions of the total scope involved and that duplication of certain activities is widespread.

The combination of the ever increasing breadth of activity of the average professional, the data explosion in any given field of endeavor, and the nationwide paucity of funds are increasing the necessity for more economical acquisition of required information.

Examination of the applicable literature and the above factors together with the expert judgement and experience of the personnel
contacted, leads to the firm conclusion that a significant nationwide contribution to the reliability profession and thereby to the enhancement of the reliability profession's service to this country's overall activities will be realized by the establishment and operation of a Reliability Engineering and Research Center. This Center would not intentionally compete with or duplicate currently successful reliability activities, but would serve as the focal point for collection, collation and dissemination of all applicable data, and provide national leadership in academic programs and reliability research.

Further evaluation was conducted to determine the most practical location and time frame for the establishment of a Reliability Engineering and Research Center. Since objectivity is of prime importance, the consensus of opinion was that success of the Center would be enhanced by utilizing a non-profit organization for management of the Center. The use of an academic institution which has a basic foundation of knowledge, flow of graduate students, and laboratory facilities commensurate with graduate degree programs and research, was also considered a very important factor.

Review of non-profit organizations with particular emphasis on academic institutions, yielded the conclusion that the reliability engineering oriented personnel, facilities, and activities located within the Aerospace and Mechanical Engineering Department of the Engineering College at The University of Arizona would form the most logical nucleus for orderly transition into a Reliability Engineering and Research Center. This nucleus is currently supported by the
General Electric Company, the U. S. Navy, the National Aeronautics and Space Administration, the U. S. Army, and other organizations within The University of Arizona such as the Division of Continuing Education, the Engineering Experiment Station, and the Departments of System Engineering, Mathematics, Economics and Management, and the Graduate College. Previous support was rendered by the National Science Foundation.

A review of the past history of reliability engineering and research activities is provided in Chapter 2. The future requirements for reliability services and the requirement for improvement of current facilities is provided in Chapter 3. A discussion of the desires of the users of reliability engineering services, the rationale for a Reliability Engineering and Research Center and the proposed organization, missions and functions statements, and a plan of implementation is provided in Chapter 4. This plan, when implemented, would constitute the creation of the Reliability Engineering and Research Center (RERCER) at The University of Arizona.
CHAPTER 2

PAST RELIABILITY ENGINEERING AND RESEARCH ACTIVITIES
AT THE UNIVERSITY OF ARIZONA

The reliability engineering and research activities at The University of Arizona have shown steady progress and growth since 1963 which is a direct reflection of the needs of government, industry and other academic institutions and the willingness of The University of Arizona to accept the responsibility to provide these services which have been demanded by these agencies.

The most prominent demands upon The University of Arizona have been for formal academic courses in the field of reliability engineering and reliability research. Figures 1 and 2 illustrate the growth of these two areas in graduate student enrollment and contract research dollars, respectively. The number of reliability engineering and directly related courses offered by The University of Arizona are shown in Figure 3. The anticipated demands upon The University in these areas during the scholastic year of 1970-1971 is depicted in dotted line on Figures 1, 2, and 3.

The major reliability engineering and research activities which have been provided in recent years are outlined below:
Fig. 1 - Graduate Students Enrolled in Reliability Engineering Programs at The University of Arizona
Contract Research in Thousands of Dollars

Fig. 2 - Contract Reliability Research Dollars
Fig. 3 - Number of Reliability Engineering Program Courses
Reliability Engineering Courses and Degree Programs

The first reliability engineering course was offered at The University of Arizona in 1963. The demand for reliability engineering courses steadily increased and in the fall of 1969 a total of nine reliability engineering and complementary courses were available. These nine courses which represent the basic requirements for a Master's degree in either Mechanical Engineering or Aerospace Engineering with a Reliability Engineering option are listed in Table III.

A total of thirty units are required for the Master's Degree Program which was instituted on a formal basis in September, 1969. As many as six technical electives were allowed to be transferred from other academic institutions and the technical electives provided by The University of Arizona are listed in Table IV. In addition to the technical courses listed in these tables, AME 410 - M.S. Thesis up to 6 units, AME 409 - Master's Report for the no-thesis option, and AME 400 - Research completes the Master's Degree Program.

Reliability Research

Reliability research for the Lewis Research Center of the National Aeronautics and Space Administration began in 1965 and is currently continuing. This research is the determination of complex-fatigue reliability and is entitled "A Probabilistic Method of Designing a Specified Reliability into Mechanical Components with Time Dependent Stress and Strength Distributions". Major areas of interest of this research are the determination of the failure governing strength
TABLE III

BASIC RELIABILITY COURSES

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>AME 206</td>
<td>Engineering Quality Control</td>
</tr>
<tr>
<td>AME 208</td>
<td>Reliability Engineering</td>
</tr>
<tr>
<td>AME 212</td>
<td>Design by Reliability</td>
</tr>
<tr>
<td>AME 213</td>
<td>Reliability &amp; Quality Analysis I</td>
</tr>
<tr>
<td>AME 214</td>
<td>Reliability &amp; Quality Analysis II</td>
</tr>
<tr>
<td>AME 218</td>
<td>Reliability Testing</td>
</tr>
<tr>
<td>AME 308</td>
<td>Advanced Reliability Engineering</td>
</tr>
<tr>
<td>AME 312</td>
<td>Advanced Design by Reliability</td>
</tr>
<tr>
<td>AME 408</td>
<td>Case Studies in Aerospace, Mechanical, and</td>
</tr>
<tr>
<td></td>
<td>Reliability Engineering</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### TABLE IV

TECHNICAL ELECTIVE COURSES AVAILABLE TO THE RELIABILITY ENGINEERING PROGRAM IN VARIOUS DEPARTMENTS AT THE UNIVERSITY OF ARIZONA

<table>
<thead>
<tr>
<th>Aerospace and Mechanical Engineering</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. AME 202 — Production Engineering</td>
<td></td>
</tr>
<tr>
<td>2. AME 205 — Industrial Management</td>
<td></td>
</tr>
<tr>
<td>3. AME 207 — Inspection Methods and Instrumentation</td>
<td></td>
</tr>
<tr>
<td>4. AME 230 — Mechanical Vibrations</td>
<td></td>
</tr>
<tr>
<td>5. AME 364 — Structural Dynamics</td>
<td></td>
</tr>
<tr>
<td>6. AME 367 — Performance Optimization in Aerospace Engineering</td>
<td></td>
</tr>
<tr>
<td>7. AME 408 — Case Studies in Aerospace, Mechanical and Reliability Engineering</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Systems Engineering</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. SE 210 — Basic Human Factors Engineering</td>
<td></td>
</tr>
<tr>
<td>2. SE 211 — Human Factors in Engineering Design</td>
<td></td>
</tr>
<tr>
<td>3. SE 212 — Human Factors Engineering</td>
<td></td>
</tr>
<tr>
<td>4. SE 220 — Engineering Statistics and Probability I</td>
<td></td>
</tr>
<tr>
<td>5. SE 221 — Engineering Statistics and Probability II</td>
<td></td>
</tr>
<tr>
<td>6. SE 240 — Operations Research I</td>
<td></td>
</tr>
<tr>
<td>7. SE 241 — Operations Research II</td>
<td></td>
</tr>
<tr>
<td>8. SE 272 — Computer Organization and Programming</td>
<td></td>
</tr>
<tr>
<td>9. SE 320 — Probabilistic Systems I</td>
<td></td>
</tr>
<tr>
<td>10. SE 321 — Probabilistic Systems II</td>
<td></td>
</tr>
<tr>
<td>11. SE 340 — Queuing Theory</td>
<td></td>
</tr>
<tr>
<td>12. SE 360 — Systems Quality Assurance</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mathematics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Math 237 — Elements of Statistics</td>
<td></td>
</tr>
<tr>
<td>2. Math 290 — Introduction to the Theory of Probability</td>
<td></td>
</tr>
<tr>
<td>4. Math 355 — Integral Transform Theory</td>
<td></td>
</tr>
<tr>
<td>5. Math 383 — Statistical Hypotheses</td>
<td></td>
</tr>
<tr>
<td>7. Math 391 — Multivariate Analysis</td>
<td></td>
</tr>
<tr>
<td>8. Math 392 — Sequential Analysis</td>
<td></td>
</tr>
<tr>
<td>9. Math 393 — Non-Parametric Inference</td>
<td></td>
</tr>
<tr>
<td>10. Math 394 — Statistical Decision Functions</td>
<td></td>
</tr>
</tbody>
</table>
### TABLE IV—Continued

#### Agriculture
1. Ag 205 - Sampling Theory and Methods
2. Ag 239 - Statistical Methods
3. Ag 240 - Design and Analysis of Experiments

#### Statistics
1. Stat 208 - Non-Parametric Statistics
2. Stat 220 - Least Squares Analysis I
3. Stat 221 - Least Squares Analysis II
4. Stat 229 - Time Series Analysis I

#### Economics
1. Econ 281 - Introduction to Econometrics
2. Econ 300 - Value and Distribution
3. Econ 380 - Econometrics
4. Econ 391 - Advanced Microeconomic Theory

#### Management
1. Mgt 234 - Statistical Analysis for Business Decisions
2. Mgt 273 - Production Management
3. Mgt 376 - Executive-Supervisory Control Techniques
4. Mgt 377 - Business Policy and Performance Simulation
5. Mgt 390 - Theory of Management and Organization
6. Mgt 392 - Quantitative Methods in Business
distribution, determination of the failure governing stress distribution, and development of the methodology for applying these determinations to the calculation of the a priori reliability of a component. The test specimens, which are machined to simulate known stress concentrations, are subjected to steady torque and reverse bending on machines which were especially designed and fabricated by The University of Arizona for the conduct of this research. These machines, utilizing the four square principle, enable a relatively large cylindrical test specimen to be subjected to a bending load which rotates with respect to the specimen while being subjected to a "locked-in" constant torque. Both the Von Mises distortion energy theory of failure and the maximum shear stress theory are utilized in this research.

Reliability research for the Office of Naval Research of the United States Navy began in early 1967 and is currently continuing. This research is for the purpose of determining mechanical machinery reliability and is entitled "Interaction Among the Various Phenomena Involved in the Design of Dynamic and Rotary Machinery and Their Effects on Reliability". Major areas of interest during this research are:

1. Studies of phenomenological interactions of applied stresses,
2. Relation of mechanical fatigue and endurance strength under sinusoidal repeated loading to mechanical fatigue and endurance strength under random loading,
3. Development of statistical S-N diagrams for the metal alloys in common use,
4. Development of statistical Goodman strength surfaces for metal alloys to facilitate design in combined-stress situations, and
5. Theoretical studies and experimental research
programs to develop the distributional characteristics of significant design factors. Extensive test plans and procedures were designed and calibration procedures for the R.R. Moore machine, the Axial Fatigue machine, the Riehle Universal Testing machine, and the Wire Fatigue machines were developed.

**Reliability Engineering and Management Institute and Short Course in Modern Design - By Reliability**

Seven Reliability Engineering and Management Institutes have been conducted at The University of Arizona since 1963. These institutes have been conducted consecutively each year and the Eighth Annual Reliability Engineering and Management Institute is scheduled for November 2 to November 11, 1970. The purpose of these institutes has been to expose personnel to the principles, instruct in, and motivate deeper involvement in reliability engineering. The length of these institutes has varied from five days to three weeks since implementation in 1963 as the institute has grown in scope and responded to the needs of the participants. The length of the institute has now stabilized to seven class days with the first week of five days devoted to the technical aspects of reliability and maintainability, followed by the weekend which can be utilized for study of handout material or personal research. The institute is completed with the first two days of the following week being devoted to systems effectiveness concepts and principles with emphasis upon management and project applications. The institute receives instruction from a highly professional staff of approximately 12 personnel representing a cross section of government,
industry and the academic community. The notes for the institute, which are retained by the attendees are detailed and comprehensive, numbering over 830 pages and are supplemented with films and workshop sessions. Attendance has been from diverse elements of the United States and from several foreign countries and is usually approximately 100 persons.

In June of 1970 a two week course entitled "Modern Design by Reliability" was offered by The University of Arizona. The purpose of this short course was to provide a working knowledge of recently developed theory and methods that underlie the powerful and highly realistic probabilistic approaches to design and to a multitude of problems in the physical sciences, where probabilistic rather than deterministic models are valid. Such techniques are becoming increasingly useful in designing a priori specified reliabilities into a given component. This course was similar in technical content to AME 212.

**National Science Foundation Supported Summer Institutes for College Teachers**

In June of 1965, the first institute of this type was conducted at The University of Arizona under a $35,000 grant from the National Science Foundation. The objectives of the institute were to (1) motivate and improve the teaching of reliability engineering and related courses in colleges and universities, (2) enable the participants to inject reliability concepts and methodologies into their courses, and (3) provide the institute participants with an opportunity to accumulate graduate credits toward M.S. and Ph.D. degrees. Thirty attendees attended both the first institute and the second one in 1966 and were
composed of high level educators of which twenty percent were Ph.D.'s and six Heads or Department Chairman attended. The institutions represented were the State University of New York, University of Florida, University of Mississippi, Virginia Polytechnic Institute, University of Southern California, St. Louis University, Newark College of Engineering, The University of Kansas, University of Minnesota, East Tennessee State University, and The University of Arizona.

The courses which were taught in 1965 were (1) AME 208 - Reliability Engineering, by Dr. Dimitri Kececioglu, Professor of Aerospace and Mechanical Engineering, The University of Arizona (2) AME 218 - Reliability Testing, by Igor Bazovsky, Associate Director, Scientific and Consulting Division, Genge Industries, Inc., Sherman Oaks, California and (3) AME 228 - Reliability Program Implementation and Management, by J. Frederick Medford, Manager of Reliability, Maintainability Engineering, and Systems Engineering, Litton Industries, Culver City, California.

The 1966 Summer Institute for College Teachers had the same objectives as the 1965 Institute and the courses taught were (1) AME 208 - Reliability Engineering, by Dr. Dimitri Kececioglu, Professor of Aerospace and Mechanical Engineering, The University of Arizona (2) AME 212 - Design by Reliability, by Edward B. Haugen, Research Specialist, Reliability Methodology, Space and Information Division, North American Aviation Inc., Downey, California and (3) AME 218 - Reliability Testing, by Dr. Harry C. Romig, Professor, Long Beach State College, Long Beach, California and Consultant to Astro Reliability Corporation, Sherman Oaks, California.
CHAPTER 3

PROJECTIONS OF THE REQUIREMENTS FOR RELIABILITY ENGINEERING AND RESEARCH ACTIVITIES AT THE UNIVERSITY OF ARIZONA

Based upon the research conducted by the author, the three most significant demands to be expected upon The University of Arizona's resources within the next two years are: (1) Increased enrollment in current academic programs with a demand for both an increased number and type of courses. The summary in Table V illustrates that of ninety-two percent of those who strongly support The University of Arizona's academic programs, nearly seven-eights of the personnel stated a preference for additional reliability oriented courses. (2) Continued demand for specific reliability research programs as indicated by Table VI, and (3) Demand for additional reliability programs which are not currently offered, particularly a Reliability Research and Literature Library and Computer Program Interchange as indicated in Table VII. These projected demands upon the resources of The University together with current demands, which are at record levels, will require significant increases in laboratory facilities, faculty, and floor space allocated to the Reliability Engineering and Research Programs at The University of Arizona.
### TABLE V

**SUMMARY OF PROBABLE ACADEMIC PROGRAM SUPPORT**

<table>
<thead>
<tr>
<th>Support Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Those who would support the current academic program and additional activities</td>
<td>79%</td>
</tr>
<tr>
<td>such as post graduate courses in reliability management and maintainability</td>
<td></td>
</tr>
<tr>
<td>engineering; B.S. Degree in Quality Engineering; and correspondence type training.</td>
<td></td>
</tr>
<tr>
<td>Those who would support the current academic program commensurate with the</td>
<td>13%</td>
</tr>
<tr>
<td>specific educational requirements of individuals in their respective</td>
<td></td>
</tr>
<tr>
<td>organizations.</td>
<td></td>
</tr>
<tr>
<td>Those who did not express an opinion or were non-committal.</td>
<td>8%</td>
</tr>
<tr>
<td>Those who would not support the academic programs at The University of Arizona.</td>
<td>0%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

The above summary delineates the extent of probable support by the personnel contacted in Appendix A.
### TABLE VI

**SUMMARY OF PROBABLE RELIABILITY RESEARCH SUPPORT**

<table>
<thead>
<tr>
<th>Description</th>
<th>Support (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Those who would fund specific reliability research projects as particular research became necessary and funds were available.</td>
<td>80%</td>
</tr>
<tr>
<td>Those who did not express an opinion or were non-committal.</td>
<td>20%</td>
</tr>
<tr>
<td>Those who would not support reliability research at The University of Arizona.</td>
<td>0%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

The above summary delineates the extent of probable support for reliability research which was specified by the personnel contacted in Appendix A. Over 90% of the personnel contacted expressed the additional opinion that more floor space and more comprehensive test facilities, particularly environmental chambers, is required to assure a viable reliability research activity at The University of Arizona.
TABLE VII

SUMMARY OF SUPPORT INDICATED IN AREAS
OTHER THAN ACADEMIC PROGRAMS AND RELIABILITY RESEARCH

<table>
<thead>
<tr>
<th>Description</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Those who would consider the funding of activities such as implementation of a Reliability Research and Literature Library and a Computer Program Interchange through the support of graduate students.</td>
<td>11%</td>
</tr>
<tr>
<td>Those who would consider participation in activities such as the Library and Interchange of Computer Programs, Test Facility Data, and Failure Rate Data by sharing the costs of operation with other companies or government agencies.</td>
<td>62%</td>
</tr>
<tr>
<td>Those who were non-committal or did not have a definite opinion.</td>
<td>22%</td>
</tr>
<tr>
<td>Those who were opposed to one or more of the programs proposed by the author as part of the Reliability Engineering and Research activities at The University of Arizona.</td>
<td>5%</td>
</tr>
</tbody>
</table>

TOTAL 100%

The above summary delineates the extent of probable support for RERCER activities other than Academic Programs and Reliability Research which are primarily the Library and Interchange Programs.
Academic Programs

The primary academic program in reliability currently offered by The University of Arizona is a Master of Science Degree in Aerospace or Mechanical Engineering with a Reliability Engineering Option. In addition, a Ph.D. Degree with the Reliability Engineering Option may be obtained. Both of these degree programs are supported by a full complement of nine courses in reliability engineering and courses directly related to the reliability disciplines. Every indication is that these option programs will continue to command the majority of the demands for future reliability engineering oriented training.

Enrollment in these programs is now at a record level and it is expected that enrollment will grow at the rate of at least ten percent per year, provided that sufficient faculty is available to handle the increase. A short range requirement which will be levied upon The University of Arizona faculty due to greatly increased enrollment is the desire of the students to have all nine courses offered each semester in lieu of the current five which would result in a major load upon faculty requirements in the next two years. It should be noted that the faculty is currently understrength by at least two members considering student enrollment and research. The understrength situation will worsen in September 1970 considering the firm commitments for admission to the Reliability Engineering Program and increased research.

In addition to the numerical expansion in enrollment in the existing reliability engineering program, a firm requirement currently exists for additional graduate courses in the broad field of reliability
engineering such as: (1) Reliability Program Implementation and Management, (2) Maintainability Engineering, (3) Advanced Maintainability Engineering, (4) Advanced Reliability Testing, and (5) Optimization of Cost and Availability.

Significant interest was displayed by government and industry, particularly the Department of Defense and National Aeronautics and Space Administration agencies for the establishment of correspondence and "dual credit" arrangements whereby qualified individuals could either eliminate deficiencies to enable enrollment in the on-site University Program or to allow the student to obtain partial graduate credit at his local duty station. These arrangements are particularly important at this time due to the paucity of funds within industry and the Department of Defense and National Aeronautics and Space Administration establishments. Any practical method which reduces the time an individual must be away from his duty station directly enhances the ability of an employer to sponsor graduate study. A specific example of a probable dual credit arrangement exists with the Army Management and Engineering Training Agency at Rock Island, Illinois. This agency trains individuals at government expense in the field of reliability engineering for the purpose of career training. Although the courses are not identical, it is anticipated that at least part of their curricula could be modified to allow application of credits obtained at their agency to an individual's graduate program at The University of Arizona. It should be noted that a co-operative program already
exists between the Army Management and Engineering Training Agency and The University of Nebraska in the field of Management.

Another area of particular interest to industry, government, and other academic institutions is a Bachelor of Science Degree in Quality Engineering. A detailed study of the educational requirements in this field for the State of California was published by Myers [10] in 1969. On a nationwide basis, there are literally hundreds of personnel in industry, the Department of Defense, and the National Aeronautics and Space Administration working the field of Quality Engineering who are both qualified and have sufficient desire to pursue this degree in their field of specialty.

**Reliability Research**

The demand for reliability research will continue to grow but at a higher rate than in the past. The increasing detail of reliability specifications in government contracts and major contracts has led to the current requirement to design specific components to a given reliability on an a priori basis. This requirement can be fulfilled on a scientific basis only when the failure governing strength and failure governing stress distributions can be specified. Warranties issued by private industry and increased use of incentive reliability clauses are creating a necessity for knowledge of these distributions and the stress interactions which have been unknown heretofore. The University of Arizona has provided national leadership in this area of exploration and every indication is that the demand for this service will increase as the
progress at The University of Arizona becomes known to industry and
government, and additional industry and government elements bid for
this service.

Reliability Engineering and Research Activities Other Than 
Academic Programs and Reliability Research

As shown in Chapter 1, the industrial, governmental and
academic communities favor the implementation of additional programs,
particularly a system for the interchange of those computer programs
related to Reliability Engineering and a Reliability Research and
Literature Library. Several potential users of services provided by
The University of Arizona are presently considering action to fund
these two endeavors based upon the immediate benefits expected. Even
without support external to The University of Arizona, the system for
interchange of computer programs and the Reliability Research and
Literature Library should be implemented on an incremental basis start­
ing with the 1970-1971 academic year. Every indication of demand
supports the assumption that these two activities will be self support­
ing within two years.

Two additional reliability engineering activities, the
interchange program of test and failure rate data and the interchange
program of capability, availability, capacity, and cost of test and
measuring equipment also have a strong demand at this time, although the
demand is less than the computer program interchange and the library.

Based upon the stated demands, the first two programs should be
implemented on an incremental basis during academic year 1970-1971 and
the other two in academic year 1971-1972. In addition, detailed evaluation of industry-government demand and detailed cost analysis to provide firm potential savings estimates should be undertaken in all four areas as soon as practical.

Requirements for Additional Faculty, Equipment and Facilities Based on Current and Projected Demands

The programs which have previously been offered or are currently offered by The University of Arizona, have without exception enjoyed a very high measure of success. The major programs are academic instruction in reliability engineering not available at any other academic institution, the nation's only significant reliability oriented institute covering technical instruction, which is the annual Reliability Engineering and Management Institute, basic reliability research including original test equipment design and fabrication, and pioneering efforts in summer instruction of college teachers in reliability subjects, and a short course in Design by Reliability. Analysis of the number of personnel and facilities which have been available to perform the required functions, reveals that the past success has been possible only by extraordinary effort and dedication of the staff supporting the reliability programs. Additional faculty members are required to allow the current staff to return to a normal workload environment and also spend additional time with graduate students and perform long term planning.

In order to estimate current and future requirements for faculty, equipment, and facilities, it is necessary to project future
demand as accurately as possible and to make certain assumptions. The projections of future demands for reliability programs are delineated in Figure 4 - Projection of the Number of Graduate Students Enrolled in Reliability Engineering Programs at The University of Arizona, Figure 5 - Projection of the Number of Reliability Program Courses at The University of Arizona, Figure 6 - Projection of the Dollar Value of Contract Research at The University of Arizona, Figure 7 - Projection of Number of Faculty Required for the Reliability Academic Programs and Reliability Research, Figure 8 - Projection of Square Feet of Facilities Required for Reliability Programs, and Table VIII - Summary of Projected Requirements. Table IX - Summary of Current Deficiencies in the Reliability Engineering Laboratory Facilities is provided for the purpose of delineating those facilities and equipment of a basic nature which are not available at this time.

The assumptions which have been made are as follows:

1. The University is proud of its leadership status in the field of Reliability Engineering Programs and Reliability Research and desires to continue its role as the nation's leader in these fields.

2. The economic climate within the nation at the time of this thesis research and the two years prior to this study was characterized by an overall paucity of funds available for Reliability Engineering Educational Programs and Basic Reliability Research Programs. Therefore, the projections of future demands, which are based primarily on past demand and modified by consultation with government and industry representatives, represent a conservative estimate.
Fig. 4 - Projection of the Number of Graduate Students Enrolled in Reliability Engineering Programs at The University of Arizona
Fig. 5 - Projection of the Number of Reliability Program Courses at The University of Arizona
Contract Research in Thousands of Dollars

- Actual
- Estimated

Trend

Academic Year - Beginning Year is Specified

Fig. 6 - Projection of the Dollar Value of Contract Research at The University of Arizona
Fig. 7 - Projection of the Number of Faculty Required for Reliability Engineering and Research Programs at The University of Arizona
Fig. 8 - Projection of Square Feet of Facilities Required for Reliability Engineering and Research Programs at The University of Arizona
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Graduate Students</td>
<td>20</td>
<td>24</td>
<td>27</td>
<td>30</td>
<td>33</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Number of Reliability Program Courses</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Dollar Value of Contract Reliability Research - Thousands</td>
<td>218</td>
<td>315</td>
<td>412</td>
<td>509</td>
<td>606</td>
<td>703</td>
<td></td>
</tr>
<tr>
<td>Number of Faculty Required</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>9</td>
<td>11</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Square Feet of Floor Space Required*</td>
<td>1600</td>
<td>1900</td>
<td>2333</td>
<td>3000</td>
<td>3667</td>
<td>4567</td>
<td></td>
</tr>
<tr>
<td>Re-investment in Equipment Thousands of Dollars**</td>
<td>277</td>
<td>63</td>
<td>82</td>
<td>112</td>
<td>121</td>
<td>141</td>
<td></td>
</tr>
</tbody>
</table>

* Upper figure is Office Area
Lower figure is Reliability Engineering Laboratory

** Number in 1970-1971 column refers to current deficiencies
<table>
<thead>
<tr>
<th>NOMENCLATURE OF THE EQUIPMENT</th>
<th>APPROXIMATE DOLLAR COST *</th>
<th>APPROXIMATE FT.² REQUIRED **</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog Computer, Model 231R 100 Volt D.C. with recorder and printer</td>
<td>200,000</td>
<td>300</td>
</tr>
<tr>
<td>Mfr: Electronic Associates</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electromagnetic Vibration Shaker</td>
<td>36,500</td>
<td>100</td>
</tr>
<tr>
<td>Capacity: 1500g - 1 lb.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>80g - 20 lb.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mfr: Ling Electronics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature Conditioner for Vibration and Temperature Tests</td>
<td>2,000</td>
<td>80</td>
</tr>
<tr>
<td>Range: -80°F. to 400°F.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mfr: Conrad</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combination Altitude and Temperature Chamber</td>
<td>11,000</td>
<td>121</td>
</tr>
<tr>
<td>Range: 150,000 feet -80°F. to 400°F.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mfr: Conrad</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combination Humidity and Temperature Chamber</td>
<td>3300</td>
<td>100</td>
</tr>
<tr>
<td>Range: Amb. to 200°F. 20% to 100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mfr: Conrad</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOMENCLATURE OF THE EQUIPMENT</td>
<td>APPROXIMATE DOLLAR COST *</td>
<td>APPROXIMATE FT.² REQUIRED **</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>---------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Shock Tower</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity: 60g - 20 lb.</td>
<td>5500</td>
<td>100</td>
</tr>
<tr>
<td>Mfr: Monterey Research</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature Chamber</td>
<td></td>
<td></td>
</tr>
<tr>
<td>with mechanical refrigeration</td>
<td>2750</td>
<td>100</td>
</tr>
<tr>
<td>Range: -80°F. to 400°F.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mfr: Conrad</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature Chamber with</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon Dioxide Cooling</td>
<td>5500</td>
<td>144</td>
</tr>
<tr>
<td>Range: -80°F. to 400°F.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mfr: Delta Design</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature Chamber to</td>
<td></td>
<td></td>
</tr>
<tr>
<td>condition Fatigue Machine</td>
<td>9,000</td>
<td>144</td>
</tr>
<tr>
<td>Range: -80°F. to 400°F.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mfr: Conrad</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calibration, Maintenance</td>
<td>1,000</td>
<td>500</td>
</tr>
<tr>
<td>and Storage Area</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>276,550</td>
<td>1689</td>
</tr>
</tbody>
</table>

* Includes ancillary equipment

** Includes access and aisle space
3. The University of Arizona is willing to program future faculty, facilities, and equipment requirements on reasonable and practical projections rather than demand actual contracts and commitment prior to provisioning for future expenditures to support reliability engineering and research activities.

4. In addition to the direct support requirement for Reliability Research, the Reliability Engineering Laboratory facilities and equipment are required to compliment the classroom instruction in the Reliability Engineering Educational Programs. The Laboratory should also provide facilities and equipment for the academic research projects of the rapidly increasing number of graduate students. The capability to perform analog computer operations and perform tests in the basic environments of hot, cold, humidity, shock and vibration are assumed to be the absolute minimum capability for the magnitude of the reliability programs now underway at The University of Arizona. See Table IX.

5. An approximate re-investment of ten percent of gross academic fees and twenty percent of gross reliability research contract dollars should be made in the Reliability Engineering Laboratory to preclude obsolescence and create a viable laboratory which is commensurate with expected future demands.

6. The implementation of the System for Computer Program Interchange and The Reliability Research and Literature Library on an incremental basis starting in the academic year 1970-1971. The assumption of the implementation of these programs will require the resources of approximately one-half faculty member per year supplemented with two
graduate students and 200 square feet of floor space with an addition of 100 square feet per year for five years. Funding of this effort by sources external to The University of Arizona is probable within two years.

7. The implementation of the Test Facility Interchange Program and the Test and Failure Rate Data Interchange Program on an incremental basis starting in the academic year 1971-1972. The assumption of the implementation of these programs will require the resources of approximately one-half faculty member per year supplemented with two graduate students and 200 square feet of floor space with an addition of 100 square feet of floor space per year for four years. Funding of this effort by sources external to The University of Arizona is probable within four years.

8. The detailed evaluation of the demand and detailed cost analysis of the four programs outlined in 6 and 7 above will be accomplished by graduate students at no appreciable cost to The University.

9. The gross floor space required for faculty and clerical staff is approximately 175 square feet. Air conditioning is considered a normal requirement for office areas in the Tucson climate.

10. Approximately .33 clerical personnel are required for each faculty member.

11. The laboratory floor space and utility requirements are primarily determined by the size and type of equipment and the safety
considerations of operating personnel. Air conditioning of all Reliability Engineering Laboratories is considered mandatory to assure accurate results.

12. A faculty member can adequately teach one reliability course per semester and supervise three graduate students and supervise forty to fifty thousand dollars of research per year on the basis of fifty percent of his time being allocated to each area of supervision.
CHAPTER 4

THE PLAN AND DESCRIPTION OF THE RELIABILITY ENGINEERING AND RESEARCH CENTER (RERCER) AT THE UNIVERSITY OF ARIZONA

As delineated in Chapter 3, the projections of future demands for reliability services at The University of Arizona indicate demands will increase at rates greater than previous rates of increase. Although it is not possible to specify future demand in an exact manner due to the inherent variability of the future, the author used a conservative approach to the projections and is convinced that the projections shown will prove to be of a minimum nature. The author's conviction is based, however, on the assumption that The University of Arizona will provide the resources required to meet the demand. It should be noted that the actual increase in reliability services provided by The University of Arizona is directly dependent upon the faculty and facilities which are made available to fulfill the demands of the industrial, government and academic communities.

Analysis of two basic plans for fulfilling the demands to be levied upon The University of Arizona was conducted. The two concepts studied were: (A) The continuation of incremental increases in faculty, facilities, and equipment and (B) The establishment of The Reliability Engineering and Research Center (RERCER).
From the customer's point of view, i.e., the potential industrial, government and academic users of reliability services, the RERCER concept was the predominant choice because:

1. Experience has shown that the concept of utilizing a purely academic type organization for research and related projects is not conducive to fast reaction to increases or decreases in demand, or changes in the type of demand. A Center or the RERCER concept allows fast reaction to user demand in either an increasing mode, decreasing mode, or change in type of demand. Personnel with special talent or experience can be obtained quickly and employment levels are more flexible.

2. Detailed control of a given project is more difficult from a user's point of view when the personnel involved have multiple responsibility. The RERCER concept would allow Program Office organization for customer visibility with regard to technical progress, schedule control, and cost control.

From the university point of view, the RERCER concept provides the following major advantages:

1. The use of technicians would be permitted to perform certain tasks within the Center. It is estimated that faculty requirements for a Center would be reduced to 50% of the level required to perform the same tasks within a university department. Faculty members would, therefore, be relieved of relatively menial tasks and could perform the more sophisticated tasks.
2. The cost per task would be reduced by utilizing technicians wherever possible in lieu of the exclusive use of faculty and students.

3. The recruiting problem due to the shortage of qualified faculty members in the field of reliability engineering, would be significantly reduced.

4. Under the RERCER concept, The University could organize to perform the applicable tasks in the most efficient manner, could delegate authority and assign responsibility for the tasks, and effect those controls required for satisfactory completion of the tasks.

All major advantages of the university community can be retained and the author is not aware of any significant disadvantages from either the user or university point of view or any other compelling rationale which would preclude the establishment of The Reliability Engineering and Research Center (RERCER) at The University of Arizona. The words of encouragement received by the author for establishment of the RERCER are provided in Appendix B.

RERCER would be primarily devoted to the field of reliability engineering and related research. The disciplines of maintainability, maintenance engineering, systems engineering, availability, configuration management, quality assurance, quality engineering, statistics, operations research, and computer technology would not be pursued as an entity within themselves but would be fully utilized as they contribute to and overlap the broadly defined discipline of reliability engineering. The Center would be, as the name implies, the worldwide hub and focal point of knowledge and cognizance of all important matters concerning
reliability engineering and related research; including, but not limited to, formal scholastic programs in reliability engineering, reliability research, reliability literature, computer programs, failure rate data, test procedure and equipment, data analysis, and consultation regarding these areas. The Center would provide service to all segments of government and industry at a cost well below existing costs. The quality of these services would be unparalleled due to the Center's primary dedication and specialization in this specific field of endeavor and the wealth of experience and knowledge to be assembled at The University of Arizona and supplemented by an extensive interchange program.

In order to provide maximum delegation of responsibility and efficiency of organization, three Deputy Directors would be appointed for Administration, Programs and Operations. All administrative and service functions would be performed under the Deputy for Administration. Those tasks which require program type management either due to their inherent program nature or the magnitude of a particular contract or activity would receive Program Management under the direction of the Deputy Director for Programs. The actual research and technical tasks would be performed in an organization specifically segmented with regard to the disciplines of engineering and science involved and directed by the Deputy Director for Operations. The basic organization described above is illustrated in Figure 9. The next level of organization which reports to the Deputy Directors, which would be required by the projected demands of industry, government, and other academic communities by the 1975-1976 academic year is illustrated in Figures 10, 11, and 12.
Fig. 9 - Basic Organizational Structure of The Reliability Engineering and Research Center (RERCER)
Fig. 10 - Organization of the Directorate of Administration
Fig. 11 - Organization of the Directorate of Programs
The Deputy Director for Operations

The Manager of The Engineering Division

The Manager of The Data Center Division

The Manager of The Laboratory Division

The Manager of The Computer Operations Division

Fig. 12 - Organization of the Directorate of Operations
The cross section of industry, government, and academic personnel contacted by the author have indicated:

1. The establishment of RERCER on a planned and orderly basis represents the optimum method for providing the needed reliability services.

2. Strong demand will continue for academic programs and reliability research at The University of Arizona.

3. The system for computer program interchange and a reliability research and literature library is practically assured of success when implemented.

4. The test facility and data interchange programs have very strong promise of success.

5. Funding of the programs per item 3 and 4 above is being considered and detailed evaluation and cost analysis of the above programs is deemed essential prior to commitment of substantial funds.

An overall plan which will provide an orderly evaluation and the probable accomplishment of the above is provided in Figure 13. The major milestones are illustrated and it should be noted that the decision point will be reached in September 1973. At this time, it can be determined whether the desires of the potential users or sponsors of RERCER will provide adequate backing in the form of dollar commitment to justify the establishment of The Reliability Engineering and Research Center at The University of Arizona.

Projections for square feet of facilities, number of faculty, and equipment were provided in Chapter 3. These projections must be
updated at this decision point and it should be noted that these pro-
jections did not include an auditorium and ancillary facilities. If
sufficient financial support for the establishment of RERCER is obtained,
the plans for RERCER facilities should definitely include an auditorium
for approximately 200 persons with equipment for all major types of
projections including closed circuit television. The missions and
functions of the Center organization as predicted at this time are
provided in Appendix C.
Perform Detailed Evaluation and Cost Analysis of All RERCER Services

Implement System for Computer Program Interchange and RERCER Library

Implement Test Facility and Data Interchange Programs

Transmit Brochures to Potential Sponsors

On-Site Presentations to Major Potential Sponsors

Obtain Firm Commitments From Sponsors of RERCER

Sale of Building Bonds

Design of Facilities and Land Purchase

Construction of Facilities


Beginning of the Specified Academic Year

Fig. 13 - Overall Plan of Implementation of The Reliability Engineering and Research Center (RERCER)
CHAPTER 5

CONCLUSIONS

It was determined that a Reliability Engineering and Research Center was desired by a cross section of the governmental, industrial, and academic communities. Eighty-two percent of the personnel interviewed were either enthusiastic supporters of the Center from a professional view or enthusiastic supporters from both a professional view and potential users of the services of the Center.

It was determined that the reliability engineering and reliability research activities previously conducted and currently being performed at The University of Arizona form an adequate base for the establishment of a Reliability Engineering and Research Center.

It was determined that an incremental expansion upon the currently available services at The University of Arizona is the most practical approach to the establishment of a comprehensive Reliability Engineering and Research Center (RERCER). The method of incremental expansion was also recommended by a significant majority of the personnel contacted.

Notwithstanding the strong support previously and currently being given to reliability oriented activities at The University of Arizona, it was found that substantial segments of private industry and
government agencies were not aware of the academic and research capabilities of The University of Arizona.

A substantial majority of the personnel expressed a strong desire for additional reliability oriented courses in testing, maintainability, reliability management, quality engineering, and the disciplines of cost analysis and optimization as related to reliability engineering.

It was concluded that the Reliability Engineering Laboratory at The University of Arizona needed and was lacking the basic capability to perform environmental testing for hot, cold, vibration, shock, and humidity and conduct that analysis requiring an analog computer. These capabilities are considered to be the minimum requirements for the academic and research programs currently being conducted.

It was determined that the past accomplishments in providing both innovative and comprehensive reliability programs including basic research were directly attributable to the dedication and extraordinary efforts of The University of Arizona staff which supported these programs.

Strong support of additional reliability engineering programs was indicated by the personnel contacted during this study. The strongest support was for the establishment of a system for the interchange of computer programs and a reliability research and literature library with less enthusiasm for a test facility interchange, data interchange and consulting services in that order. Funding of these
additional activities by private industry and government agencies is highly probable, especially if implemented on a pilot basis by The University of Arizona.

The support of private industry and government agencies for the additional reliability engineering programs at The University of Arizona is dependent upon the performance of detailed evaluation of the requirements and cost analysis of the projected savings to the potential users of the RERCER.
CHAPTER 6

RECOMMENDATIONS

Based upon the results and conclusions reached during the research for this thesis, the comments and suggestions of the personnel contacted who are listed in Appendix A and the experience of the author in the areas of interest, the following recommendations are made:

The availability of the current educational programs and additional educational opportunities, as they are made available, at The University of Arizona should receive substantial additional publicity, especially to the operating elements of government and industry.

The opportunity for advanced degree study by qualified individuals should be expanded by implementing additional courses and by development of educational programs with other academic institutions, government agencies, and industry which will allow elimination of deficiencies and acquisition of course credits at an individual's local duty station.

The University of Arizona reliability engineering laboratory facilities should be expanded as soon as practical to provide laboratory facilities commensurate with the academic programs offered and to increase the capability to perform research.
The faculty which administers the reliability oriented programs at The University of Arizona should be expanded to meet the needs of the expanding graduate student enrollment and research projects and the additional services needed by private industry and government agencies.

A Reliability Research and Literature Library should be instituted with additional manpower and facilities by The University of Arizona on an incremental basis.

A Computer Program Library to be eventually utilized in a computer program interchange should be instituted with additional existing manpower and facilities by The University of Arizona on an incremental basis.

Detailed evaluations of the nationwide requirements and cost analysis of: (1) reliability research, (2) reliability oriented academic programs, (3) a computer program interchange, (4) a reliability research and literature library, (5) a test facility interchange program, (6) a data interchange program, and (7) consultation services should be conducted as soon as practical.

Based upon these detailed evaluations and cost analysis, a formal brochure should be transmitted to potential users of The Reliability Engineering and Research Center and negotiations conducted to obtain firm commitments of support during March 1972 to September 1973.

Based upon these commitments, an adequate facility and staff should be acquired for the establishment and operation of The Reliability Engineering and Research Center at The University of Arizona in September 1975.
APPENDIX A

LIST OF PERSONNEL CONTACTED

The following list of persons contacted during the thesis research are arranged in alphabetical order. The primary method of contact was person to person interviews and this method was supplemented with letters of inquiry and telephonic interviews. The major elements of government agencies, industry and academic institutions were all included and variation within these elements was obtained. Both military and civilian officers were contacted in Department of Defense agencies. In addition, a cross section of level of responsibility within these elements was obtained by contacting personnel at the levels of president, director, chiefs of operating elements, and journeymen. The views of top management, sales management, and technical management were solicited.

Mr. G. E. Abely, Sales Manager, Continental Testing Laboratories Incorporated, Fern Park, Florida

Mr. W. L. Bottin, Marketing Manager, The Stanwick Corporation, Upland, California

Mr. J. E. Condon, Director, Office of Reliability and Quality Assurance, National Aeronautics and Space Administration Hqs., Washington, D.C.

Mr. James F. Dowdy, Chief of Training, George C. Marshall Space Flight Center, Huntsville, Alabama

Colonel T. K. Fullerton, Deputy Commander, U. S. Army Mobility Equipment Command, St. Louis, Missouri

Mr. A. A. St. Germain, Head, Product Effectiveness Section, Tucson Engineering Laboratory, Hughes Aircraft Company, Tucson, Arizona

Mr. L. L. Gober, The Chief Engineer, U. S. Army Mobility Equipment Command, St. Louis, Missouri

Mr. J. G. Grimes, Test and Evaluation Directorate, U. S. Army Strategic Communications Command, Fort Huachuca, Arizona

Mr. M. Halebsky, Advanced Marine Technology Division, Litton Industries, Long Beach, California

Mr. E. B. Haugen, Associate Professor, Department of Aerospace and Mechanical Engineering, The University of Arizona, Tucson, Arizona

Mr. M. P. Hogarty, President, QEST Associates, Downey, California

Mr. K. E. Joy, Director of Product Assurance, U. S. Army Missile Command, Redstone Arsenal, Alabama

Mr. W. C. Karl, Power Program, Office of Naval Research, Department of the Navy, Washington, D.C.

Dr. D. B. Kececioglu, Professor, Aerospace and Mechanical Engineering Department, The University of Arizona, Tucson, Arizona

Mr. V. R. Lalli, Head, Spacecraft Technology Division, Lewis Research Center, National Aeronautics and Space Administration, Cleveland, Ohio

Mr. J. B. Lee, Executive Vice President, Contracts and Customer Relations, Astro Reliability Corporation, Sherman Oaks, California

Mr. S. J. Lorber, Director of Product Assurance, U. S. Army Materiel Command, Washington, D.C.

Mr. H. R. Lowers, The Chief Engineer, U. S. Army Missile Command, Redstone Arsenal, Alabama

Mr. F. L. Luke, Chief of Training and Employee Development, U. S. Army Mobility Equipment Command, St. Louis, Missouri

Lt. Colonel R. L. Manning, Acting Director of Product Assurance, U. S. Army Mobility Equipment Command, St. Louis, Missouri

Major H. D. Morgan, Deputy Director of Product Assurance, U. S. Army Mobility Equipment Command, St. Louis, Missouri
Mr. J. S. Meyer, Executive Vice President, Technical Operations, Astro Reliability Corporation, Sherman Oaks, California

Mr. R. L. Myers, Director, Quality Technology Program Study, Rio Hondo Junior College, Whittier, California

Mr. C. Neau, Advanced Marine Technology Division, Litton Industries, Long Beach, California

Dr. R. H. Noble, Professor and Vice Chairman, Optical Sciences Center, The University of Arizona, Tucson, Arizona

Mr. J. L. Olmstead, Assistant Manager, Tucson Systems Engineering Department, Hughes Aircraft Company, Tucson, Arizona

Mr. C. A. Pinyerd, Deputy Project Manager, PERSHING Project Managers Office, U. S. Army Missile Command, Redstone Arsenal, Alabama

Mr. P. Rolphes, Deputy Director for Quality Assurance, Defense Contract Administration Services, Los Angeles, California

Mr. A. J. Schwartz, Director of Reliability Assurance, TRW Systems Group, TRW Incorporated, Redondo Beach, California

Mr. Bart J. Slattery Jr., Director of Public Affairs, George C. Marshall Space Flight Center, Huntsville, Alabama

Mr. T. Ulmer, President, Astro Reliability Corporation, Sherman Oaks, California

Dr. E. P. Virene,Visiting Professor, Aerospace and Mechanical Engineering Department, The University of Arizona, Tucson, Arizona

Mr. W. Weare, Army Management and Engineering Training Agency, Rock Island Arsenal, Illinois
Several of the personnel contacted, who are listed in Appendix A, wrote letters containing comments or words of encouragement to the author. Exact copies of some of these letters are included in this Appendix. For the convenience of the reader, the following list delineates the agency.

The U. S. Army Materiel Command
The U. S. Army Mobility Equipment Command
The U. S. Army Management and Engineering Training Agency
The George C. Marshall Space Flight Center
The George C. Marshall Space Flight Center
The Astro Reliability Corporation
Mr. Robert C. Cook  
9339 E. Broadway  
Tucson, Arizona 85710

Dear Sir:

Reference is made to your June 15, 1970 letter which asked for our comments on your thesis proposal to establish a Reliability Engineering and Research Center.

The alternate possibilities for completion of the first semester's work in reliability engineering at the local level as expressed in your proposal would be a highly desirable feature of the program. Methods which provide our journeymen engineers and scientists with an opportunity to commence their graduate work while at the same time retaining their on-the-job availability and keeping costs to a minimum are a necessity in today's environment.

Authority to approve requests for training of civilian employees is one of the delegations to commanders of major subordinate commands and separate installations reporting directly to this headquarters, which provides them with the ability to manage their personnel resources. In addition, policy statements issued by this headquarters encourage participation by military and civilian personnel in educational programs not only as a means of self-development but also to improve the quality of the USAMC work force.

The provisions of Civilian Personnel Regulation 400, Employee Performance and Utilization, and Army Materiel Command Regulation 690-2, Policy and Procedures for Implementing Civilian Personnel Regulations, apply in establishing, conducting, and funding such a program for civilian employees. The means for military personnel to participate in such a program and receive tuition assistance for part-time attendance is available within the provisions of Army Regulation 621-5. Veterans Administration assistance is another means for qualified military members to obtain support for educational self-development. Full time attendance by military personnel in such a program would be controlled from Department of the Army. In this regard, Army Regulation 350-200, Training of Military Personnel at
AMCPT-TL

Civilian Institutions, is the basic regulation governing voluntary applications for graduate training from military personnel.

Present intern training programs at the US Army Management Engineering Training Agency and the Army Materiel Command Intern Training Center, in conjunction with Texas A&M University, are providing USAMC with an adequate flow of civilian personnel trained in reliability engineering. Validated spaces within USAMC which require the military incumbent to possess an advanced degree in engineering currently total 95, 36 in Aeronautical and 59 in Mechanical Engineering. There is no identification of reliability engineering specialization within these two fields.

I trust that this information will be of some assistance to you in your thesis preparation.

Sincerely,

ROBERT C. FORBES
Major General, USA
Director of Personnel, Training and Force Development
Mr. Robert C. Cook  
9339 E. Broadway  
Tucson, Arizona  85710

Dear Bob,

I have reviewed the missions and functions of the proposed Reliability Engineering and Research Center. It appears to me to be a good approach to solving the growing demand for information in this vital area.

Although at this time I cannot commit funds to such a project, I believe such a service would be of considerable assistance to us in our efforts to increase the reliability of Army equipment.

I am sure we would give support to this program to the extent that work and funds permit.

Sincerely,

[Signature]

HAROLD D. MORGAN  
MAJOR, GS  
Deputy Director of Prod Assur
Mr. Robert C. Cook  
9339 E. Broadway  
Tucson, Arizona 85710  

Dear Mr. Cook:  

I apologize for the delay in answering your letter. I am very interested in the concept of the Reliability Engineer & Research Center and of the exploration of innovations for helping qualified personnel obtain advanced degrees in the field of Reliability Engineering.  

Examination of the course descriptions of the first semester University of Arizona courses (AME 206, 208, 212, and 213) reveals that there is not a direct correspondence between these and existing AMETA courses. AME 206 appears to be closely paralleled by our Statistical Quality Control I Course. Many of the topics contained in the other three courses are included in a variety of our courses such as, Design & Analysis of Experiments, Elements of Reliability & Maintainability, and Probabilistic Methods in Operations Research. The Program of Instruction is inclosed for each of these courses. It would appear that any mutual agreement for "dual credit" would require a revision of the Reliability courses in the AMETA curriculum to correspond with the University's courses. Implementation of such an agreement would require approval from AMC Headquarters.  

For your consideration I would like to suggest some possible alternate approaches for attaining the required training.  

This Agency has arranged for certain courses to be offered for "dual credit" by the University as correspondence courses. The inclosed brochure provides a summary of such courses offered by correspondence by the University of Nebraska. A similar arrangement with the University of
AMXOM-AMS
Mr. R.C. Cook

8 Jul 70

Arizona would make the first semester Reliability courses more readily available to qualified students.

Another alternative for exploration with the University of Arizona would involve the scheduling of these courses as short intensive courses, i.e., three or four weeks of full-time study. Schedules would depend upon known demand for a particular course(s).

Perhaps the University could arrange for qualified students to obtain credit for these courses through a self-study program to be followed by proficiency examinations administered by the University.

Local University programs sometimes offer courses which are similar to the subject courses. An arrangement for transfer of credit to the University of Arizona for such courses may be helpful.

Perhaps the University would accreditate qualified instructors at some key locations where there are high demands for these courses. This would allow the courses to be offered locally with little interference with the students on the job activities.

My last suggestion would provide for proficiency exams to be given by the University upon completion of related courses and self-study by the student. For example; a student who has completed the AMETA Statistical Quality Control I Course may be allowed to take a proficiency exam for credit in the AME 206 courses.

The preceding suggestions offer a variety of approaches which may or may not be acceptable to the University of Arizona. Implementation of one or a combination of several of these approaches may be used to facilitate students gaining credit for the first semester courses. I am very interested in the results of your investigation and if I can be of help in any way please advise.

Sincerely,

WILBUR L. WEARE
DH, AMS

Cy furnished:
AMCQA, Mr. Lorber

5 Incls
as stated
Mr. Robert C. Cook  
9339 East Broadway  
Tucson, Arizona 85710

Dear Mr. Cook:

In reply to your letter dated June 2, 1970, we are pleased to note you are proposing advanced academic degrees and research in Quality and Reliability Engineering and related areas there at the University.

As you probably know, NASA is presently operating under very stringent funding limitations. For this reason our involvement in such programs as you offer would be extremely limited at this time. However, this is not to say we would not be interested in the future as we are assigned more programs. Certainly we hope your proposed services succeed and that we can avail ourselves of them at some later date.

Enclosed is the current organizational chart as you requested.

We appreciate your interest in our activities at this Center.

Sincerely yours,

Bart J. Slattery, Jr.  
Director of Public Affairs

Enc: as stated
Mr. Robert C. Cook
9339 East Broadway
Tuscon, Arizona 85710

Dear Mr. Cook:

Your letter of June 2 has been duplicated by Mr. Bart Slattery, our Director of Public Affairs, and sent to both the Director of Science and Engineering and Director for Program Management. We in the Center's Training Staff have been designated to reply.

You will be happy to know that we had already learned of the formal academic programs in reliability engineering at the University of Arizona. Mr. Frank Pizzano was nominated in March and approved June 8 to attend the academic year 1970-71. Frank is from our Program Management Directorate, Saturn V Office. We have recently suggested that you may be able to offer him some personal advice in obtaining suitable housing in Tuscon.

Other proposed services of the Reliability Engineering and Research Center create an interest in several places. At this time the Marshall Space Flight Center's role in the space program is being studied, and is undergoing change. No one can say with clarity or certainty what the requirements for proposed services II-VI would be.

Quality and Reliability managers in each of our program offices in the Program Management Directorate might have an interest in some of the proposed services. Dr. W. G. (Bill) Johnson and Mr. Grau, whom you also remember, have received copies of your letter.

Within the Science and Engineering Directorate two divisions of the Astronautics Laboratory, Materials and Test, may be interested in proposed services II, IV, and V.

Enclosed is an organization chart with offices or organizations mentioned marked for your convenience. You may want to correspond with them.
We are interested in the development and progress of the proposed services and the University of Arizona programs. Please keep us informed.

Sincerely,

James F. Dowdy
Chief of Training

1 Enclosure:
As stated

cc:
Mr. Slattery, PA
Mr. Boyd, A&TS-MA-PMB
Mr. Styles, A&TS-MA-DIR
Mr. James, PM-DIR
Mr. Weidner, S&E-DIR
Mr. Grau, S&E-QUAL-DIR
7 July 1970

Mr. Robert C. Cook
9339 E. Broadway
Tucson, Arizona 85710

Dear Bob:

It was certainly good to see you again and to talk with you regarding the reliability developments at the University of Arizona.

Frankly, I was somewhat surprised to hear of the progress being made and the extent of the program. Astro Reliability Corporation is very interested in the programs you discussed. As you know, for the past five years, we have been heavily involved in the reliability of mechanical equipment and as in most items of this sort, the more you become involved, the greater the understanding of what needs to be accomplished. We are particularly interested in the Reliability Center itself, and the University-Industry Library and Graduate programs. We would appreciate having the University continue to keep us aware of those programs, and look forward to cooperating in any manner that we can. Although neither Al Reed nor John Conner are available this week, I do intend to have them visit during the week of the 13th and I am anxious to learn in more detail, of the programs being conducted and those anticipated.

Thanks again for bringing this program to our attention, and I am looking forward to getting a first hand report from the visit next week. While I personally cannot break away at this time, I will plan to get down for a visit during the Fall. Kindest personal regards to the family.

Sincerely,

Joseph S. Meyer
Executive Vice-President

JSM:pb
APPENDIX C

LISTING AND DELINEATION OF THE MISSION AND FUNCTIONAL STATEMENTS OF THE RELIABILITY ENGINEERING AND RESEARCH CENTER

The following list delineates the individual mission and functions statements which are provided in this Appendix. For convenience to the reader, the page number on which each statement appears is provided in the list.

Mission Statement of the Reliability Engineering and Research Center (RERCER) . . (p. 73)

Functions Statement of the Reliability Engineering and Research Center (RERCER) . . (p. 74)

Mission Statement of the Director of the RERCER . . (p. 77)

Functions Statement of the Director of the RERCER . . (p. 78)

Mission Statement of the Deputy Director for Administration of the RERCER . . (p. 79)

Functions Statement of the Deputy Director for Administration of the RERCER . . (p. 80)

Mission Statement of the Manager of the Advance Planning Office . . (p. 82)

Functions Statement of the Manager of the Advance Planning Office . . (p. 83)

Mission Statement of the Comptroller and Manager of the Budget . . (p. 84)

Functions Statement of the Comptroller and Manager of the Budget . . (p. 85)

70
Mission Statement of the Manager of the Laboratory Division . . (p. 107)
Functions Statement of the Manager of the Laboratory Division . . (p. 108)
Mission Statement of the Manager of the Computer Operations Division . . (p. 109)
Functions Statement of the Manager of the Computer Operations Division . . (p. 110)
THE RELIABILITY ENGINEERING AND RESEARCH CENTER (RERCER)

RERCER shall be primarily devoted to the field of reliability engineering and related research. The disciplines of maintainability, maintenance engineering, systems engineering, availability, configuration management, quality assurance, quality engineering, statistics, operations research, and computer technology will not be pursued as an entity within themselves but will be fully utilized as they contribute to and overlap the broadly defined discipline of reliability engineering and reliability research.

The Center shall be as the name implies, the worldwide hub and focal point of knowledge and cognizance of all important matters concerning reliability engineering and related research; including but not limited to formal scholastic programs in reliability engineering, reliability research, reliability literature, computer programs, failure rate data, test equipment, data analysis, and consultation.

The Center will provide service to all segments of government and industry at a cost well below existing costs. The quality of these services will be unparalleled due to the Center's primary dedication to this specific field of endeavor and the wealth of experience and knowledge to be assembled at The University of Arizona and supplemented by an extensive interchange program.
FUNCTIONS

The Reliability Engineering and Research Center (RERCER)

1. Formal scholastic programs in Reliability Engineering and closely allied fields of endeavor. As a minimum, formal Master's Degree and Doctorate programs in all significant branches of engineering will be provided; with an option for either Reliability Engineering or Maintainability Engineering. To the extent demanded by government and industry, additional programs in Reliability Management, Availability, Design by Reliability, Quality Engineering, Quality Assurance, Value Engineering, Industrial Engineering, and Configuration Management will be instituted.

2. Basic and applied research in the fields of reliability and maintainability engineering to include basic research of the methodology of design with special emphasis upon continuation of the research which has previously been conducted and is now continuing for the purpose of determining the failure governing strength distribution, the failure governing stress distribution and the characteristics of fatigue failure.

3. Compilation of and operation of a computer program interchange. The interchange program will collect, identify and collate the programs which currently exist in the broad field of reliability and
re-distribute the programs as requested by users. Expert advice and creation of new programs will be provided as required by the users of the Center.

4. Compilation of existing failure data and operation of a failure data interchange program which will supplement and modify as required, the existing data interchange programs. Test data to include failure rate data and failure rates identified to a particular failure mode will be independently generated as required by the users of the Center.

5. Compilation to the extent practical, a description of the test facilities in existence and operation of an interchange of pertinent information concerning the capability and availability of these facilities. Serve as focal point for creation of additional facilities for multi-usage by the users of the Center. Provide design, development, and operation of special research test facilities as required by the users of the Center.

6. Creation and operation of a Reliability Research and Literature Library. All pertinent data will be physically collected and collated at the Center and will be available to all users of the Center. To the extent allowed by legal and proprietary considerations, the material will be distributed to the users upon request. An index of the contents of the library will be distributed to the users of the Center on a periodic basis.
7. Compilation and maintenance of a dossier of the personnel, facilities, and companies engaged in the broadly defined field of reliability. Consultation services or the recommendation of specific consulting services will be provided as requested by the users of the Center.
MISSION

Director of The Reliability Engineering and Research Center (RERCER)

The Director and his personal staff will maintain continuous cognizance of the needs of industry and government and consider these needs in the exercise of his overall management and future planning of the Center.

The Director will maintain continuous cognizance of the objectives and policies of The University of Arizona and assure compliance with these objectives and policies by all Center personnel.

The Director will assure maximum utilization of previous research and existing data, programs and facilities by the Center and provide direction to the Center in those areas requiring new research, data, programs, or facilities.
FUNCTIONS

Director of The Reliability Engineering and Research Center (RERCER)

1. Personally conducts The Annual RERCER Conference to provide top level representatives of the appropriate industrial firms and government agencies with a summary of the significant developments in the field of reliability during the preceding two years.

2. Obtain by direct inquiry and from the annual seminars, a consensus of those services which should be provided by RERCER either directly or through modification or as a supplement to existing services.

3. As a member of The University of Arizona Administration, attend appropriate policy meetings and conferences and assure the Center operates within the policies and regulations of The University.

4. By selection of and direction to his personal staff and Deputy Directors, assures the employment and retention of only those individuals of the highest integrity and capability by the Center.

5. By selection of and direction to his personal staff and Deputy Directors, assures that programs and activities conducted by the Center do not constitute a duplication of effort of equal programs and activities.

6. By selection of and direction to his personal staff and Deputy Directors, assures to the extent practical and permitted by funds and the state-of-the-art that the bona fide needs of industry and government are provided by the Center.
MISSION

Deputy Director for Administration of The RERCER

Working under the general direction of the Director of the Center, provides management of and coordination of advanced planning, procurement, budgets and cost control, marketing operations, and the planning for and maintenance of both facilities and equipment.

Assures that facilities, equipment, and test sites are available when required to support all authorized activities of the Center and to the extent practical, programs the incoming workload commensurate with the manpower and facilities which are available.

Assures compliance of the Center to all pertinent regulations of the Center, The University, and other appropriate regulatory bodies concerning visitors and travel, fund allocation and management, safety and fire, building and equipment maintenance, and the calibration of equipment.
FUNCTIONS

Deputy Director for Administration of The RERCER

1. Selects, provides necessary training and supervision of the Manager of Advanced Planning, Comptroller and Manager of the Budget, Marketing Manager, and the Manager of Logistics and Supply. Approves/disapproves all changes in organization and supervisory personnel in the Directorate of Administration.

2. In conjunction with the Manager of Advance Planning, conducts continuous evaluations to determine the personnel, facilities, and equipment for basic research, applied research, testing and other Center related services which are likely to be required by the Center and construct plans for their acquisition.

3. In conjunction with the Comptroller and Manager of the Budget, assures all expenditures are applied to the proper account and assures adequate funds are available for planned expenditures.

4. In conjunction with the Marketing Manager, assures that the current capabilities and planned capabilities are well known to the appropriate representatives of government and industry and that all inquiries to the Center are properly answered. Assures comprehensive distribution of brochures of special events and publication of an annual progress report to government and industry.
5. In conjunction with the Manager of Logistics and Supply, assures that long range facility planning is formally updated at least once each year and projects anticipated requirements at least ten years into the future. Assures adequate inventories of supplies and the procurement, proper maintenance, and calibration of equipment.
MISSION

Manager of the Advance Planning Office

The Manager of Advanced Planning shall maintain constant
cognizance of the current and projected needs of government and industry
which could be fulfilled by RERCER.

Continuous surveillance of possible sources of funds from
charitable institutions, foundations, government agencies at all levels
and individual corporations and benefactors shall be maintained.

Current levels of funded RERCER activity and the projected level
of funded activities shall be maintained.

On a periodic basis, long term projections of anticipated
activity commensurate with the needs of government and industry and
probable levels of funding will be formulated.
FUNCTIONS

Manager of the Advance Planning Office

1. On an annual basis, a ten year plan which specifies the anticipated level of RERCER activity will be prepared. This plan will specify those activities which will be funded directly by customers of the Center and those activities which will be funded by foundations, institutions, government agencies, and benevolent companies or individuals.

2. Principle points of contact with the appropriate foundations, institutions, government agencies, and possible sources of benevolent grants will be developed and maintained.

3. The eligibility of RERCER to obtain grant type funds will constantly be evaluated by submission of the proper data to these organizations and individuals.

4. Projections of possible grant type funds will be provided to the Manager of Logistics and Supply for his use in long term facility planning.

5. Projections of direct type expenditures from the Center's users will be obtained from the Marketing Manager for use in the annual preparation of the ten year plan.
MISSION

Comptroller and Manager of the Budget

The Comptroller shall assure that certified funds are available or will be available for payment of all activities of the Center. The Comptroller will assure that the costs of the Center are applied to the proper account. Requests for expenditure will be obtained from all elements of the Center and a budget will be prepared for approval of the Director of the Center. The budgets will be prepared in sufficient detail to preclude the non-completion of activities promised by the Center due to monetary considerations. The Comptroller shall comply and assure compliance by all RERCER personnel with all applicable monetary policy and regulation of The University of Arizona.
FUNCTIONS

Comptroller and Manager of the Budget

1. Prepare an annual overall Center budget in sufficient time for approval prior to the beginning of the fiscal year.

2. Institute those internal regulations and controls to assure that obligations of the Center to perform activities are commensurate with approved budgetary allocations.

3. Institute those internal regulations and controls required to assure that activities of the Center are charged to the proper account.

4. Conduct monthly budgetary conferences with all applicable personnel of the Center to review past budgetary performance and preclude future deviation in excess of prescribed standards.

5. Institute those internal regulations and controls to assure compliance with all monetary policies and regulations of The University of Arizona.
MISSION

Manager of the Marketing Division

The Manager of Marketing shall maintain contact with all past, current, and potential users of the services of the Center, and advise them of the current and potential capabilities of the Center on a continuous basis. A report will be published and transmitted to these users on a periodic basis which outlines the past progress and performance of the Center. The planned activities of the Center will be properly advertised and inquiries to the Center will be logged and adequate replies assured.
FUNCTIONS

Manager of the Marketing Division

1. Publishes an annual report to potential users of the Center which summarizes past progress and significant activities and outlines the proposed future activities of the Center. This report is published approximately three months prior to The Annual RERCER Conference.

2. Designs and implements a specific long term mutual commitment plan with important users of the Center. This long term commitment plan is the lifeblood of the Center since it provides stability to Center operations and in turn provides priority to the significant supporters of the Center.

3. Maintains liaison with all significant elements of government and industry and advises these personnel of the past, current, and future activities of the Center.

4. Directly supports the Director of RERCER in conducting The Annual RERCER Conference.

5. Issues flyers and other literature on an as required basis to selected personnel to announce important Center accomplishments or specific opportunities to users of the Center.

6. Obtains a complete definition of new and innovative services which are considered a requirement by potential Center users and transmits this information in final form to appropriate elements of the Center.
MISSION

Manager of the Logistics and Supply Division

The Manager of the Logistics and Supply Division shall select, train and supervise the personnel required to assure adequate and timely fulfillment of the functions of the Division.

The Manager of the Logistics and Supply Division shall assure that adequate facilities, utilities, equipment, and supplies are available at the time and place required to accomplish all authorized activities of the Center. Written maintenance and calibration plan and procedure will be designed, approved, and implemented. A traffic and travel element shall be established which assures adequate transportation is provided to all authorized personnel of the Center at the least practical cost.
FUNCTIONS

Manager of the Logistics and Supply Division

1. Develops and implements long range plans for acquisition of land, facilities, utilities, and equipment in conjunction with specific input from appropriate elements of RERGER.

2. Constructs plant layout diagrams of all Center facilities, utilities, and installed equipment and approves/disapproves all requested changes.

3. Develops policy and implements written procedures to assure the maintenance of all facilities, utilities and equipment and proper calibration of all applicable equipment which is traceable to the National Bureau of Standards.

4. Maintains a central supply element which assures the availability of all necessary expendables and implements a stock control procedure to preclude oversupply.

5. Maintains accountability records of all equipment not considered to be expendable.

6. Institutes and manages a traffic and travel element which provides transportation services to meet all requirements of all Center personnel at the least practical cost.
MISSION

Deputy Director for Programs of the RERCER

Performing under the general direction of the Director of RERCER, the Deputy Director for Programs provides program management of and coordination of all program oriented functions of the RERCER to include formal academic degree programs, institutes, conferences, seminars, short courses, consultation services and interdepartmental programs. In addition, Programs Managers are appointed to manage specific important, complex or costly research programs to assure adequate cost control, scheduling, and customer satisfaction.

The Deputy Director for Programs together with the Director of RERCER, the Deputy Director for Administration, and Deputy Director for Operations comprise the RERCER Board of Directors, who through scheduled meetings and published minutes, provide the overall policy guidance and direction for all Center activities.
FUNCTIONS

Deputy Director for Programs of the RERCER

1. Selects, provides training, and supervises the Manager of Consulting Services, the Manager of Academic Programs, the Manager of Institutes and Conference Programs, and Program Managers of specific research programs.

2. In conjunction with the Manager of Consulting Services, provides consulting services directly or through prior agreements. Advises RERCER users in obtaining services not available through RERCER as requested.

3. In conjunction with the Manager of Academic Programs, provides a program of formal degree programs which fulfill the requirements of the general pursuit of knowledge as well as the specific requirements of government agencies and industry.

4. In conjunction with the Manager of Institutes and Conference Programs, provides for the special requirements of the academic community, government and industry with special grants from foundations and direct fees to participants.

5. Appoints and terminates Program Managers and in conjunction with Program Managers of research projects, assures adequate cost and schedule control and customer satisfaction.

6. As a member of the RERCER Board of Directors, provides overall policy guidance and direction for all RERCER activities.
MISSION

Manager of Consulting Services

The Manager of Consulting Services shall be cognizant of all important personnel and developments in the field of consultation and appoint, train, and supervise those consultants specifically required by the users of RERCER. The Manager of Consulting Services will negotiate agreements with members of RERCER, the faculty of the University of Arizona, and other qualified consultants in order to provide minimum response time to the users of RERCER. He shall provide expert consultation and advice to the users of RERCER as required or advise the users of RERCER in obtaining services from other personnel or companies.
FUNCTIONS

Manager of Consulting Services

1. Directs the consulting services of the RERCER.

2. Prepares and maintains a dossier of all consultants in the field of Reliability Engineering and Research with delineation of the scope of their activities.

3. Prepares projections of the requirements of government, industry and other educational and research institutions.

4. Selects, trains, and supervises a minimum staff of consultants to provide immediate response to the users of RERCER based on known requirements.

5. Negotiates working agreements with members of RERCER, members of the faculty of The University of Arizona, and qualified members of the consultation community for the purpose of providing timely response to RERCER's users, based upon maximum anticipated requirements.

6. Provides advice and assistance to the users of RERCER for required consultation services which are not available within RERCER or available per prior agreement.
MISSION

Manager of Academic Programs

In conjunction with the appropriate officials of The University of Arizona, the Manager of Academic Programs shall plan and direct all formal degree programs under the cognizance of The Reliability Engineering and Research Center. He shall maintain cognizance of the requirements of government, industry, and other academic institutions for formal degree programs and develop the applicable programs in conjunction with the colleges and centers of The University, The Graduate College, and other officials of The University of Arizona. The Manager of Academic Programs shall negotiate with other universities and responsible organizations for the establishment of locally sponsored formal education, such as correspondence programs, on an individual basis as the need arises.
FUNCTIONS

Manager of Academic Programs

1. Directs the Academic Programs of RERCER.

2. Maintains continuous contact with appropriate officials of government, industry, and other academic institutions to determine the requirements for formal degree programs at the B.S., M.S., and Ph.D. levels.

3. In conjunction with the appropriate officials of The University, develops academic programs commensurate with the specific requirements.

4. Develops special programs in conjunction with other universities, The Army Management and Engineering Training Agency and other responsible agencies which permit local training or correspondence type self-learning which allow qualified personnel to obtain partial fulfillment of the formal degree requirements or to eliminate deficiencies.

5. Utilizes the services of all Departments of The University on a maximum basis to preclude duplication of courses.

6. Develops new courses to meet the demands of the users of RERCER.

7. Provides descriptive literature for transmission to potential applicants and employers for the current academic programs.
MISSION

Manager of Institutes and Conference Programs

The Manager for Institutes and Conference Programs shall evaluate the requirements for, plan, and direct all institutes, seminars, conferences, short courses, and any other similar activities under the cognizance of the Center. As a prominent expert in his field, he shall maintain cognizance and assure that the Center satisfies all of the unfilled needs of government and industry and does not duplicate those activities of equal content which are conducted by other qualified agencies. The Program Manager shall assure preparation of the required literature for publication, schedule the events, and assure adequate personnel and facilities are available at the required time.
**FUNCTIONS**

*Manager of Institutes and Conference Programs*

1. Directs all institutes and conference type programs.

2. Maintains continuous contact with the significant elements of government, industry, special agencies such as the National Science Foundation and the academic community to determine the current and future requirements for conferences, seminars, short courses, institutes and other similar activities. Maintains lists of personnel who are probable attendees of the specific events.

3. Designs the particular event to best fulfill the requirement at the least cost practical.

4. Schedules these events and provides literature to properly notify the appropriate agencies and personnel.

5. Schedules faculty and visiting participants and all facilities and supplies.

6. Provides day to day management of the events as they are conducted. Obtains feedback from the participants and effects the necessary corrective action.

7. Maintains cognizance of the content, quality, scheduling, and capacity of these types of events which are conducted by other institutions and assures that the Center does not unnecessarily duplicate any seminar, institute, short course, conference or similar activity.
Typical Program Manager

The Program Manager shall exercise program management over all aspects of the particular program under his personal control and direction. Special emphasis shall be placed upon cost control, scheduling and reporting, and assurance of customer satisfaction. The Program Manager shall not view his position as permanent but shall be constantly alert to the possibility that the research or test program under his control may not require program management. The Program Manager shall maintain constant cognizance of all activities applicable to his program at the Center and shall serve as the single point of contact with the applicable customer.
FUNCTIONS

Typical Program Manager

1. Directs all significant actions and provides singular and overall management of the program to which he is assigned.

2. Establishes those cost reports and cost controls which are required to assure compliance with contractual agreements. Advises the RERCER and the customer of bona fide and significant cost problems.

3. Establishes detailed schedules of work to be accomplished by the RERCER and reports progress to the RERCER and the customer. Provides evaluation to all appropriate elements when schedule is not met or a slippage is anticipated.

4. Assures customer satisfaction to the maximum extent practical.

5. Maintains cognizance of all program activities at the Center and acts a single point of contact with the customer.

6. Recommends abolishment of his assignment as Program Manager when the complexity of program, problems, and scheduling does not require this specialized form of management.
Deputy Director for Operations of the RERCER

Performing under the general direction of the Director of RERCER, the Deputy Director for Operations provides all primary technical services of the Center which include, but are not limited to, basic and applied reliability research, operation of the laboratories and testing facilities, engineering, technical libraries and computer program evaluation, research and preparation. The Deputy Director for Operations maintains cognizance of the technical progress of the functions performed, the current and projected needs of RERCER users and through the planning and budgeting processes, assures RERCER technical services meet or exceed the state-of-the-art.

The Deputy Director for Operations together with the Director of RERCER, the Deputy Director for Administration and the Deputy Director for Programs comprise the RERCER Board of Directors, who through scheduled meetings and published minutes, provide the overall policy guidance and direction for all RERCER activities.
FUNCTIONS

Deputy Director for Operations of the RERCER

1. Selects, provides training, and supervises the Manager of the Engineering Division, the Manager of the Data Center Division, the Manager of the Laboratory Division, and the Manager of the Computer Operations Division.

2. In conjunction with the Manager of the Engineering Division, provides the staff of engineering and scientific personnel required to perform the basic and applied research, test equipment and procedural design, and develop technical proposals for either RERCER users or independent research by the RERCER.

3. In conjunction with the Manager of the Laboratory Division, provides a nationwide and periodic listing of the location, capability, and availability of all significant test equipment and facilities. Provides laboratory and testing services, and related advice as required by RERCER users.

4. In conjunction with the Manager of the Computer Operations Division, maintains a comprehensive listing of computer programs and either provides a hard copy or the specific information to obtain the program at least cost. Develops new computer programs and translates programs for use with specific computer hardware as required by the users of RERCER.
5. In conjunction with the Manager of the Data Center Division, provides an integrated system for providing all required data to RERCER users by utilizing all available data from other sources and providing the supplemental data in the RERCER Laboratories or through other sources. Maintains the Reliability Research and Literature Library.

6. As a member of the RERCER Board of Directors, provides overall policy guidance and direction for all RERCER activities.
MISSION

Manager of the Reliability Engineering Division

The Manager of the Reliability Engineering Division shall remain cognizant of all significant developments in reliability engineering and conduct basic or applied research to create and refine existing knowledge as required by the users of RERGER. Independent research will be conducted as considered appropriate. The Manager of the Reliability Engineering Division shall select, train, and supervise that staff of especially qualified personnel at a level of competence commensurate with providing world wide leadership in the field of reliability research.
FUNCTIONS

Manager of the Reliability Engineering Division

1. Directs the engineering and scientific staff of RERCER and collaborates with supporting personnel from other university elements.

2. Conducts basic and applied reliability research as required by the users of RERCER.

3. Conducts independent research as directed by the Director of RERCER.

4. Designs special equipment and machinery when required as a prerequisite for research activities.

5. Maintains cognizance of all significant developments in the field of reliability engineering and directly related fields of endeavor.

6. Develops and proposes research projects to appropriate government agencies and industry.
MISSION

Manager of the Data Center Division

The Manager of the Data Center Division shall select, train, and supervise the staff of personnel required to provide expert and timely assistance to the users of RERCER with regard to test and failure rate data. As required, data shall be identified with regard to the appropriate failure mode. The Manager of the Data Center Division shall assure the maximum possible failure rate and test data is available to users by utilizing existing data programs such as FARADA and IDEP and creating the required supplemental data at RERCER or through an interchange program between the users of RERCER. A comprehensive library of all reliability research and literature will be maintained for the users of RERCER.
FUNCTIONS

Manager of the Data Center Division

1. Directs all data and library functions of the RERCER.

2. Maintains continuous cognizance of the testing and failure rate data requirements of the users and potential users of RERCER.

3. Maintains continuous cognizance of the test and failure rate data which is currently available through existing programs such as IDEP and FARADA.

4. Develops methods and agreements between government and industry to supplement the existing data programs.

5. Develops methods and agreements to provide future data requirements.

6. Within legal and proprietary limitations, provides data to all RERCER users on an interchange basis.

7. Collects, collates, and identifies by category all pertinent reliability research and literature data in the form of a library and provides all material to RERCER users at cost. Publishes a periodic index of the library's contents.
MISSION

Manager of the Laboratory Division

The Manager of the Laboratory Division shall select, train, and supervise the staff required to provide expert and timely assistance to the users of RERCER with regard to reliability research equipment and testing equipment, and the Test Facility Interchange Program. Research and test laboratories will be provided commensurate with the needs of the academic programs and specific research programs. The Manager of the Laboratory Division shall be cognizant of all significant publications, interchange programs and test facility developments, and design or assemble test facilities as required. An interchange of data regarding test facilities will be maintained.
FUNCTIONS

Manager of the Laboratory Division

1. Directs, assembles, and operates the test facilities, either on-site or at remote locations, as required to fulfill the requirements of the academic programs and research programs conducted by the RERCER.

2. Designs special type test equipment when required to fulfill RERCER research programs.

3. Provides advice to RERCER users regarding the availability and capability of test equipment.

4. Publishes an indexed compilation of all significant test equipment in the United States, and to some extent the free world, with details concerning capacity, cost, and availability. Utilizes to the maximum extent practical, those publications which already exist.

5. Designs and implements a test facility interchange program which allows reciprocal usage of test facilities by the users of RERCER and construction of needed facilities on a multi-ownership basis.

6. Performs research of the design, construction, and operation of test equipment as required by the users of RERCER.
MISSION

Manager of the Computer Operations Division

The Manager of the Computer Operations Division shall select, train, and supervise the staff of personnel required to provide expert and timely assistance to the users of RERCER with regard to computer programs. To the extent practical, the capability and status of the debugging process of all known programs in the field of reliability engineering and research will be made available to RERCER users. Off the shelf computer programs in debugged condition will be provided. On those instances where a program does not exist, the Manager of the Computer Operations Division will design and debug the required program or arrange its procurement for the RERCER user.
FUNCTIONS

Manager of the Computer Operations Division

1. Directs the computer program operation of RERCER. Selects, trains, and supervises the immediate staff required.

2. Collects, collates, and maintains a library of computer programs related to reliability engineering and research.

3. Transmits a complete index, properly identified by category and computer hardware, to the users of RERCER on an annual basis. On a quarterly basis, provides the same information on programs which have been added to the library since the last annual or quarterly report. On an as required basis, provides a description of any extra-ordinary development or individual program to the RERCER users.

4. Develops methods of reproducing computer programs and transmits programs to the users of the Center as requested.

5. Operates an interchange program wherein users of the Center provide their programs to the library for use by other users in return for the programs of other RERCER users and the resultant lower average cost of their needs.

6. Designs and debugs new computer programs for specific operations as requested.
REFERENCES


Place Holder