

Benchmarking Commercial Reliability Practices

DISTRIBUTION STATEMENT A

Approved for public release;
Distribution Unlimited

19960716 012

RAC

Reliability Analysis Center

RAC is a DoD Information Analysis Center
Sponsored by the Defense Technical Information Center

DTIC QUALITY INSPECTED 1

Benchmarking Commercial Reliability Practices

Prepared by:

Reliability Analysis Center
P.O. Box 4700
Rome, NY 13442-4700

Under contract to:

Rome Laboratory
Griffiss AFB, NY 13441-4505



Reliability Analysis Center

RAC is a DoD Information Analysis Center sponsored by the Defense Technical Information Center and operated by IIT Research Institute, Rome, NY

The information and data contained herein have been compiled from government and nongovernment technical reports and from material supplied by various manufacturers and are intended to be used for reference purposes. Neither the United States Government nor IIT Research Institute warrant the accuracy of this information and data. The user is further cautioned that the data contained herein may not be used in lieu of other contractually cited references and specifications.

Publication of this information is not an expression of the opinion of the United States Government or of IIT Research Institute as to the quality or durability of any product mentioned herein and any use for advertising or promotional purposes of this information in conjunction with the name of the United States Government or IIT Research Institute without written permission is expressly prohibited.

REPORT DOCUMENTATION PAGE

Form Approved

OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave Blank)		2. REPORT DATE July 1995	3. REPORT TYPE AND DATES COVERED	
4. TITLE AND SUBTITLE Benchmarking Commercial Reliability Practices			5. FUNDING NUMBERS	
6. AUTHOR(S) Ned H. Criscimagna				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Reliability Analysis Center P.O. Box 4700 Rome, NY 13442-4700			8. PERFORMING ORGANIZATION REPORT NUMBER None	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) SPONSORING/MONITORING Defense Technical Information Center (DTIC-AI) Cameron Station Alexandria, VA 22314-6145			10. AGENCY REPORT NUMBER F30602-94-C-0087	
11. SUPPLEMENTARY NOTES Hard copies available from the Reliability Analysis Center, PO Box 4700, Rome, NY 13442-4700. (Price: \$50.00 U.S., \$60.00 Non-U.S.). DTIC will provide microfiche copies at standard microfiche price. DTIC source code:				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited. Available from RAC or DTIC. Microfiche available from DTIC.			12b. DISTRIBUTION CODE Unclassified	
13. ABSTRACT (Maximum 200 words) The Reliability Analysis Center (RAC) conducted a fact-finding, study project to benchmark the reliability practices used by commercial industry. The project was performed for the Office of the Under Secretary of Defense for Economic Security, Weapon Support Improvement Group. The project consisted of four distinct tasks: a literature search, a survey of the reliability practices of a wide range of commercial companies, personal interviews of a smaller group of companies, and an analysis of the data collected. Based on the results of these tasks, areas of commonality and divergence among commercial reliability practices were identified, as well as the general commercial approach to designing, developing, and manufacturing reliable products. Four benchmarks and eight Keys to Success were derived from the findings and conclusions. Insights were gained into the motivations behind commercial companies' approaches and their use of military specifications, standards, and handbooks. The report includes a discussion of Defense Acquisition Reform, a bibliography, summaries of selected documents, and the results of the survey and interviews. In the case of the surveys and interviews, information was treated on a not-for-attribution basis.				
14. SUBJECT TERMS Reliability Practices Commercial Reliability Reliability Benchmarking			15. NUMBER OF PAGES 140 (including appendixes)	
17. SECURITY CLASSIFICATION	18. SECURITY CLASSIFICATION	19. SECURITY CLASSIFICATION	16. PRICE CODE 20. LIMITATION OF ABSTRACT	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

The Reliability Analysis Center (RAC) is a Department of Defense Information Analysis Center sponsored by the Defense Technical Information Center, managed by the Rome Laboratory (formerly RADC), and operated by IIT Research Institute (IITRI). RAC is chartered to collect, analyze and disseminate reliability, maintainability and quality information pertaining to systems and products, as well as the components used in them. The RAC addresses both military and commercial perspectives and includes such reliability related topics as testability, Total Quality Management and lifetime extension.

The data contained in the RAC databases is collected on a continuous basis from a broad range of sources, including testing laboratories, device and equipment manufacturers, government laboratories and equipment users (government and industry). Automatic distribution lists, voluntary data submittals and field failure reporting systems supplement an intensive data solicitation program. Users of RAC are encouraged to submit their reliability, maintainability and quality data to enhance these data collection efforts.

RAC publishes documents for its users in a variety of formats and subject areas. While most are intended to meet the needs of reliability practitioners, many are also targeted to managers and designers. RAC also offers reliability consulting, training, and responses to technical and bibliographic inquiries. A synopsis of RAC's services and other products is included at the back of this document.

REQUESTS FOR TECHNICAL ASSISTANCE
AND INFORMATION ON AVAILABLE RAC
SERVICES AND PUBLICATIONS MAY BE
DIRECTED TO:

Reliability Analysis Center
201 Mill Street
Rome, NY 13440

Product Ordering:	(800) 526-4802
Training Inquires:	(800) 526-4803
TQM Inquiries:	(800) 526-4804
Technical Inquiries:	(315) 337-9933
TeleFax:	(315) 337-9932
DSN:	587-4151
E-mail:	rac@mail.iitri.com
Internet:	World Wide Web http://rome.iitri.com/RAC/

ALL OTHER REQUESTS SHOULD BE
DIRECTED TO:

Rome Laboratory
RL/ERDS
Attn: R. Hyle
525 Brooks Rd.
Griffiss AFB, NY 13441-4505

Telephone: (315) 330-4891
DSN: 587-4891

© 1995, IIT Research Institute

This material may be reproduced by or for the US Government pursuant to the copyright license under the clause at DFARS 252.227-7013 (Oct. 1988)

PREFACE

As introduced by Xerox, benchmarking is a process for finding the world-class standards for a product, service, or system and then adjusting one's own products, services, and systems to exceed those standards. These world-class standards can be found by looking at competitors who are recognized leaders for the product, service, or system. Benchmarking done using competitors as models is called competitive or strategic benchmarking. Operating units or functions within a company can also be used as the model; this approach is called internal benchmarking. Finally, benchmarking can be done using companies that are the best practitioners of a particular function, regardless of what industry the exemplar is in. This type of benchmarking is called functional benchmarking. Benchmarking is a method now commonly used by companies as part of their efforts to improve quality, and it is a necessary element for winning the Malcolm Baldrige National Quality Award.

Another form of benchmarking is called *normative benchmarking*. In normative benchmarking, a consultant collects data from a group of companies on a product, service, or process and then delivers a set of statistics to the companies with company names expunged. The benchmarking effort described herein incorporated elements of normative and functional benchmarking.

The Reliability Analysis Center (RAC) conducted a fact-finding, study project to benchmark the reliability and maintainability (R&M) practices used by commercial industry. The project was performed for the Office of the Under Secretary of Defense for Economic Security, Weapon Support Improvement Group. Initially, the study objectives were to:

- Gain an understanding of the best R&M practices being used by commercial industry
- Recommend changes to existing DoD R&M standards and handbooks
- Identify R&M tools and techniques and, when possible, evaluate their effectiveness, applications, and cost.

As Defense Acquisition Reform progressed, the second and third objectives were deferred. The project was rescoped to focus on the first objective and on reliability as a means of providing useful input to the ongoing DoD acquisition reform effort.

The benchmarking consisted of four distinct tasks: a literature search, a survey of the R&M practices of a wide range of commercial companies, personal interviews of a smaller group of companies, and an analysis of the data collected. Based on the results of these tasks, areas of commonality and divergence among commercial reliability practices were identified, as well as the general commercial approach to designing, developing, and manufacturing reliable products. Three benchmarks and eight Keys to Success were

derived from the findings and conclusions. Insights were gained into the motivations behind commercial companies' approaches and their use of military specifications, standards, and handbooks.

This document is organized into five chapters and six appendixes:

- | | | |
|------------|---|---|
| Chapter 1 | - | <u>Introduction</u> - The background leading up to the benchmarking effort is described as is the benchmarking process. |
| Chapter 2 | - | <u>Technical Approach</u> - The approach used to perform the benchmarking is described. |
| Chapter 3 | - | <u>Results</u> - The results of each step in the benchmarking effort are presented. |
| Chapter 4 | - | <u>Conclusions</u> - Conclusions are presented. |
| Chapter 5 | - | <u>Areas Requiring Additional Research</u> - Areas related to reliability engineering and its implementation that require further research are presented. |
| Appendix A | - | <u>Defense Acquisition Reform</u> - Background information on the current reform efforts. |
| Appendix B | - | <u>Literature Search Results</u> - Bibliography and synopses of selected references. |
| Appendix C | - | <u>Survey Forms</u> - Samples of the survey forms used. |
| Appendix D | - | <u>Interview Questions and Notes</u> - Samples of the interview questions and expurgated notes from the interviews. |
| Appendix E | - | <u>Terms and Definitions</u> |
| Appendix F | - | <u>RAC Product Order Form</u> |

ACKNOWLEDGMENTS

The RAC gratefully acknowledges the cooperation of the following companies for participating in the surveys and interviews described in this document.

3M Co., Telecon Resources	General Motors Corp., Electro-Motive Div.
Abbott Laboratories	General Motors, Mid-size Cars
AC Rochester	Intermagnetics General Corp.
Allen-Bradley	Intermedics, Incorporated
Allied Signal Aerospace	Johnson Controls, Incorporated
Allied Signal, Air Trans. Avionics	Medtronics, Incorporated
Amana Refrigeration	Miles, Incorporated
AT&T Bell Laboratories	Motorola Codex Corporation
Bell Helicopter TEXTRON	Motorola Cellular Subscriber Group
Boeing Commercial Aircraft Co.	Navistar International Transportation
Carrier Corporation	Niagara Mohawk Corporation
Cessna Aircraft Corporation	Northwest Airlines, Tech Operations
Chrysler Corporation	Ohmeda Medical Company
Control Data Systems	Robert Shaw
Cummins Engine Company, Inc.	Rohr, Incorporated
Eastman Kodak	Sun Micro Systems
Eldec Corporation	Sundstrand Data Control
GE Medical Systems	TRW Vehicle Systems
GE Transportation Systems	Union Pacific Railroad
General Railway Signal Corporation	Watkins Johnson Company, Inc.
	Woodward Governor Company

TABLE OF CONTENTS

	Page
1.0 INTRODUCTION	1
1.1 Background.....	1
1.2 Benchmarking.....	2
1.3 Organization of Report.....	4
2.0 TECHNICAL APPROACH	5
2.1 Overview.....	5
2.2 Literature Search.....	5
2.3 Surveys.....	6
2.3.1 Rationale for Surveys.....	6
2.3.2 Selection and Qualification of Companies.....	7
2.3.3 Development of Survey Form.....	9
2.4 Interviews.....	10
3.0 RESULTS	13
3.1 Literature Search Results.....	13
3.2 Survey Results.....	13
3.3 Interview Results.....	16
3.4 Overall Discussion.....	17
3.5 General Findings.....	20
3.5.1 The Environment.....	20
3.5.2 The Practices.....	21
3.6 Specific Findings.....	22
4.0 CONCLUSIONS	27
4.1 The Practices.....	27
4.1.1 Reliability Tasks.....	27
4.1.2 Approach to Achieving Reliability.....	28
4.2 The Contracting Environment.....	28
4.3 The Benchmarks.....	29
4.4 Other Keys to Success.....	29
5.0 AREAS REQUIRING ADDITIONAL RESEARCH	31
APPENDIX A: DEFENSE ACQUISITION REFORM	
APPENDIX B: LITERATURE SEARCH RESULTS	
APPENDIX C: SURVEY FORMS	
APPENDIX D: INTERVIEW QUESTIONS AND NOTES	
APPENDIX E: TERMS AND DEFINITIONS	
APPENDIX F: RAC PRODUCT ORDER FORM	

LIST OF FIGURES

Figure 1: Xerox's Ten-Step Model for Benchmarking.....	3
Figure 2: Relative Importance of Reliability Tasks.....	15
Figure 3: CAD/CAM Facilitates Customer Focus.....	17

LIST OF TABLES

Table 1: Industries Identified for Study.....	8
Table 2: Criteria for Identifying Candidate Companies	8
Table 3: List of Companies Interviewed.....	11
Table 4: Overview of Companies Surveyed and Interviewed	13
Table 5: Most Important Reliability Tasks According to Survey.....	14
Table 6: Anecdotal Comments.....	19
Table 7: Reliability Tasks Grouped by Objective	27
Table 8: Characterizing the Commercial Sector Contracting Environment.....	28

1.0 INTRODUCTION

The document describes the results of a study conducted by the Reliability Analysis Center (RAC) for the Office of the Assistant Secretary of Defense (OASD) for Economic Security (ES), Weapon Support Improvement Group (WSIG). Initially, the study objectives were to:

- Gain an understanding of the best R&M practices being used by the commercial sector
- Recommend changes to existing DoD R&M standards and handbooks based on the best commercial practices
- Identify R&M tools and techniques and, when possible, evaluate their effectiveness, applications, and cost

To provide timely input to efforts within DoD to examine current acquisition policies and streamline the acquisition process, the project was rescoped to focus on gaining an understanding of the reliability practices being used by commercial industry. So, although R&M is sometimes used in this report, the focus of the effort was on reliability.

The report does not address related issues, such as whether government specifications and standards should be used at all or how to streamline the government acquisition process. These issues are being investigated by other government-industry groups. It is, however, important to view the report in the context of Defense Acquisition Reform. Consequently, a discussion of Defense Acquisition Reform is provided in Appendix A.

1.1 BACKGROUND

Prior to the Second World War, weapons were relatively simple in capability and complexity. Most portions of a system seldom failed and when they did were easily fixed.¹ Due to technological advances made during the war, military weapons evolved into extremely complex systems. Complexity was a byproduct of efforts to build more capable, effective systems to counter more lethal threats; efforts that were successful as evidenced by systems such as airborne radar and the P-61 all-weather fighter. Complexity created new problems for the operators who discovered that they not only required more training to use the systems, but that the systems were, to some extent, more fragile. That is, the systems tended to fail more frequently and required more maintenance (more in terms of frequency and required skills). From this new reality, the Department of Defense (DoD) created² the disciplines of reliability and maintainability (R&M) engineering. With the assistance of forums, such as the Advisory Group on

¹From our perspective. At the time, systems such as the P-40 were considered very complex and maintenance crews surely did not consider their job easy. With apologies to our predecessors, the fact remains that technology changed more during WW II than it had during the previous 50 years, and the rate of change has since accelerated.

²Or at least formalized them. During WW II, the V-1 missile project team, led by Dr. Von Braun, developed what was probably the first reliability prediction model. The team consulted with Eric Pieruschka who asserted that if the probability of survival of an element is $1/x$ then the probability that a set of n identical elements will survive is $(1/x)^n$. The formula derived from this assertion is sometimes called Lusser's law (Robert Lusser is considered a pioneer of reliability) but is more frequently known as the reliability of a series system: $R_S = R_1 \times R_2 \times \dots \times R_n$.

Reliability of Electronic Equipment, the DoD developed standards and other guidance documents on R&M, beginning in the 1950s. Since then, the specific tasks, methods, and approaches described in the documents have changed, but the underlying reason for having the documents has remained constant: to capture the "best R&M practices" for designing and producing reliable and maintainable systems. "Best R&M practices" refer to those engineering and manufacturing tasks, methods, and approaches that have proven effective in fielding systems with good R&M performance.

In the past, commercial companies based their R&M programs on those of the DoD and adopted many DoD standards, revising them as necessary for their purpose. Within the last few years, however, the commercial industries in the United States have undergone what has been described as chaotic change. This change, which continues today, is a response to an increasingly competitive world marketplace in which quality and R&M have become the foundation of success. Unfortunately, progress in quality and R&M has been led, or at least is perceived to have been led, by countries other than the US. In an attempt to "catch up," US commercial companies have been aggressively developing or enhancing tools and methods for achieving high levels of quality and, presumably, R&M. However, DoD's general approach to achieving good R&M and the DoD standards on R&M has not changed substantially in over 15 years, and may not reflect the best practices recently developed and currently used by the commercial sector.

R&M are not the only disciplines for which the validity of standards is in question. Many top-level government officials are inclined to abolish the use of (or require a waiver to use) government-mandated standards (and related documents such as specifications) and adopt a commercial approach to procuring goods and services. It is, in the opinion of these officials, not simply a question of whether these documents are current, but whether they are or can be applied effectively. Too often, a contract will include an almost inexhaustible list of standards, handbooks, and specifications. Many of these have little if any applicability to the product or service involved. Others are cited without "tailoring." Tailoring literally means making the document fit the specific application. In a world of tight schedules where inexperienced young officials often develop contract requirements, lists of government documents are often blindly added with no tailoring and no appreciation of the associated cost.

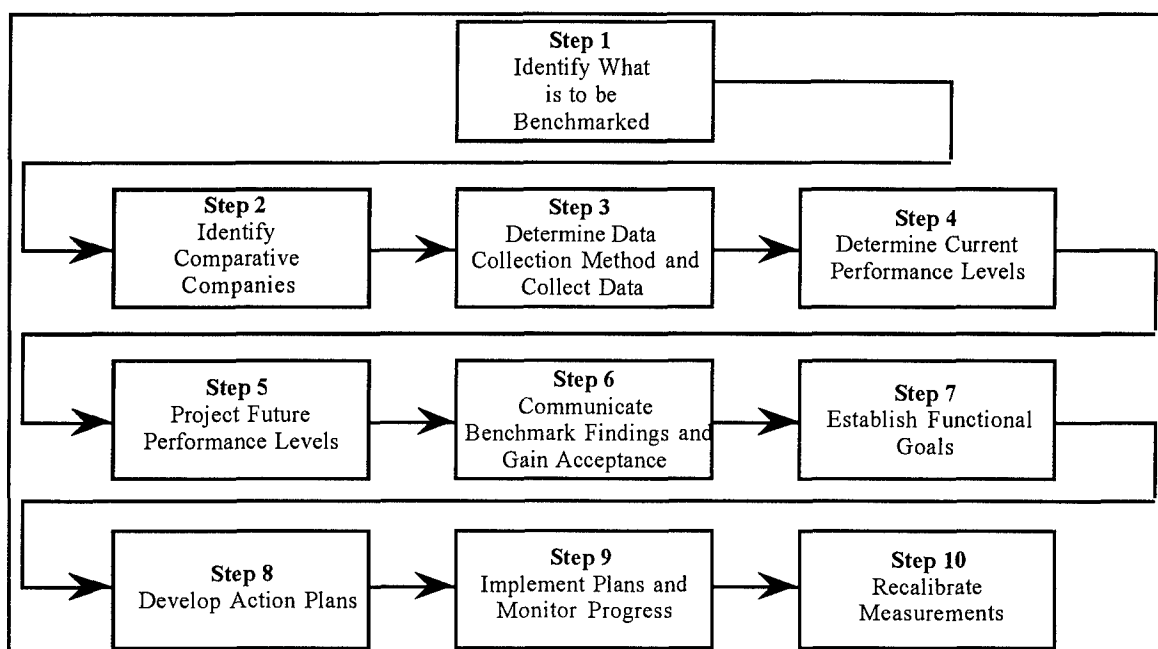
1.2 BENCHMARKING

Benchmarking, a term originally used by land surveyors to compare elevations, was pioneered in the U.S. business community by Xerox Corporation in the late 1970s. As introduced by Xerox, benchmarking is a process for finding the world-class standards for a product, service, or system and then adjusting one's own products, services, and systems to exceed those standards³. These world-class standards can be found by looking at competitors who are recognized leaders for the product, service, or system. Benchmarking done using competitors as models is called competitive or strategic

³A more formal definition is: a systematic and rigorous examination of your organization's product, service, or work processes measured against those of organizations recognized as the best, to produce changes and improvements in your enterprise. (Ettorre, Barbara, "Benchmarking: The Next Generation," *Management Review*, June 1993, pp 11-16)

benchmarking⁴. Operating units or functions within a company can also be used as the model; this approach is called internal benchmarking. Finally, benchmarking can be done using companies that are the best practitioners of a particular function, regardless of what industry the exemplar is in. This type of benchmarking is called functional benchmarking. Benchmarking is a method now commonly used by companies as part of their efforts to improve quality and is a necessary element for winning the Malcolm Baldrige National Quality Award (in 1991, benchmarking was added by the Baldrige organization as an element of the Information and Analysis examination category). The model used by Xerox for benchmarking is shown in Figure 1. A similar model is described in a book⁵ by Gregory H. Watson, a vice-president of Xerox.

Another form of benchmarking is called *normative benchmarking*. In normative benchmarking, a consultant collects data from a group of companies on a product, service, or process and delivers a set of statistics to the companies with the company names expunged. The effort described in this report includes elements of normative and functional benchmarking, and the project findings provide a reasonable understanding of the reliability practices used by commercial industry.



Source: Geber, Beverly, "Benchmarking: Measuring Yourself Against the Best," *Training*, Nov. 1990, pp. 36-44.

Figure 1: Xerox's Ten-Step Model for Benchmarking.

⁴Definitions of the types of benchmarking are taken from *Strategic Benchmarking* by Gregory H. Watson, John Wiley & Sons, NY, 1993.

⁵See *Strategic Benchmarking*, Gregory H. Watson, John Wiley and Sons, 1993, New York, NY.

1.3 ORGANIZATION OF REPORT

This report is organized into five chapters and six appendixes. Chapter 1, Introduction, provides background information and states the objective of the study. Chapter 2 is a discussion of the technical approach used in performing the study. Results of the study are described in Chapter 3. Conclusions and general recommendations are provided in Chapters 4 and 5, respectively. Appendix A is a discussion of Defense Acquisition Reform. Appendix B includes the detailed results of the literature search and the survey of companies. Appendix C contains an example of the forms used for the surveys. Appendix D contains the interview questions and a copy of the interview notes. All information from the surveys and interviews have been treated on a not-for-attribution basis as requested by the participating companies. The interview notes in Appendix D, Section 2, provide expurgated summaries of the interviews. Appendixes E and F are Terms and Definitions and a RAC Product Order Form, respectively.

2.0 TECHNICAL APPROACH

2.1 OVERVIEW

A four-step approach was used. First, a literature search was made to identify:

- any documented, current commercial reliability practices
- possible points of contact in the commercial world
- any previous, similar studies

Next, a survey was made of a broad cross-section of commercial companies representing seven industries. The survey was made to collect data on the reliability practices used by these companies to design and produce reliable, easily maintained products. As requested by the participants, the survey results were treated on a non-attribution basis. The survey approach approximated what is termed normative benchmarking. In normative benchmarking, a consultant collects data from a group of companies on a product, service, or process and then delivers a set of statistics to the companies with company names expunged.

The third step, interviewing selected companies, was conducted to obtain more detailed, in-depth information on the R&M practices identified in the survey.

Finally, the literature search and survey results were analyzed to:

- identify "best" reliability practices by product or system
- compare the commercial practices with those documented in DoD standards and handbooks

2.2 LITERATURE SEARCH

A search was made of the RAC library and through the Defense Technical Information Center (DTIC) and the International Benchmarking Clearinghouse⁶ (IBC). As previously stated, the search was conducted for three purposes.

- Determine if current commercial reliability practices are documented and, if so, to identify them
- Identify possible points of contact in the commercial world
- Determine if previous, similar studies had been made and, if so, identify the findings and recommendations

⁶A service of the American Productivity and Quality Center.

Searches were made of the RAC library and through DTIC and the IBC using the following keywords in conjunction with the keywords reliability and maintainability: benchmarking, best practices, commercial practices, and Total Quality Management (TQM). "Brute-force" searches were also made of the RAC library searching only on reliability, then R&M, and finally on TQM. These searches, as would be expected, resulted in hundreds of documents being identified; a manual review of the titles and abstracts was then made to identify documents pertinent to the study. Appendix B contains the results of the literature search.

2.3 SURVEYS

To gather information on the procedures being used by commercial industry to develop reliable and easily maintained products, over 100 companies representing seven different industries (based on the Standard Industrial Classification [SIC] codes⁷) were identified as candidates to participate in a survey. Based on calls made to points of contact (POCs) for these companies, companies were selected to participate in the survey.

2.3.1 Rationale for Surveys

Ideally, each of the candidate companies would have been visited. Face-to-face discussions and tours of facilities are the preferred method for gathering the type of information needed for this study. However, the companies covered a geographic area spanning the United States, from east to west and north to south. Budget and time constraints did not allow for on-site visits to all the companies. Also, it is sometimes difficult to convince a company to make time for a visit unless some previous relationship has been established and the visit is acknowledged to be of mutual value.

Mailed surveys are an inexpensive and relatively quick way of gathering such information. However, surveys have two disadvantages. First, the response to surveys is historically poor; often insufficient data are collected to support a meaningful evaluation. Second, the responses to a survey may not be complete, may be vague, or may be inappropriate due to misinterpreting a question. A means had to be found to capitalize on the advantages of a mailed survey while avoiding the pitfalls.

A five-step approach was adopted for effectively using a mailed survey.

- Call the POCs identified for all candidate companies. Confirm that POCs are the correct individuals to discuss their companies' reliability practices. If not, determine correct POCs.
- Solicit participation of POCs on behalf of their companies in the mailed survey effort. Explain the purpose of the project and resulting product. Mail

⁷The SIC codes are established and published in the Standard Industrial Classification Manual by the Executive Office of the President, Office of Management and Budget.

survey only to POCs "committing" to participate on behalf of their companies (i.e., qualify the company).

- Keep the survey form short and require least amount of writing by the person completing the form (the final form consisted of one page of introductory material and three pages with a total of ten questions)
- Develop questions not subject to broad interpretation that focus on the tasks (i.e., procedures) used to develop reliable, maintainable products.
- Make follow-up calls as needed based on responses to survey.

Determining the person (POC) for each company with whom to discuss reliability increased the probability of a receptive audience. Personally calling the person and discussing the objective of the project established a level of understanding. These precautions were taken to avoid the poor response normally associated with "blind mailings," to establish a relationship with the company, and to reduce the possible number of interpretations of the survey questions. Finally, follow-up calls allowed any questionable responses to be clarified.

2.3.2 Selection and Qualification of Companies

As was previously stated, seven key industries from which to select companies to participate in the study were identified. These industries, and their SIC codes are listed in Table 1. The industries identified cover a broad range of product types, product complexity (level of technology), and include both manufacturing and service companies.

After identifying the industries, companies within these industries were identified as candidates for the survey. In identifying the candidate companies, it was important to get a good cross section of products, not just by type of product but by level of complexity and rate of production. Most of the weapon systems procured by DoD are complex and produced in volumes that are low in comparison to production volumes for most commercial products. Even within the DoD, however, some systems or products that are procured are not overly complex and are bought in large numbers. So it was important that the products manufactured by the candidate companies represented a reasonably broad range of complexity and production volume. Also, it was important to identify some companies that do not manufacture products but are large "consumers" of products from other companies. These latter companies represent the service and communications industry listed in Table 1. In short, the range of manufacturing companies was to be representative of the range of defense companies, and some companies that are "comparable" to DoD (i.e., they purchase products that must be reliable and maintainable) had to be chosen. The complete set of criteria for identifying candidate companies is shown in Table 2. Only one criterion had to be met for a company to be identified as a candidate.

Table 1: Industries Identified for Study

Industry Title*	SIC Code(s)**	Examples of Products or Services
Measuring, Controlling & Medical Equipment	381-385 and 387	X-ray machines, MRI equipment, boiler controls, digital testers, flow meters, optical mirrors, thermometers
Transportation Equipment	371-379	Automobiles, buses, gasoline engines, motor vehicle parts, aircraft engines, ships
Electrical & Electronic	361-369	Transformers, dynamos, power regulators, microwave ovens, washers and dryers, light bulbs, telephone and telegraph equipment, television
Industrial Machinery & Equipment	351-356 358-359	Gas turbines, marine engines, farm elevators, mining equipment, elevators and escalators, conveyers, cranes, machine tools, linotype machines, ball and roller bearings
Computer and Office	357	Mini and micro computers, mainframes, PCs, disk drives, calculators, plotters, postage meters, and cash registers
Photographic Equipment	386	Cameras, diazotype equipment, photographic film, photocopy machines
Service & Communications	411, 451 481, and 491	Subway and light rail transport, air transportation, telephone service, electric utility service

*Abbreviated version.

**The Industry Group No. was used rather than the Major Group because the Major Groups are very broad. For example, Major Group 38 includes measuring, analyzing, and controlling instruments, photographic, medical, and optical groups; and watches and clocks.

Table 2: Criteria for Identifying Candidate Companies

- product is produced in low quantity and is very complex (e.g., magnetic resonance imaging machine), or
- product is produced in large quantity and is relatively simple in design or to manufacture (e.g., PCs), or
- product is produced in large quantity and is fairly complex in design or to manufacture (e.g., automobiles), or
- company purchases complex, expensive products (e.g., airlines, utility companies), or
- company is a Baldrige Award winner, or
- company has a reputation for or advertises high reliability, or
- company produces or uses products for which reliability is essential for safety (e.g., airlines, nuclear power plant, aircraft manufacturer), or
- company is a major buyer or integrator of systems for which reliability is important (e.g., system integrator)

Using the criteria listed in Table 2, sources such as the Thomas Register were used to identify about 15 companies within each industry⁸. A POC(s) was then identified for each of these companies. To do this, the Thomas Register, the literature search, the RAC's own knowledge base (i.e., previous work done for a company by the RAC or IITRI), and membership lists of technical and professional groups (e.g., the Society of

⁸Our goal was to identify a total of at least 105 companies evenly distributed across the seven industries, obtain the participation of 70 companies (70% of total), and to actually receive completed survey forms from 40 companies (60% of participants, 40% of total identified).

Automotive Engineers [SAE] G-11 Committee on Reliability, Maintainability, and Supportability) were used. In most cases, several possible POCs were identified for a company, and the "best" one could not be determined. In those cases, one with whom to begin was arbitrarily picked.

In summary, qualifying a company consisted of ensuring it met one of the criteria in Table 2, determining the "best" person in that company with whom to discuss the survey, and obtaining a "commitment" to participate in the survey. The "best person" was someone who worked in the area of reliability and was in a position that provided visibility into the company's overall reliability policy. A commitment was a statement by the POC that the survey form would be completed and returned within two weeks of receipt.

One lesson learned in calling POCs was that the process is time-consuming and requires a great deal of patience and persistence. More than 300 calls were needed to contact the right POC for each of the more than 100 candidate companies. Individuals were on travel, in meetings, or no longer with the company (even individuals who were with the company within the previous few months had left or had transferred to another division). In today's volatile economic environment, reorganizations and downsizing are becoming the norm; our efforts to contact individuals were hampered by this reality. In addition, at least one of the companies believed to be a manufacturing company had recently divested itself of all manufacturing and is now a systems integration firm. (Incidentally, this firm was included because it, like DoD, has the task of allocating system-level requirements to the subsystem level, contracting with suppliers to provide the subsystems, and then verifying that each subsystem meets the allocated requirements.) Finally, some companies declined to participate due to concerns for proprietary data⁹, due to the costs associated with the time to complete the survey, and simply because they were not interested.

2.3.3 Development of Survey Form

The survey form consisted of introductory material and a set of questions. Two versions of the form were developed: one for service firms and one for firms manufacturing products (copies of each are provided in Appendix C). The introductory material of the survey provides a common basis of understanding: the purpose of the project, purpose of the survey, and definition of reliability tasks. The questions were designed to determine:

- what reliability tasks are used
- when during the product life cycle the tasks are performed
- the relative importance and effectiveness of the reliability tasks
- the use of non-DoD reliability standards and handbooks

⁹We explained that information would be handled on a non-attribution basis and treated as proprietary. We also explained that such information would not be releasable under the Freedom of Information Act (another concern voiced by some). Finally, we offered to sign non-disclosure agreements. Despite these efforts, some individuals and companies declined to participate.

- the source of reliability task requirements (i.e., customer, company policy, government regulations, etc.)
- the nature of the product (i.e., type, production volume, unit cost, etc.)

2.4 INTERVIEWS

The third step was to interview a small number of companies (for practical and funding considerations, the number of companies to be interviewed was limited to 15) to obtain more detailed information on the reliability¹⁰ practices being used. Beginning in October 1993, the project team began contacting companies to schedule interviews. The companies targeted for interviews primarily consisted of those companies that participated in the mailed survey but also included a few that did not.

Companies were chosen using the same criteria used to select companies for the mailed survey. In addition, companies that had provided the most promising¹¹ responses to the survey were asked to participate in the interviews. These criteria helped to focus on those companies that, on the basis of their responses to the survey, appeared to have new procedures or unique applications of existing reliability procedures.

A set of interview questions was developed (see Appendix D). The questions were used as a guide and to ensure that a common set of questions was asked of each interviewee. However, the interviews were not restricted to only these questions or the order in which they were written; instead, the interviewers followed the lead of those being interviewed and allow the discussion to take its course. Two RAC staff members participated in each interview to ensure that a complete and accurate record of the interview was taken and to foster a more productive discussion. Two-hour interviews were scheduled at the convenience of the company and individual being interviewed. In some cases, an individual or company declined to be interviewed. Some of the reasons given for declining to be interviewed are the same as those given for not participating in the mailed survey: proprietary data, cost, and, simply, no interest. The names of the companies that participated in the interviews are listed in Table 3.

¹⁰Subsequent to the literature search and surveys, the project was rescoped to focus on reliability.

¹¹In other words, responses that indicated a new, possibly revolutionary R&M procedure not incorporated in DoD standards and handbooks, or a unique or highly successful application of an established procedure.

Table 3: List of Companies Interviewed

Company	Products Include
*AC Rochester Flint, MI	Engine management systems
Bell Helicopter Fort Worth, TX	Rotary-wing aircraft
*Boeing Commercial Airplane Group Renton, WA	Commercial aircraft
*Carrier Corp. Syracuse, NY	Commercial and industrial cooling systems
*Eastman Kodak Rochester, NY	Film, blood analyzers, photocopy machines
*ELDEC Corp. Lynnwood, WA	Power conversion, monitor and control, and aircraft sensing systems
General Motors Corp. Midsize Car Div. Warren, MI	Automobile platforms and components
Intermagetics General Corp. Guilderland, NY	Magnets for MRIs
Motorola Cellular Phone Libertyville, IL	Cellular phones
Ohmeda Columbia, MD	Incubators, Bili-blankets, infant warmers
*Sun Microsystems Computer Corp. Mountain View, CA	Microcomputers
*Participated in mailed survey	

3.0 RESULTS

3.1 LITERATURE SEARCH RESULTS

A total of 40 documents were identified and collected in support of this study. A complete list of the documents is provided in Appendix B, as are synopses of those documents most relevant to the study.

3.2 SURVEY RESULTS

Of the more than 300 POCs (representing over 100 candidate companies) contacted, 78 (representing 73 companies) agreed to participate. Of these, 40 provided responses. Edited versions of their responses¹² and a copy of the survey forms are included in Appendix B. Table 4 provides a summary of the companies interviewed and surveyed, in terms of the product markets, technologies, production volume, unit cost, and type of product. (The nature of new development was not revealed through the surveys but from the interviews.)

Table 4: Overview of Companies Surveyed and Interviewed

Criteria	Description for Companies Surveyed and Interviewed
Types of Products	Automobiles and automotive products, telephones and test equipment, heating and air conditioning equipment and systems, diesel engines, computer workstations, data communication products, aircraft fuel and speed controls, commercial and general aviation aircraft, diesel/electric locomotives, medical equipment
Nature of New Development	Predominately evolutionary in nature. Revolutionary changes or improvements in products are the exception. Proven design and technology characterizes most development.
Unit Cost	Ranges from less than \$100 per unit to several millions of dollars per unit
Production Volume	Ranges from a single unit per year (large, custom product) to millions of units per year
Technologies	Range from proven, off-the-shelf technologies to state-of-the-art technologies for material, processes, and functional design.
Markets	Include mass markets in the U.S.; world-wide markets; small, select customer markets; and all level of customers (i.e., industry, OEMs, general public, etc.)

The survey proved to be most useful in identifying specific tasks that are performed, when they are performed, why they are performed (i.e., required by customer or required by company), and which tasks are most important. Also, the surveys provided some insight into the guidance and regulatory documents used or imposed on commercial industries.

¹²Most responses were hand written. Editing was performed to correct spelling, delete the names of companies to treat the responses on a non-attribution basis, and to reflect clarifications obtained in follow-up calls. The edited versions were then typed to make them easier to read.

One question in the survey form asks for information on the reliability tasks being performed by the company: what tasks are performed, at what phase of the product's life they are performed, and what is the relative importance of each task. Another question asks if the company tries to determine the value of specific tasks. Although many respondents answered yes to the latter question, only one indicated a method that would allow the value of a specific task to be judged (the probable cost of failure and the task cost are compared).

Based on the responses to the questions dealing with tasks, the "most important" reliability tasks were identified in three ways. First, those tasks that were most frequently cited (i.e., what percent of respondents said the task was used) were identified. Second, those with the highest normalized scores (based on importance rating given by respondents) were identified. Finally, those tasks ranked 2 or 3 in importance by the respondents were given a positive rating; and those ranked 0 or 1 were given a negative rating. Table 5 and Figure 2 summarize the results of these three perspectives of importance (we also considered average rankings, tasks receiving highest percentage of a 3

Table 5: Most Important Reliability Tasks According to Survey

A. Most frequently cited tasks and when they are performed				
Rank	Task	% of Respondents Who Cite the Tasks*	When the Task is Performed**	
			Development	Production
1	FRACAS	97	51	65
2	Design Reviews	89	91	24
3	Predictions	89	91	12
4	FMECA	86	90	20
5	RQT	86	89	32
6	Sub/Vendor Control	84	70	76
7	Parts Control	84	63	72
8	ESS	78	66	55
9	Thermal Analysis	73	86	14
10	TAAF	73	90	50
B. Most important tasks based on normalized score				
Rank	Task	Normalized Score***		
1	FRACAS	88.3		
2	Design Reviews	83.8		
3	Sub/Vendor Control	72.1		
4	Parts Control	71.2		
5	FMECA	68.5		
6	RQT	70.3		
7	Predictions	62.2		
8	TAAF	59.5		
9	Thermal Analysis	58.6		
10	ESS	54.1		

*And who rate it as 1, 2, or 3 in importance (not all respondents rated importance)

**Percent of those citing the task

***Normalized score = $100\% \times (\Sigma \text{ importance entries}) / (\text{number of entries} \times 3)$.

ranking, and tasks receiving highest percentage of a 2 or 3 ranking in making an overall evaluation of importance). Note that although the task titles are those used by DoD, the task implementation within the commercial sector may be quite different from that in a military standard. Evidence of this difference was found during follow-up calls to survey participants and from interviews.

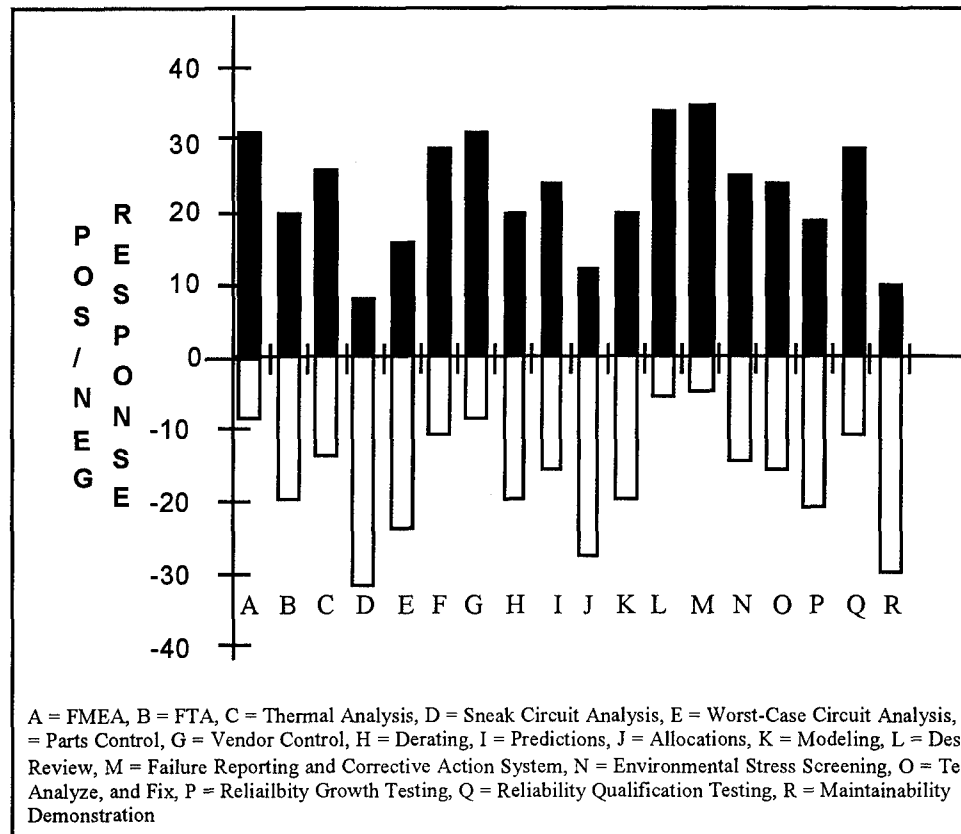


Figure 2: Relative importance of reliability tasks (number of respondents rating a task 2 or 3 [positive values] or 0 (no rating) or 1 [negative values])

Regulatory documents imposed or used by the respondents included Federal Communications Commission (FCC) and Department of Transportation (DOT) regulations, American Society of Mechanical Engineers (ASME) specifications, Occupational Safety and Health Administration (OSHA) regulations, Environmental Protection Agency (EPA) emissions standards, DoD and U.S. Military Specifications and standards, Underwriters Laboratory (UL) requirements, and Canadian Standards Association (CSA) and International Standards Organization (ISO) standards. Documents used to define procedures for Reliability tasks include MIL-HDBK-217, Bellcore TR-NWT-00332, National Aeronautics and Space Administration (NASA)-STD-978, MIL-STD-2155, Nuclear Regulatory (NUREG) Fault Tree Analysis (FTA) and Computer-aided FTA (CAFTA), MIL-STD-1629, Federal Aviation Administration (FAA) Circular 120-17A, MIL-STD-883, and Association for the Advancement of Medical Instrumentation (AAMI) STD for Pacemakers.

Additional insight into the meaning and limitations of the survey responses, especially in evaluating specific tasks, was gained from the interviews that were conducted.

3.3 INTERVIEW RESULTS

Complete notes were taken during each interview. In Appendix D, Section 2, are summaries of all interviews¹³. One insight gained from the interviews that was not available from the survey was the nature of product development. In general, the products built by the companies are evolutionary, rather than revolutionary in nature. Although new technologies are found in many of these products, each successive product is an improvement or advancement of its predecessor. Even the new technologies tend to be adopted from other, more risky segments of industry (e.g., the defense industry and basic R&D organizations). Also, a product is not pushed to market before extensive testing is done and the design and risks are well-understood.

An analysis of the interviews showed that the information provided in the surveys must be viewed with some reservations for three reasons.

1. It was found that although certain reliability tasks might have been cited in the survey as being important, the company is not performing the tasks as part of the product development efforts. In other words, a survey response that a task is performed actually could mean "I (the respondent) think it is important."
2. Closely related to the previous point is many of those interviewed indicated that their responses represent their company's vision for the future; some of this vision may not yet be implemented. Consequently, some stated "best practices" are either not fully implemented or are immature and the tasks identified in the survey as important may not yet be in use.
3. Information from the interviews contradicts information from the surveys. For example, qualification testing received a normalized score of 70.3 based on the survey responses. Yet, in the interviews, even those of survey respondents, qualification testing was generally criticized as being of no value. It is most probable that the survey questions were not accurately stated, the possible responses were too limited, or survey respondents were then defining the tasks differently (despite the fact that definitions were included with the survey forms).

The remaining discussion of the findings from the interviews will be covered in the following manner. First, an overall discussion of the interview findings is provided. This overall discussion is then broken out by general and specific findings. A series of general findings is provided, followed by the specific findings presented in the format that follows.

¹³In accordance with the wishes of the participants, only expurgated summaries are provided. In this way, specific comments or views can not be associated with the contributor.

Approach: [The composite approach, or philosophy, articulated by the companies.]

Implementation: [The way the companies apply the approach or philosophy.]

3.4 OVERALL DISCUSSION

Those interviewed agreed on several basic points regarding developing and producing a reliable product. First, concurrent engineering, also referred to in terms such as "the product development team concept," is essential to being competitive. Product teams promote a feeling of "ownership" by all involved in the analyses, assumptions, and compromises made during the development process. Concurrent engineering requires that modern development tools, such as CAD/CAM, be available. reliability analyses tools must be a part of the CAD/CAM system so that the reliability engineer can interact with the development team in real-time. Analyses done "off-line" by a traditional, separate reliability office typically are completed too late to affect the design. (Figure 3 illustrates the extent to which CAD/CAM is being implemented by some companies.) Unfortunately, many of those interviewed admitted that reliability analyses are not yet fully integrated into their CAD/CAM systems.

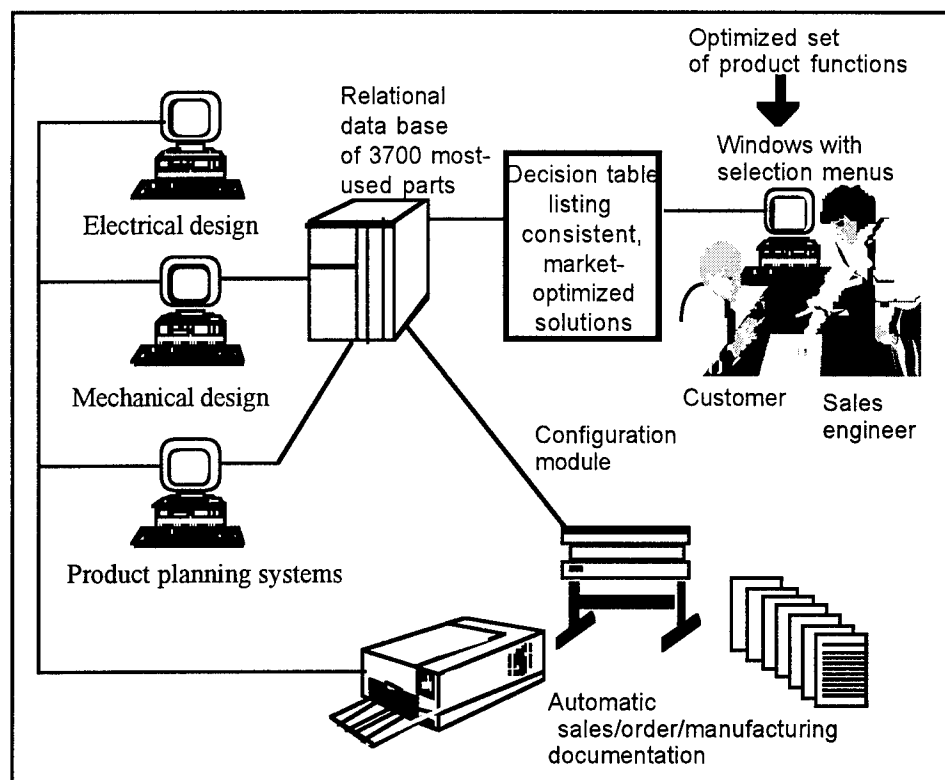


Figure 3: CAD/CAM facilitates customer focus.

A second basic point subscribed to by all those interviewed is the need to understand the physics of failure¹⁴. Thoroughly understanding the design is essential not only to

¹⁴They did not suggest that physics of failure be a substitute for predictions; only that it be a means for understanding the design.

reliability but to the entire range of performance and "ility" characteristics. In trying to understand the design, however, it was indicated that the limitations of deterministic design have been the source of problems in the past. Probabilistic methods are necessary to account for unknowns and as a means of developing a robust design. A "dynamic tension" between the engineer (deterministic) and statistician (probabilistic) was described as a desirable state of affairs. It was also pointed out that modern systems and components often have reliability requirements that cannot be measured in any practical way using currently available techniques. Bayesian statistical methods and accelerated testing were methods mentioned for this purpose.

Another commonly held view is that the reliability of the product is no more important than the reliability of the processes. Although the subject of process reliability (including the reliability of the tools and manufacturing equipment) is new to the companies interviewed, all recognize its importance.

Third, the interviewees agreed on the importance of strong supplier relationships¹⁵. Those interviewed indicated that whatever requirements were imposed within their companies¹⁶ are imposed on their suppliers. A stable group of suppliers is part of commercial industry's method of reducing risk and is consistent with a focus on using proven designs.

Fourth, customers are not deeply involved in the design and development process and, in general, they do not wish to be. Customers, in some cases, may be asked to participate in one or more design reviews. Such participation is almost always at the initiation of the product developer who want to ensure that the voice of the customer has been heard and properly understood. Customers demand good products and depend on competition and market pressures to incentivize the contractor to make the "best effort" in developing the product. When service problems arise, successful contractors work with the customer to resolve the problem as quickly as possible. However, after-sales problems can reduce a company's profit, so considerable emphasis is placed on up-front, concurrent engineering.

Finally, it is clear that those interviewed find little fault in the technical content of military specifications, handbooks, and standards. They suggested that the technical information, such as recommended temperature dwell and cycle times during temperature cycling tests, in these documents is of value.

Table 6 lists anecdotal comments from the interviews that provides additional insight into the commercial perspectives on reliability. In some cases, comments have been paraphrased for the sake of clarity and brevity.

¹⁵A further indication of commercial industry's emphasis on supplier quality was reported in the January 1994 issue of Quality Progress. According to the article, Chrysler, Ford, and General Motors have merged their standards for supplier quality systems, as have major manufacturers (e.g., Navistar, International, and Freightliner) of trucks. In so doing, the two industries have established a quality system standard for suppliers covering the entire domestic automotive industry.

¹⁶The scope of tasks and requirements required by company policy varies greatly among the companies. Some have no mandates; the product managers are free to use any or no tasks, and no quantitative requirements are developed. Others mandate some basic, general requirements (i.e., no single-point safety failures) but still vest most of the authority and decision-making in the product managers. To "encourage" decisions that take long-term effects into consideration, the product managers usually have life-cycle responsibility for their products. In one case, the product manager must budget for warranty costs and is held responsible for in-service performance.

Table 6. Anecdotal Comments

A failure is any incident that sends the customer back to the dealer for repairs.

Most critical challenge is converting the voice of the customer into a product specification (i.e., quality function deployment).

CAD/CAM is a tool for translating art to part.

The quality of warranty data is suspect. Such data must be supplemented with controlled testing and data collection efforts, and sensitivity analyses used to determine the "critical few" problems.

Reliability is the engineering discipline with the greatest potential for affecting product life cycle cost.

Military specifications and standards, if used blindly with no regard for their applicability or value-added (i.e., no tailoring or applied too late to influence the design), can drive up costs with no positive affect on reliability.

The military standards, in many cases, form the basis for commercial reliability practices. Their limitations are out-of-date information (i.e., not kept up-to-date) and limited applicability of data (i.e., MIL-HDBK-217). For these reasons, many companies revise or modify the standards for their use or develop their own standards using the military standards as a model.

Administration of MIL-SPECs/STDs/HDBKs, without tailoring, can impose documentary and proof burdens not relevant to the close supplier-contractor partnerships seen in commercial business.

In commercial business, the contracting community clearly plays a support role to the technical community.

Authority for decisions that have long-term implications must be balanced by responsibility for those implications.

An effective product design effort does not compartmentalize reliability and remove it from the mainstream design effort.

Demonstration testing (i.e., MIL-STD-781 tests), is an after-the-fact activity that adds little value; it should be done only if required by the customer. Development testing (e.g., growth testing, fatigue testing, proof testing, etc.) should be the focus of the testing community.

High reliability and compressed development schedules can coexist. Compressed schedules force the development and use of tools and methods that allow a better understanding of the design, an understanding that results in higher reliability.

Customers must recognize the need for trust and partnership between themselves and their contractors. Contractors are incentivized by emphasizing and nurturing capital enterprise.

Whenever bureaucracy and administrative burdens are imposed on a product development, the design and manufacturing processes suffer, costs increase, and competitiveness wanes.

The most structured and cohesive approach to reliability is that used by the military.
However, the approach used by commercial industry is more economical and about as effective.

3.5 GENERAL FINDINGS

3.5.1 The Environment

- a. Companies are changing many of their processes to incorporate robust design, concurrent engineering, and other concepts to improve their products and be more competitive. Through these changes, reliability is being made an integral part of design, rather than an “add-on.”
- b. Companies are adopting a total quality management approach to design and production. Quality and reliability are intimately related in the minds of those interviewed. Indeed, many companies have one manager in charge of both areas. Basically, quality is considered the more general term, describing the degree to which the product satisfies the customer’s needs and expectations. Reliability is just one characteristic that determines overall quality.
- c. Many of those interviewed indicated that their responses represent their company's vision for the future; some of this vision may not yet be implemented. Consequently, some stated “best practices” are either not fully implemented or are immature.
- d. The extent to which customers are involved in the design and development process varies but is basically “hands off”. Customers do not usually require specific reliability tasks and analysis and often do not explicitly state a reliability requirement; when they do, the requirement is stated in functional and general terms. These functional customer requirements are most analogous to the ideal “user needs” discussed in DoD Directive 5000.1. The commercial contractor has a great deal of flexibility in determining the design parameters (type and magnitude). Seldom, if ever, is the customer aware of the contractor's procedures, use of concurrent engineering, or development testing program. The customer is only interested in the results. The only “proof” demanded by the customer is the product’s reliability in actual use.
- e. Genuinely “custom” products are the exception. Customizing a product for a customer usually involves “bundling” different options or components to meet a specific customer’s needs. Genuinely custom, one-of-a-kind products present a higher risk to achieving high reliability; however, the approach of using product design teams, development testing, and proven designs still applies.

3.5.2 The Practices

- a. In most cases, commercial companies see no value in reliability demonstration tests, of which qualification testing is one type. First, such tests come much too late to make cost-effective design changes. Second, the very high reliability demanded of, and achieved in, modern designs cannot be demonstrated with any reasonable degree of statistical confidence. Finally, these tests are considered accounting tests (as they are called in MIL-STD-781), meant only to determine compliance. In contrast, development testing, intended to confirm the soundness of design, receives great attention. Development testing, analytical methods, and accelerated life testing techniques replace demonstrations and qualification tests in the commercial world.
- b. Although the design of products by most of the companies interviewed is evolutionary in nature, some designs incorporate new technologies or otherwise reflect more of a revolutionary nature. Between the evolutionary and revolutionary designs, the most frequently stated difference in the technical approach was the amount of development testing conducted. Whenever risk is higher, as is the case with new technologies and unproved designs, commercial companies invest more time and resources into testing. In addition, more detailed and extensive analyses, such as a Failure Modes and Effects Analysis (FMEA), will be conducted.
- c. Commercial companies specify the environmental conditions for their products. In doing so, and for many other reliability activities, those interviewed use military standards, although the standards are often revised or modified. They find little fault in the technical content of military specifications, handbooks, and standards. (However, it was stated that in many documents the data are not current and not always applicable. In the case of MIL-HDBK-217, for example, some commercial companies have developed their own failure rate data.) They suggested that the technical information, such as recommended temperature dwell and cycle times during temperature cycling tests, in these documents is not duplicated elsewhere.
- d. Only DoD is doing and funding the research needed to develop technical information included in military standards and making that information available to industry¹⁷. If and when commercial companies perform such research, the results are usually proprietary. So it is not the technical aspect of the military documents that is at fault. The fault is found in the enforcement and administrative aspects that have no value in the commercial world. When a document is invoked on a defense contract, it is the lack of

¹⁷At the time this study was being conducted, a cooperative effort among the industrial societies was being proposed by the Society of Automotive Engineers. Under this proposed effort, the various societies and representatives of industry, academia, and government would work together to develop "world-class" reliability, maintainability, and supportability standards for industry. These industry standards could be cited in military procurements.

tailoring, administration, and requirement for extensive documentation that those interviewed believe adds no value. All cautioned against "throwing out" the military specifications, standards, and handbooks.

3.6 SPECIFIC FINDINGS

First the composite approach, or philosophy, articulated by the companies is given. Then, the manner in which the companies apply the approach or philosophy is described.

1. Approach: Thoroughly understanding the design is essential not only to reliability but to the entire range of performance and "ility" characteristics.

Application: Extensive emphasis is placed on development testing to characterize failures mechanisms, validate models and analyses, and verify design concepts. FMEA, physics of failure, and other analyses are used to identify critical areas. Design and test efforts focus on these critical areas. In addition, all the companies interviewed make some attempt to collect and analyze failure data. For fielded products, these data are collected usually as part of the warranty program. Based on the results of analyzing failure data, the design (including parts selection and application), test procedures, or manufacturing processes may be changed. This process is equivalent to the failure reporting and corrective action system (FRACAS) usually imposed under MIL-STD-785.

2. Approach: The value of testing is in confirming the design and engineering approach, not in showing compliance. Customers almost never ask for demonstration tests; however, acceptance tests, especially for high-value, build-to-order systems are sometimes required by the customer. Customers demand good products and depend on competition and market pressures to incentivize the contractor to make the "best effort" in developing the product. When service problems arise, successful contractors work with the customer to resolve the problem as quickly as possible. However, after-sales problems can reduce a company's profit, so considerable emphasis is placed on up-front, concurrent engineering.

Application: Demonstration testing (also called qualification testing) is not done, unless required by the customer (seldom) or by a government regulation (occasionally). Development, accelerated, and other engineering tests are planned to characterize failure mechanisms; address risk areas; address areas of new technology or technology application; and confirm the design, engineering models, and analyses results.

3. Approach: Deterministic design has limitations that have been the source of problems in the past. Probabilistic methods are needed to account for unknowns and as a means of developing a robust design. The high reliability being demanded of and achieved in modern designs cannot be cost-effectively

demonstrated or measured with any reasonable degree of statistical confidence. Simulation and modeling play an increasingly important role in compressing the time schedule for the development and characterization of new designs.

Application: Accelerated testing techniques (generally at the card- and box-level), the use of Bayesian statistical methods, and other analytical methods are used extensively to supplement deterministic design. These techniques and methods were singled out as needing additional study and research.

4. Approach: Concurrent engineering, also referred to in other terms such as "the product development team concept," is considered by commercial companies as essential to being competitive. Concurrent engineering reflects a true system approach that must be implemented from the beginning of the product development process. It provides the means to integrate the various and sometimes competing aspects of a product, such as cost, producibility, reliability, and other performance requirements. In the specific case of reliability, analyses done "off-line" by a traditional, separate reliability office typically are completed too late to affect the design and are, therefore, useless. Businesses generally recognize that market success and profitability both depend on ever-shorter product development cycle times. Consequently, a development approach with no concurrency is increasingly non-competitive in today's business environment.

Application: Product teams, which have authority and a great deal of autonomy (sometimes called empowerment) promote a feeling of "ownership" by all concerned in the analyses, assumptions, and compromises made during the development process. Design, reliability, quality, producibility, risk, safety, and other issues are all considered concurrently to meet aggressive development cycle times. A member of the team has the primary task of designing for reliability, but reliability is a team objective and the responsibility rests with the team leader. This member may be called a reliability engineer, product assurance engineer, or design engineer. Ideally, R&M analyses, and the necessary tools, are made a part of the CAD/CAM system so that the "reliability engineer" interacts with the development team in real-time. Unfortunately, those interviewed acknowledged that many of the reliability analyses are still done "off-line."

5. Approach: Designing for reliability must include the reliability of the processes as well as the product. Although the subject of process reliability (including the reliability of the tools and manufacturing equipment) is new to the companies interviewed, all recognize its importance. Those interviewed stated that the traditional partition between design and manufacturing is detrimental to product performance and quality.

Application: Concurrent engineering (see specific finding 4) is helping to raze the design-manufacturing partition and helping both design and manufacturing

engineers better understand the impact product design and manufacturing have on each other and the product. Design of experiments (DOE) is one technique specifically mentioned as an excellent tool for identifying the key factors influencing manufacturing quality and reliability, as well as the reliability and performance of the product.

6. Approach: All reliability tasks, even those cited (in the survey) as being "very important", are tailored for or deleted from a specific product development program based on program needs. A cost-benefit **judgment** is made before a task or other requirement is invoked. Each invoked reliability task is tailored so that it best mitigates a specific risk(s). Conversely, if a known risk is not mitigated, the reliability task has no value.

Application: Commercial companies emphasize design objectives (such as no single-point failures) and tailor the use of only those tasks best suited to achieving that objective. Commercial customers seldom, if ever, impose specific reliability tasks. No specific means of evaluating the benefits (or risks) of a given task were evident from our survey or interviews. It is a matter of engineering judgment and experience. The decision to use or delete tasks is made by the project manager. The manager's authority is balanced by accountability for development, the reliability of the resulting product, and, in many instances, warranty costs.

7. Approach: Even for tasks included in documents such as MIL-STD-785, Reliability Program for Systems and Equipment Development and Production, very little, if any, administration, documentation, or burden of proof usually associated with the standards is allowed.

Application: Customers are neither given nor expect extensive documentation (other than operating and maintenance manuals). Technical information, such as the content of MIL-STDs and HDBKs, is used for guidance and "lessons learned" but is usually not imposed on design teams by company policy and almost never by the customer. This frees the commercial contractor from the "burden of proof" or administrative burdens associated with these documents.

8. Approach: Reliability tasks must not become ends in and of themselves; the focus must be on the end product and the needs of the customer.

Application: The contractor takes the initiative to ask customers to participate in one or more design reviews. Such participation is intended to ensure that the voice of the customer has been heard and properly understood. Contractors focus on the end objective, the "user needs," and select those tasks that most effectively contribute to those objectives. Tasks are tailored and applied (or not applied) in accordance with the needs of the specific product.

9. Approach: Parts application is critical. The objective is to select the part most appropriate for the design and stress levels.

Application: None of the companies interviewed require the use of parts having a certain quality level (i.e., a MIL-SPEC part). As was stated by several individuals, a MIL-SPEC part misapplied is a part that will fail. That is not to say that MIL-SPEC parts are not used by commercial industry. It means that the emphasis is on the design engineer understanding the design and stress levels and then selecting appropriate parts. Robust designs, in which relatively large shifts in a part's characteristics do not affect system performance and stress levels are kept low, make it possible to select parts that might otherwise be excluded from consideration.

10. Approach: Strong supplier relationships are essential. In general, the objective is to establish long-term relationships, referred to by most as partnerships, characterized by common objectives and trust.

Application: All the companies interviewed have a program for reducing the number of suppliers and for certifying those suppliers. In most cases, certification allows incoming inspections of supplier-provided components to be eliminated or reduced (e.g., from 100% to periodic sampling). Those interviewed also indicated that the same requirements imposed within their companies are imposed on suppliers. Economic penalties for delivering poor product are sufficient to keep everyone honest. Suppliers are not just judged on the unit costs of piece parts but also on the overall life cycle cost (LCC). Included in this LCC are purchase price; cost of inspection, rejected parts, field failures, and non-conforming parts; and customer dissatisfaction. Most companies have reduced or are reducing the number of their suppliers but try to keep two for each critical item.

4.0 CONCLUSIONS

4.1 THE PRACTICES

4.1.1 Reliability Tasks

Based on the survey and interview data, the tasks (or groups of tasks) considered to be the most effective in designing for reliability and offering the most value-added are:

- Predictions, simulation, and modeling
- Design reviews
- Subcontractor/vendor control
- Failure reporting and corrective action system (includes failure analysis)
- Development testing, such as test, analyze, and fix (TAAF)
- FMEA and other related analyses
- Design of Experiments (DOE)
- Parts control

DOE is a task identified through the survey and interviews that is not normally associated with reliability. It is an excellent tool for identifying the key factors influencing reliability, performance, or manufacturing quality.

Commercial industry emphasizes the objective of doing a reliability task, such as determine feasibility, and uses all applicable tools to achieve that objective. Although the survey and interview participants cited tasks that also happen to be included in MIL-STD-785, their emphasis is not on performing a task, completing the documentation, and complying with a contractual requirement but rather on objectives. **For that reason, it is more important to look at the objectives of commercial reliability practices than at specific tasks.** Consider the tasks listed previously. As shown in Table 7, these and other tasks can be grouped by an R&M objective based on the more detailed information gleaned from the interviews.

Table 7: Reliability Tasks Grouped by Objective

Objective	Tasks that Contribute to Objective
Determine feasibility	Predictions, simulation, modeling
Understand the design and environment (eliminate single-point failures, identify key design parameters, understand failure mechanisms, apply parts correctly)	Design reviews, FMEA, FRACAS, DOE, development testing, Worst Case Analyses, Thermal Analysis, derating
Use proper parts	Parts control, failure analysis
Address all sources of components, materials, etc.	Vendor/supplier control
Validate the design	Development testing

4.1.2 Approach to Achieving Reliability

Making reliability a design consideration from the start of the design process (i.e., an up-front design approach) is essential to achieving a reliable product. Concurrent engineering, product design teams, and a systems approach are concepts that support this belief in up-front design. All are at least part of the vision of the companies surveyed/interviewed, if not already fully implemented. Consequently, reliability must be an integral part of the up-front design and cannot be treated as a separate effort. Compartmentalizing, or stove piping, causes duplicative effort, stifles information exchange, and is inefficient. Centralizing some reliability functions, such as training and the development of tools and policy is acceptable. But implementation of reliability engineering must be decentralized and must be the responsibility of product design teams.

4.2 THE CONTRACTING ENVIRONMENT

As important as the technical aspects (i.e., specific tasks, the engineering approach, etc.) of commercial reliability may be, the contracting environment is equally if not more important. The contracting environment in the commercial sector is characterized in Table 8. Briefly stated, the environment is such that customers can state their operational needs, and the contractors can determine how to meet that need. **In other words, customers tell the contractor what is needed but not how to do it.** The financial rewards for success, competitive environment, and liability laws adequately motivate manufacturers to keep the customer happy. These same factors provide adequate remedies for the customer should a manufacturer fail; that is, the customer can seek compensation through the courts in extreme cases or simply buy from a competitor.

Table 8: Characterizing the Commercial Sector Contracting Environment

Customer/contractor relationship	Trust and partnership with prompt and direct remedies for failure
Decision process	Few decision-makers, minimal oversight
Contractor/suppliers relationship	Long-term, partnership
Economics	Value, fitness for use emphasized
Risk/Payoff	High (only end results specified)
Customer Requirements	Functional, guidelines
Documentation	Limited to essential needed for design or liability and operating and support manuals
Customer focus	Interested in product performance only
Contractor focus	Primary focus on meeting customer needs and being competitive
Penalties	Non-payment, loss of business/markets

Finally, the individuals who were interviewed are aware of the efforts within the Department of Defense to streamline acquisition and of the Congressional pressures to adopt commercial practices. Based on the comments of those interviewed, one must

conclude that commercial industry has found that the technical content of the military specifications and standards is very useful and have based much of their practice on these documents. Neither the commercial nor the defense sector has the definitive answer to how to design reliable, maintainable products. At a technical level, the two sectors can learn much and profit from each other. However, until and unless Federal laws and regulations regarding acquisition and procurement are changed to provide a contracting environment that more closely resembles that of the commercial sector, it is doubtful that the defense industry will be able to apply the technical knowledge in the way commercial industry does.

4.3 THE BENCHMARKS

Three major benchmarks of reliability practice were identified from the study that reflect those elements of a commercial approach to reliability most universally implemented or deemed important.

Completely analyze all failures, regardless of when or where they occur in development, to identify the root cause of failure and determine the necessary corrective action, including redesign and revision of analytical tools and models.

Avoid dedicated reliability demonstration testing. If required, demonstrations should focus on new components or assemblies, or the integration of old items in a new way. Emphasize engineering development testing to understand the and validate the design process and models. Accelerated testing should be used to age high reliability items and to identify their failure mechanisms.

Assign responsibility for reliability to an Integrated Product Team (also referred to as a Product Development Team). Give the team the authority to determine the reliability requirements and to select the design, analysis, test, and manufacturing activities needed to achieve that reliability

4.4 OTHER KEYS TO SUCCESS

In addition to the benchmarks just listed, eight design and manufacturing (Mfg.) "keys to success" were derived from the study results. These keys are not absolutes (i.e., exceptions to each to accommodate customer or government requirements were evident in the companies interviewed) but do represent a preferred way of doing business. These keys are described on the following page.

DESIGN KEYS	Use an evolutionary approach to new product development. If a new technology or unproved design must be considered, invest additional time and resources into failure analysis and development testing.
----------------	---

Emphasize design objectives (such as no single-point failures) and tailor the use of only those reliability tasks best suited to achieving that objective. Do not allow reliability tasks to become ends in and of themselves.

Apply parts properly (rather than emphasizing the quality level of the part).

Integrate reliability analyses and modeling tools in computer-based design and manufacturing (CAD/CAM) systems as part of a concurrent engineering approach.

Use standards for guidance and “lessons learned” but do not impose them on design teams. Do not burden the use of standards with administrative requirements.

Use design reviews to obtain an “independent” peer assessment of the design.

**MFG.
KEYS**

Develop and foster strong, long-term relationships with a small number of suppliers to ensure consistent, high quality of products, keeping at least two suppliers for each critical item.

Recognize that reliability is impacted by the manufacturing processes as well as the design process and include manufacturing on the product design team.

5.0 AREAS REQUIRING ADDITIONAL RESEARCH

Based on the findings of this study, the following areas of additional research are recommended:

- DoD continue to support research needed to develop and update reliability tools, techniques, procedures, etc. The results of such research should continue to be made available to industry either in the form of military documents or as information that can be incorporated in commercial standards.
- DoD work with industry and professional associations to conduct the research needed to develop reliability standards usable in both commercial and military acquisitions. All such standards, including military standards on reliability that are retained, should be applied only as general guidelines in future solicitations to encourage innovative proposals by those responding.

Research should also be conducted to:

- **Develop one or more “model” R&M programs** that manage buyer risks, ensure a reliable product, allow for appropriate milestones, minimize use of military standards, and are an integral part of the design process. These model programs, which would be coordinated with industry and government experts, will be suitable for inclusion in RFPs. The models would include:
 - cost-effective procedural and tailoring guidelines for the key R&M tasks.
 - guidelines that promote innovative proposals
 - performance-oriented R&M requirements.
 - methods for evaluating proposals (discontinuation of a forced common baseline, using a MIL-STD, for example, will make comparison of competing proposals potentially more difficult - this will be a major issue in adopting a commercial approach to contracting).
- **Evaluate existing R&M MIL-STDs, HDBKs and other documents.** This evaluation should:
 - identify alternative industry documents or develop alternative approaches that address the risks and issues the government documents were intended to address.
 - identify those government documents having no commercial counterpart and which should be continued; for those, develop recommendations for revising.

- result in efforts to develop, through professional and industry associations, non-government standards in the areas of reliability where none now exist.
- **Determine the feasibility and value of developing a means of evaluating or measuring the effectiveness** of R&M tasks given independent variables such as risk, level of complexity and required reliability, criticality of product function, etc.
- **Evaluate specific reliability tools** or types of tools to identify those having best value-added.
- **Determine the level to which reliability software tools have been integrated** into CAD/CAM systems and the steps needed to improve the degree of integration.

The results of the last three research efforts would be used in developing model programs, developing guidelines for evaluating proposals, and so forth.

APPENDIX A

DEFENSE ACQUISITION REFORM

DEFENSE ACQUISITION REFORM

THE IMPETUS FOR REFORM

Since taking his position as Secretary of Defense, William J. Perry has taken several bold actions to streamline and improve the way in which the Department of Defense (DoD) does business. These actions are part of what is called Defense Acquisition Reform (DAR). DAR is a response, in part, to the continuing downsizing of the DoD and the Military Services and, in part, to recommendations of the Vice President's National Performance Review. In a news conference on June 29, 1994, the Secretary stated:

More than 100 years ago Victor Hugo said that more powerful than the tread of mighty armies is an idea whose time is come, and integrating the defense industrial base into the national industrial base is an idea whose time has come. The Defense Department cannot afford the extra costs associated with keeping its industrial base isolated from the national base, . . . the Defense Department has to basically and fundamentally change the way it does its procurement. We have to buy more commercial products, we have to make greater use of commercial buying practices, and we have to use industrial standards in place of military specifications.

THE USE OF PROCESS ACTION TEAMS

To develop his approach for changing the DoD's business practices, Secretary Perry is using Process Action Team (PAT), made up of high-level government and business leaders, and chartered at the Deputy Under Secretary level. These PATs are examining key areas, such as procurement laws and practices and the system of specifications and standards, developing recommendations, and submitting a final report to the Secretary for his review and approval.

SPECIFICATIONS AND STANDARDS PAT

The first such PAT was chartered by Colleen Preston, Deputy Under Secretary for Acquisition Reform, and chaired by Darold Griffin, former principal deputy of acquisition in the Army Materiel Command. The PAT was tasked to review the system of military specifications and standards. Specifically, it was told to develop recommendations to:

- eliminate unnecessary and obsolete specifications and standards
- use performance specifications and standards
- use commercial standards and specifications to the greatest extent practicable
- encourage industry to propose alternative solutions to military specifications and standards
- and reduce paperwork

Specific recommendations were made by the PAT in a final report¹⁸ submitted to Secretary Perry. The Secretary essentially accepted the recommendations as submitted, and, in a five-page memorandum "Specifications & Standards - A New Way of Doing Business" issued June 29, 1995, directed they be implemented. A five-page memorandum is rarely signed by a cabinet-level Secretary and that, if for no other reason, quickly got the attention of the press and of executives, managers, and technical personnel in the military services and military industries. Another indication of the importance attached to the memorandum is the fact that the previously mentioned news conference was held for the express purpose of announcing the issuance of the memorandum.

The intent of Perry's memorandum can be summarized as three "overarching" objectives:

- Establish a performance-oriented solicitation process
- Implement a document improvement process
- Create irreversible cultural change in the way DoD does business

As the memorandum states, military specifications and standards may not be used for purchasing new systems, major modifications, upgrades to current systems, and non-developmental and commercial items. Instead, the purchasing agency must use performance specifications. If it is not practicable to use a performance specification, then a non-government standard shall be used. If it necessary to define an exact design solution because no acceptable non-government standard exists or because the use of a performance specification or non-government standard is not cost effective, the use of military specifications and standards is authorized as a last resort **with an approved waiver**. (Note: contractors are free to propose the use of any military document without the need for a waiver.) Clearly, the intent is to avoid using military specifications and standards, at least those that are not performance-based, and use commercial specifications and standards.

PERFORMANCE-BASED REQUIREMENTS

The June 29, 1994 memorandum requires that requirements be performance-based. That is, the requirements should describe how a product should function, the environment in which it must operate, and interface and interchangeability characteristics; they should *not* specify how the product should be designed or manufactured - that should be left to the supplier. Table 1 compares performance- and non-performance-based requirements. Four types of performance-based specifications have been identified by the Defense Standards Improvement Council. These types are:

- commercial item descriptions - describe requirements in terms of function, performance, and essential form and fit requirements

¹⁸*Blueprint for Change*, April 1994. Changes were recommended in six categories: Policy Issuance and Changes, Document Improvement, Training, Automation, Pollution Prevention, and Miscellaneous Acquisition Reform Initiatives. An implementation plan based on the report was issued June 23, 1994.

- guide specifications - standardize functional or performance requirements that are common for systems, subsystems, equipments, and assemblies
- standard performance specifications
- program-peculiar performance specifications

**Table 1: Comparing Performance-Based
and Non-Performance-Based Requirements**

Area of Comparison	Performance-Based Requirement	Non-Performance-Based Requirement
Purpose	Describes functions product is to perform	Describes how product is to be designed and manufactured
Key criteria	Describe means for verifying performance	Describe means of ensuring specified processes followed
Design latitude given to contractor	Allows the contractor to determine best way to achieve results	Forces the contractor to use prescribed methods and approaches
Responsibility	Responsibility for results clearly belongs to the contractor	Responsibility for results shared by customer and supplier

WAIVERS AND TIERING

Two important prohibitions regarding the use of specifications and standards are included in the new policy promulgated by the June 29, 1994 memorandum. First, a military specification or standard may be cited for reference only unless a waiver is granted by the appropriate Milestone Decision Authority. Second, a specification or standard may not reference other documents beyond the first tier. In other words, if a specification references a second specification, any references in the second specification are ignored.

IMPACT OF THE SPECIFICATIONS AND STANDARDS MEMORANDUM

As a result of the memorandum, the preparing activities of military specifications and standards are reviewing their documents and will be recommending disposition to the Secretary. One of eight possible recommendations for disposition of a military specification or military standard may be made. They are:

- Retain as performance-based document (some revision may be necessary)
- Retain as interface standard
- Retain as test method standard
- Convert to handbook
- Inactivate for new design (reprocurement only)
- Delete in favor of a commercial item description
- Delete in favor of a non-government standard
- Cancel

From articles on the subject printed in The Defense News, the DoD Standardization Newsletter, and other publications, most observers anticipate that the majority of documents will be deleted, either outright or in favor of a non-government standard(s). This anticipation is strongest regarding those standards dealing with functional areas, such as reliability and maintainability, systems engineering, and configuration.

Implementation of Secretary Perry's direction by the military services has been uneven and inconsistent. In some cases, procurement activities have forbade the inclusion of military specifications and standards, even when used only for guidance. Inclusion of these documents for guidance only is permitted without the need for a waiver¹⁹. In other cases, contractors have been alerted by procuring activities to not include military specifications and standards in their proposals. This latter action is in conflict with the intent of the Perry memorandum. Clearly, much work remains to be done regarding implementation.

ADOPTING COMMERCIAL PRACTICES

Certainly the Department of Defense and the defense industry can learn from the changes commercial industry has made to remain competitive in the face of foreign competition. It is also true that the technical content of the military specifications and standards reflects years of "lessons learned" that have proved useful to commercial industry. Much of commercial practice is based on these documents. It is probably safe to say that neither the commercial nor the defense sector has the definitive answer to how to do procurement. It is also true that the contracting environment, its rules, motivations, and laws, in the commercial sector is much different than that of the government.

In the commercial sector, procurement serves the technical needs of the company. Purchases are made in a way that best satisfies the technical need at an affordable price. Products may be bought without any legal concern for "competing" the procurement. Once a company finds a "good" source for an item, it can continue to do business with that source until it finds a better source. Profit levels are limited only by the law of supply and demand and the company's ability to operate efficiently.

In the government sector, concerns for small businesses and minority-owned businesses, the desire to have free and open competition, acknowledgment of the government's large buying power, and other issues complicate procurement. Technical concerns must often take a back seat to procurement legal issues. Suppliers must periodically recompetete regardless of well they have been doing or how satisfied the technical customer may be with the product. Profits are limited by law, often at a much lower level than that of the commercial sector.

¹⁹Confirmed by government representatives to a Society of Logistics Engineers (SOLE) sponsored conference, *Specifications and Standards in Transition*, Crystal City, VA, January 26-27, 1995, and by articles in the DoD Standardization Newsletter.

A FINAL THOUGHT

Defense Acquisition Reform is essential just as continual improvement is essential to a commercial company. It is important, especially as defense budgets continue to decrease, to find more efficient and effective processes to buy the products needed to support the military services. Examining the way in which commercial industry does business is a valid and worthwhile step in improving defense acquisition. In many respects, the Department of Defense is benchmarking certain processes using commercial industry as the exemplar. When a process used by commercial industry is superior to that used by the Department of Defense or its contractors, then that process should be adopted. In some cases, however, commercial processes may not be usable, given Federal procurement laws; in some instances, the defense industry's process may actually be better.

The defense and commercial sectors can learn much and profit from each other and should take the necessary actions to adopt the other's practices when it promises improvement. However, Federal laws and regulations regarding acquisition and procurement are an obstacle to the government adopting many commercial practices. Until and unless these laws and regulations are changed to provide a contracting environment that more closely resembles that of the commercial sector, it is doubtful that the Department of Defense and the defense industry will be able to fully adopt and apply commercial practices. Hopefully, the PAR chartered to examine procurement laws and regulations will recommend ways to eliminate the obstacle.

APPENDIX B

LITERATURE SEARCH RESULTS

Section 1: RAC Library Listing

Section 2: Summary of Selected References

APPENDIX B

SECTION 1

RAC Library Listing

RELIABILITY ANALYSIS CENTER
P.O. Box 4700
Rome, NY 13440-8200 (315)330-4151 or (315)337-0900
AUTOVON 587-4151
LIBRARY REPORT
DOCUMENT TITLE AND ABSTRACT SEARCH

NOTE: Some of the following documents may be obtained by contacting one of the following agencies:

National Technical Information Service (NTIS)
Department of Commerce
5285 Port Royal Road Springfield, VA 22151 (703) 487-4650

U.S. Defense contractors may contact:

Defense Technical Information Center (DTIC)
Cameron Station
Alexandria, VA 22304-6145
(202) 274-7633

A limited number may be available in microfiche from:

Defense Logistics Studies Information Exchange (DLSIE)
US Army Logistics Management Center
Fort Lee, VA 23801-6043

When requesting documents from any of the above agencies, the AD/LD (ordering) number (if known) as well as the title and Sponsoring Agency Document number should be given.

Key Words:

AD/LD Order No:
Proprietary Code: None

Publication Date: 93/01/25 RAC Owner/Location/DAN: RAC/NORM/27257-031

TITLE

NEXT GENERATION COMMERCIAL AIRPLANES: RELIABILITY FOR AIRLINE ECONOMICS - PANEL PREFACES

Journal Name: PROCEEDINGS ANNUAL R&M SYMPOSIUM Vol.: No.: 1993 Pages: 192-198

Sponsoring Agency Name: IEEE Document No.: Contract Number:

Performing Agency Name: BOEING COMMERCIAL AIRPLANE GROUP Document No.:
ABSTRACT

CONCEPTS FOR THE NEXT GENERATION AIRPLANES ARE BEING DEVELOPED WITH SIZE, SPEED, COMFORT, TECHNOLOGY, AND AIRLINE ECONOMICS SOME OF THE MAJOR ATTRIBUTES BEING DISCUSSED. A 650 (OR MORE) PASSENGER AIRCRAFT WHICH COULD TRAVEL AT HIGH SPEED MIGHT HAVE AN IMPORTANT COMMERCIAL MARKET, BUT IT WOULD POSE APPRECIABLE TECHNICAL CHALLENGES IN TERMS OF SAFETY, RELIABILITY, AND EFFICIENCY. ABOVE ALL, FUTURE AIRPLANES MUST BE EQUIPPED WITH ECONOMICALLY JUSTIFIED TECHNOLOGY. THE PANEL MEMBERS ARE FROM AIRCRAFT MANUFACTURERS, AIRCRAFT-PARTS MANUFACTURERS, AND REGULATORS; ALL ARE AIRLINE PASSENGERS.

AUTHORS
SHARMA, T. C.

Key Words:

AD/LD Order No:
Proprietary Code: None

Publication Date: 93/01/00 RAC Owner/Location/DAN: RAC/NORM/28014-000

TITLE

AUTO INDUSTRY QUALITY---WHAT ARE THEY DOING?

Journal Name: QUALITY Vol.: 32 No.: Pages: 16-22

Performing Agency Name: HITCHCOCK PUBLISHING COMPANY

Document No.:
ABSTRACT

CHRYSLER, FORD, AND GM ARE LEARNING THAT QUALITY WORKS.

AUTHORS
WOLAK, J.

Key Words:

AD/LD Order No:
Proprietary Code: None

Publication Date: 92/10/00 RAC Owner/Location/DAN: RAC/NORM/27724-000

TITLE

REPORT OF SURVEY CONDUCTED AT COMPUTING DEVICES INTERNATIONAL, BLOOMINGTON, MINN ESOTA

Journal Name: BEST MANUFACTURING PRACTICES Vol.: No.: Pages: 1-23

Sponsoring Agency Name: U.S. NAVY

Performing Agency Name: BEST MANUFACTURING PRACTICES (BMP) TEAM Document No.: Contract Number:

AUTHORS
ANONYMOUS

ABSTRACT

THE PURPOSE OF THE BEST MANUFACTURING PRACTICES (BMP) SURVEY CONDUCTED AT COMPUTING DEVICES INTERNATIONAL IN BLOOMINGTON, MINNESOTA WAS TO IDENTIFY BEST PRACTICES, REVIEW MANUFACTURING PROBLEMS, AND DOCUMENT THE RESULTS. THE INTENT IS TO EXTEND THE USE OF PROGRESSIVE MANAGEMENT TECHNIQUES AS WELL AS HIGH TECHNOLOGY EQUIPMENT AND PROCESSES THROUGHOUT INDUSTRY AND GOVERNMENT FACILITIES. THE ULTIMATE GOAL OF THE BMP PROGRAM IS TO STRENGTHEN THE U.S. INDUSTRIAL BASE AND REDUCE THE COST OF DEFENSE SYSTEMS BY SOLVING MANUFACTURING PROBLEMS AND IMPROVING QUALITY AND RELIABILITY. THE RESULTS OF BMP SU

Key Words:

AD/LD Order No: Publication Date: 92/08/31 RAC Owner/Location/DAN: RAC/NORM/27524-000
Proprietary Code: None

TITLE

SOFTWARE QUALITY AND TESTING: WHAT DOD CAN LEARN FROM COMMERCIAL PRACTICES

Sponsoring Agency Name: AIRMICS Document No.: Contract Number:

Performing Agency Name: AIRMICS Document No.: ASQB-GI-92-012

AUTHORS
KINDL,M.R.

ABSTRACT

WITH REGARD TO SOFTWARE TESTING IN DOD, WE CAN SUMMARIZE OUR CONCLUSIONS IN TWO FUNDAMENTAL IDEAS. FIRST, DOD KNOWS HOW TO PRODUCE QUALITY SOFTWARE AT LOW COST. THIS IS BECAUSE ORGANIZATIONS SUCH AS DOD STEP, ARMY STEP, AND SOFTWARE ENGINEERING INSTITUTE HAVE ALREADY RESEARCHED AND DOCUMENTED POLICIES FOR DOD. A FEW COMMERCIAL SOFTWARE DEVELOPERS PRACTICE MANY OF THE DOD POLICIES AND DIRECTIVES NOW, AND PRODUCE QUALITY SOFTWARE (FOR EXAMPLE, IBM FSC HOUSTON). SECOND, QUALITY CANNOT BE TESTED INTO SOFTWARE. ONLY A WELL-DEFINED, WELL-DISCIPLINED PROCESS WITH A CONTINUOUS IMPROVEMENT CYCLE CAN EN

Key Words:

AD/LD Order No: Publication Date: 92/08/24 RAC Owner/Location/DAN: RAC/NORM/27795-000
Proprietary Code: None

TITLE

MANUFACTURING 2005: A STRATEGY FOR A STRONG, RESPONSIVE AIR FORCE INDUSTRIAL BASE

Sponsoring Agency Name: USAF Document No.: Contract Number:

Performing Agency Name: MATERIEL COMMAND Document No.:

AUTHORS
ANONYMOUS

ABSTRACT

THIS DOCUMENT IS A SUMMATION OF THE ACTIVITIES AND THE CONSIDERATIONS THAT ESTABLISHED THE EARLY MANUFACTURING 2005 GROUND WORK LAID BY THE AIR FORCE AND INDUSTRY PRIOR TO RECEIVING GENERAL YATES' CONCURRENCE, THEN COMMANDER OF AIR FORCE SYSTEMS COMMAND, ON 16 MARCH 1992, TO PROCEED WITH IMPLEMENTATION. IT IS A HISTORICAL DOCUMENT AND DOES NOT INCLUDE CURRENT IMPLEMENTATION PLANS BEING WORKED BY THE AIR FORCE'S MANUFACTURING TECHNOLOGY PROGRAM AND OTHERS. THE DOCUMENT WAS ORIGINALLY INTENDED AS AN INTERNAL WORKING DOCUMENT AND IS BEING RELEASED IN DRAFT FORM TO SHARE IMPORTANT HISTORICAL INFOR

Key Words:

AD/LD Order No:
Proprietary Code: None

Publication Date: 92/08/00 RAC Owner/Location/DAN: RAC/NORM/26731-000

TITLE

THE COMPETITIVE STRENGTH OF U.S. INDUSTRIAL SCIENCE AND TECHNOLOGY: STRATEGIC ISSUES

Sponsoring Agency Name: NATIONAL SCIENCE FOUNDATION Document No.: Contract Number:

Performing Agency Name: NATIONAL SCIENCE BOARD Document No.: NSB-92-138

ABSTRACT

CONCERNED ABOUT THE ISSUES OF DECLINING U.S. LEADERSHIP IN INDUSTRIAL SCIENCE AND TECHNOLOGY, THE NATIONAL SCIENCE BOARD (NSB) ESTABLISHED THE COMMITTEE ON INDUSTRIAL SUPPORT FOR R&D TO CARRY OUT A STUDY ON THE NATURE OF THE PROBLEMS AND SUGGEST BROAD REMEDIES. THIS REPORT REPRESENTS THE CULMINATION OF THE COMMITTEE'S EFFORT TO PRESENT AN INTEGRATED, MULTIDIMENSIONAL VIEW OF THE ISSUES SURROUNDING U.S. INDUSTRIAL R&D.

AUTHORS
VARIOUS

Key Words:

AD/LD Order No:
Proprietary Code: None

Publication Date: 92/07/00 RAC Owner/Location/DAN: RAC/NORM/27723-000

TITLE

REPORT OF SURVEY CONDUCTED AT WATERVLIET ARSENAL, WATERVLIET, NEW YORK

Journal Name: BEST MANUFACTURING PRACTICES Vol.: No.: Pages: 1-30

Sponsoring Agency Name: U.S. NAVY Document No.: Contract Number:

Performing Agency Name: BEST MANUFACTURING PRACTICES (BMP) TEAM Document No.:
ABSTRACT

THE PURPOSE OF THE BEST MANUFACTURING PRACTICES (BMP) SURVEY CONDUCTED AT THE WATERVLIET ARSENAL (WVA) IN WATERVLIET, NEW YORK WAS TO IDENTIFY BEST PRACTICES, REVIEW MANUFACTURING PROBLEMS, AND DOCUMENT THE RESULTS. THE INTENT IS TO EXTEND THE USE OF PROGRESSIVE MANAGEMENT TECHNIQUES AS WELL AS HIGH TECHNOLOGY EQUIPMENT AND PROCESSES THROUGHOUT INDUSTRY AND GOVERNMENT FACILITIES. THE ULTIMATE GOAL OF THE BMP PROGRAM IS TO STRENGTHEN THE U.S. INDUSTRIAL BASE AND REDUCE THE COST OF DEFENSE SYSTEMS BY SOLVING MANUFACTURING PROBLEMS AND IMPROVING QUALITY AND RELIABILITY. THE RESULTS OF BMP SURVEYS

AUTHORS
ANONYMOUS

Key Words:

AD/LD Order No:
Proprietary Code: None

Publication Date: 92/06/00 RAC Owner/Location/DAN: RAC/NORM/27719-000

TITLE

REPORT OF SURVEY CONDUCTED AT HEWLETT-PACKARD PALO ALTO FABRICATION CENTER, PALO
ALTO, CALIFORNIA

Journal Name: BEST MANUFACTURING PRACTICES Vol.: No.: Pages: 1-16

AUTHORS
ANONYMOUS

Sponsoring Agency Name: U.S. NAVY Document No.: Contract Number:

Performing Agency Name: BEST MANUFACTURING PRACTICES (BMP) TEAM Document No.:
ABSTRACT

THE PURPOSE OF THE BEST MANUFACTURING PRACTICES (BMP) SURVEY CONDUCTED AT HEWLETT-PACKARD (HP) PALO ALTO FABRICATION CENTER (PAFC) WAS TO IDENTIFY BEST PRACTICES, REVIEW MANUFACTURING PROBLEMS, AND DOCUMENT THE RESULTS. THE INTENT IS TO EXTEND THE USE OF PROGRESSIVE MANAGEMENT TECHNIQUES AS WELL AS HIGH TECHNOLOGY EQUIPMENT AND PROCESSES THROUGHOUT INDUSTRY AND GOVERNMENT FACILITIES. THE ULTIMATE GOAL OF THE BMP PROGRAM IS TO STRENGTHEN THE U.S. INDUSTRIAL BASE AND REDUCE THE COST OF DEFENSE SYSTEMS BY SOLVING MANUFACTURING PROBLEMS AND IMPROVING QUALITY AND RELIABILITY. THE RESULTS OF BMP SUR

Key Words:

AD/LD Order No: Publication Date: 92/06/00 RAC Owner/Location/DAN: RAC/NORM/27722-000

Proprietary Code: None

TITLE

REPORT OF SURVEY CONDUCTED AT TEXAS INSTRUMENTS SEMICONDUCTOR GROUP MILITARY PRO
DUCTS, MIDLAND, TEXAS

Journal Name: BEST MANUFACTURING PRACTICES Vol.: No.: Pages: 1-21

Sponsoring Agency Name: U.S. NAVY Document No.: Contract Number:

Performing Agency Name: BEST MANUFACTURING PRACTICES (BMP) TEAM Document No.:
ABSTRACT

THE PURPOSE OF THE BEST MANUFACTURING PRACTICES (BMP) SURVEY CONDUCTED AT TEXAS INSTRUMENTS SEMICONDUCTOR GROUP (TI/SG/MP) WAS TO IDENTIFY BEST PRACTICES, REVIEW MANUFACTURING PROBLEMS, AND DOCUMENT THE RESULTS. THE INTENT IS TO EXTEND THE USE OF PROGRESSIVE MANAGEMENT TECHNIQUES AS WELL AS HIGH TECHNOLOGY EQUIPMENT AND PROCESSES THROUGHOUT INDUSTRY AND GOVERNMENT FACILITIES. THE ULTIMATE GOAL OF THE BMP PROGRAM IS TO STRENGTHEN THE U.S. INDUSTRIAL BASE AND REDUCE THE COST OF DEFENSE SYSTEMS BY SOLVING MANUFACTURING PROBLEMS AND IMPROVING QUALITY AND RELIABILITY. THE RESULTS OF BMP SURVEYS ARE

AUTHORS
ANONYMOUS

Key Words:

AD/LD Order No: Publication Date: 92/04/00 RAC Owner/Location/DAN: RAC/NORM/26657-000

Proprietary Code: None

TITLE

REPORT OF SURVEY CONDUCTED AT CHARLESTON NAVAL SHIPYARD, CHARLESTON, SOUTH CAROLINA

Journal Name: BEST MANUFACTURING PRACTICES Vol.: No.: Pages: 1-27

Sponsoring Agency Name: U.S. NAVY Document No.: Contract Number:

Performing Agency Name: BEST MANUFACTURING PRACTICES (BMP) TEAM Document No.:

AUTHORS
ANONYMOUS

ABSTRACT

THE PURPOSE OF THE BEST MANUFACTURING PRACTICES (BMP) SURVEY CONDUCTED AT THE CHARLESTON NAVAL SHIPYARD (CNSY) WAS TO IDENTIFY BEST PRACTICES, REVIEW MANUFACTURING PROBLEMS, AND DOCUMENT THE RESULTS. THE INTENT IS TO EXTEND THE USE OF PROGRESSIVE MANAGEMENT TECHNIQUES AS WELL AS HIGH TECHNOLOGY EQUIPMENT AND PROCESSES THROUGHOUT INDUSTRY AND GOVERNMENT FACILITIES. THE ULTIMATE GOAL IS TO STRENGTHEN THE U.S. INDUSTRIAL BASE, SOLVE MANUFACTURING PROBLEMS, IMPROVE QUALITY AND RELIABILITY, AND REDUCE THE COST OF DEFENSE SYSTEMS. THE RESULTS OF BMP SURVEYS ARE ENTERED INTO A DATABASE TO TRACK BEST

Key Words:

AD/LD Order No: Publication Date: 92/01/23 RAC Owner/Location/DAN: RAC/REF/255842-003

Proprietary Code: None

TITLE

NASA PREFERRED RELIABILITY-PRACTICES FOR DESIGN AND TEST

Journal Name: 1992 PROCEEDINGS ANNUAL R&M SYMP Vol.: No.: Pages: 7-11

Performing Agency Name: NASA Document No.: ABSTRACT

AUTHORS
LISK,R.C.

THE DIVERSITY AND RELATIVE AUTONOMY OF THE NASA FIELD CENTERS FOSTERS A SITUATION WHERE UNNECESSARY REPETITION OF DESIGN EFFORT AND THE DANGER OF LOSS AND DESIGN TECHNIQUES USED FOR HIGH RELIABILITY HARDWARE IS POSSIBLE. INTERCENTER COMMUNICATION OF TECHNICAL APPROACHES THAT HAVE CONTRIBUTED TO MISSION SUCCESS REDUCES THE CHANCE FOR DUPLICATION OF TECHNICAL EFFORT, PROVIDES A MECHANISM FOR RETAINING NASA'S CORPORATE KNOWLEDGE IN RELIABILITY AND PROMOTES CLOSED TEAMWORK BETWEEN THE ENGINEERING AND ASSURANCE COMMUNITIES.

Key Words:

AD/LD Order No: Publication Date: 91/06/00 RAC Owner/Location/DAN: RAC/REF/25584-002

Proprietary Code: None

TITLE

RELIABILITY PREDICTION, THE RIGHT WAY

Journal Name: RELIABILITY REVIEW Vol.: 11 No.: 2 Pages: 8-10

Performing Agency Name: GMC Document No.: ABSTRACT

AUTHORS
BIEDA,J.
HOLDBROOK,M.

THE PROPER USE OF RELIABILITY PREDICTIONS IN ASSESSING THE DESIGN RELIABILITY OF COMPONENTS, ASSEMBLIES, AND PROCESSES IS A FREQUENTLY DISPUTED ISSUE AMONG ENGINEERS. SOME INDIVIDUALS CONTENT THAT THE RELIABILITY PREDICTION DOES NOT ACCURATELY ASSESS A PRODUCT'S RELIABILITY OR CORRELATE WITH FIELD AND TEST EXPERIENCE. OTHER INDIVIDUALS CLAIM THAT RELIABILITY PREDICTIONS DO AID THE DESIGN ENGINEER TO REDUCE OR ELIMINATE RELIABILITY TESTS AND MAKE DECISIONS TOWARD FEASIBLE DESIGN PROPOSALS.

Key Words:

AD/LD Order No:

Proprietary Code: None

Publication Date: 91/03/00 RAC Owner/Location/DAN: RAC/NORM/26335-000

Performing Agency Name: NONE

TITLE

AN INTRODUCTION TO BELLCORE'S RELIABILITY AND QUALITY GENERIC REQUIREMENTS (RQGR)

Sponsoring Agency Name: BELLCORE Document No.: TR-NWT-000874 Contract Number:

Performing Agency Name: NONE Document No.:

ABSTRACT

THIS TECHNICAL REFERENCE (TR) INTRODUCES THE BELLCORE GENERIC CRITERIA DOCUMENTS THAT ARE KNOWN COLLECTIVELY AS THE RELIABILITY AND QUALITY GENERIC REQUIREMENTS (RQGR), FR-NWT-000796. THE RQGR GIVES BELLCORE'S VIEW OF PROPOSED GENERIC REQUIREMENTS THAT ARE NEEDED TO ENSURE THE UNINTERRUPTED PERFORMANCE, RELIABILITY, AND QUALITY OF PRODUCTS INTENDED FOR USE AS NETWORK ELEMENTS IN A TYPICAL BELLCORE CLIENT COMPANY (BCC) NETWORK. THIS TR PRESENTS AN OVERVIEW OF THE RQGR STRUCTURE, PROVIDES ORDERING INFORMATION FOR THE RQGR DOCUMENTS, AND DESCRIBES EACH DOCUMENT IN THE RQGR.

AUTHORS
ANONYMOUS

Key Words:

AD/LD Order No:

Proprietary Code: None

Publication Date: 91/02/00 RAC Owner/Location/DAN: RAC/NORM/28010-000

QUALITY, RELIABILITY, AND TRAINING

Sponsoring Agency Name: ZYTEC Document No.: Contract Number:

Performing Agency Name: AMER. PRODUCTIVITY & QUALITY CENTER Document No.:

ABSTRACT

IN 1990, TRISH ASSOCIATES, INC., SANTA CLARA, CALIFORNIA, CONDUCTED A SURVEY TO ASCERTAIN THE MOST IMPORTANT CUSTOMER PERCEPTION ATTRIBUTES ASSIGNED BY OEM POWER SUPPLY CONSUMERS. THE SURVEY REPORT WAS PUBLISHED WITH THE FOLLOWING RESULTS: ZYTEC WAS RATED THE "NUMBER 1" POWER SUPPLY SUPPLIER, AND THE 3 ATTRIBUTES RECEIVING THE HIGHEST IMPORTANCE RATINGS IN THE POWER SUPPLY MARKET WERE 1) PRODUCT QUALITY, 2) PRODUCT RELIABILITY, AND 3) ON-TIME DELIVERY. ZYTEC HAS INTERNALIZED THESE CUSTOMER NEEDS, AND THE 1991 QUALITY AND RELIABILITY PLAN REFLECTS THE COMMITMENT TO PROVIDING QUALITY PRODUCTS WI

AUTHORS
SCHMIDT,R.D.

Key Words:

AD/LD Order No:

Proprietary Code: None

Publication Date: 91/01/29 RAC Owner/Location/DAN: RAC/REF/27261-020

TITLE

SIMULATION OF COMMERCIAL - AIRCRAFT RELIABILITY

Journal Name: PROCEEDINGS ANNUAL R&M SYMPOSIUM Vol.: No.: 1991 Pages: 112-119

AUTHORS
YANG,W.
ZHU,Y.
TU,Q.

Sponsoring Agency Name: IEEE Document No.: Contract Number:
Performing Agency Name: VARIOUS Document No.: ABSTRACT

BY APPLYING MONTE-CARLO SIMULATION METHODS, A SIMULATION MODEL IS ESTABLISHED IN THIS PAPER, WHICH CONSIDERS FACTORS SUCH AS R&M CHARACTERISTICS OF THE AIRCRAFT, WEATHER CONDITIONS, MANAGEMENT, FLIGHT DISPATCHING, NUMBER OF AIRCRAFT, ROUTE STRUCTURE, MAINTENANCE LEVEL, PERSONNEL SKILLS, SPARE PARTS SUPPLY, ETC. THE ANALYSIS RESULTS CAN PROVIDE THE DECISION-MAKING BASIS TO IMPROVE PRODUCT'S R&M FOR MANUFACTURERS AND TO ADJUST FLIGHT, DISPATCH PROCEDURE, LOGISTIC SUPPORTS, ETC., RATIONALLY FOR AIRLINES.

Key Words:

AD/LD Order No:
Proprietary Code: None

Publication Date: 91/01/29 RAC Owner/Location/DAN: RAC/REF/27261-088

TITLE

RANDOM VIBRATION TESTING FOR COMMERCIAL COMPUTERS

Journal Name: PROCEEDINGS ANNUAL R&M SYMPOSIUM Vol.: No.: 1991 Pages: 521-524

Sponsoring Agency Name: IEEE Document No.: Contract Number:

Performing Agency Name: VARIOUS Document No.:

AUTHORS
FREY,R.A.

ABSTRACT

OVER THE PAST SEVERAL YEARS WORK WAS CONDUCTED AT IBM TO DEVELOP A RANDOM VIBRATION TEST THAT WOULD PROVIDE AN EFFICIENT AND REASONABLY WORST-CASE SIMULATION OF THE ACTUAL VIBRATION ENVIRONMENT FOR IBM EQUIPMENT OPERATING AT CUSTOMER INSTALLATIONS. THE RANDOM VIBRATION TEST TECHNIQUES DEVELOPED FOR MILITAR PRODUCTS WERE INVESTIGATED AND THEN TAILORED FOR USE WITH COMMERCIAL COMPUTER PRODUCTS.F THE USE OF RANDOM VIBRATION PROVIDED A TECHNICALLY UP-TO-DATE TEST THAT MORE ACCURATELY REPRESENTED THE VIBRATION ENVIRONMENT SEEN IN ACTUAL COMPUTER INSTALLATIONS AND ALSO PROVIDED A TEST THAT SIMULAT

Key Words:

AD/LD Order No:
Proprietary Code: None

Publication Date: 91/00/00 RAC Owner/Location/DAN: RAC/REF/25605-039

TITLE

NEW DEFINITIONS OF BASIC R&M TERMS

Journal Name: MICROELECTRONICS AND RELIABILITY Vol.: 31 No.: 2 Pages: 525-535

Sponsoring Agency Name: PERGAMON PRESS Document No.: Contract Number:

Performing Agency Name: BOEING AEROSPACE AND ELECTRONICS

Document No.:

AUTHORS
DUNCAN,B.

ABSTRACT

THIS PAPER IS ADDRESSED TO DESIGNERS AS WELL AS R&M SPECIALISTS. EXISTING DEFINITIONS OF BASIC RELIABILITY AND MAINTAINABILITY TERMS ARE VAGUE AMBIGUOUS. LACKING STRUCTURE, THEY FAIL TO INTERRELATE; AND FAILING THIS, THEY LACK

PRECISION. ALSO, SOME BASIC TERMS THAT OUGHT TO HAVE BEEN DEFINED, WERE NOT. STARTING WITH RELIABILITY ITSELF, AND AVAILABILITY IN THE CASE OF MAINTAINABILITY, THE PAPER TRACES THEIR GENEALOGIES, DIAGRAMMING BASIC MINIMUM SETS OF TERMS FOR EACH. MEMBERS OF EACH SET ARE THEN RESTATED WITH DUE REGARD FOR LOGICAL INTERRELATIONSHIPS.

Key Words:

AD/LD Order No:
Proprietary Code: None

Publication Date: 91/00/00 RAC Owner/Location/DAN: RAC/REF/26209-000

TITLE
QUALITY MANAGEMENT BENCHMARK ASSESSMENT
Performing Agency Name: ASQC QUALITY PRESS

AUTHORS
RUSSELL, J.P.

Document No.:

ABSTRACT

THE QMBA PROVIDES A CHECKLIST USEFUL TO EVALUATE YOUR COMPANY'S QUALITY PROGRESS AND TO SET SPECIFIC GOALS FOR IMPROVEMENT. ITS TASK-ORIENTED LISTS, IN EASY-TO-USE NOTEBOOK FORM, ALLOW YOU TO COMPARE YOUR COMPANY'S PERFORMANCE WITH TWO WIDELY-ACCEPTED SETS OF QUALITY CRITERIA: THOSE OF THE 1991 MALCOLM BALDRIGE NATIONAL QUALITY AWARD AND THE CURRENT STANDARDS OF THE INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO 9004: 1987[E]). (THE ISO 9004 STANDARDS ARE EQUIVALENT TO THE ANSI/ASQC Q-94-1987 GUIDELINES). THE QMBA DECODES QUALITY JARGON INTO EASY-TO-UNDERSTAND TERMS.

Key Words:

AD/LD Order No:
Proprietary Code: None

Publication Date: 90/11/00 RAC Owner/Location/DAN: RAC/NORM/24669-000

TITLE

BENCHMARKING

Performing Agency Name: UNKNOWN

AUTHORS
GEBER, B.

Document No.:

ABSTRACT

BACK IN THE RECESSIONARY DAYS OF 1980, FORD MOTOR CO. WAS GETTING CUFFED AROUND UNMERCIFULLY. NO AMERICAN CAR COMPANY WAS UNFAZED BY THE ONSLAUGHT OF HIGH OIL PRICES AND GAS-SIPPING IMPORTS, BUT FORD WAS SICKER THAN THE REST. A FAIR NUMBER OF FORD INSIDERS SUSPECTED THAT LAST RITES WERE IMMINENT. DESPERATE TIMES BREED DESPERATE ACTIONS. ONE THAT THE COMPANY DECIDED TO TAKE WAS A DRAMATICALLY DIFFERENT APPROACH TO DESIGNING CARS. THE AUTOMAKER BROKE THE BACK OF ITS LONGSTANDING NOT-INVENTED-HERE SYNDROME BY TRUCKING IN 50 MIDSIZE CARS FROM AROUND THE WORLD.

Key Words:

AD/LD Order No:
Proprietary Code: None

Publication Date: 89/04/06 RAC Owner/Location/DAN: RAC/NORM/23530-000

TITLE

INTEGRATION OF AUTOMATED DESIGN FOR RELIABILITY AND MAINTAINABILITY IN COMPLEX MECHANICAL SYSTEMS

AUTHORS
ANON.

Document No.:

ABSTRACT

DEFENSE CONTRACTORS ARE FACED WITH INCREASING DEMANDS FOR HIGH LEVELS OF RELIABILITY AND MAINTAINABILITY (R&M) IN THE PRODUCTS THEY PROVIDE TO THE GOVERNMENT. THIS MOVEMENT IS A RESULT OF THE GROWING RECOGNITION OF THE CRITICAL ROLE OF QUALITY, IN GENERAL, AND R&M, IN PARTICULAR, IN WEAPON SYSTEM READINESS, SUSTAINABILITY, AND LIFE CYCLE COSTS. IN RESPONSE TO INCREASED DEMANDS FOR WEAPON SYSTEM QUALITY, THE DEPARTMENT OF DEFENSE (DOD) INITIATED THE COMPUTER-AIDED ACQUISITION AND LOGISTIC SUPPORT (CALS) PROGRAM TO EFFECT QUALITY IMPROVEMENTS THROUGH PROCESS AUTOMATION AND INTEGRATION.

Key Words:

AD/LD Order No:

Proprietary Code: None

Publication Date: 89/03/00 RAC Owner/Location/DAN: RAC/REF/23459-004

TITLE

RELIABILITY-ENABLED CHANGES IN THE DESIGN AND MANUFACTURE OF COMMERCIAL ELECTRONIC PRODUCTS

Journal Name: QUALITY AND RELIABILITY ENGINEERING Vol.: 5 No.: 1 Pages: 23-27

Performing Agency Name: PRODUCTION AUTOMATION INC.

Document No.:

ABSTRACT

IT HAS NOW BECOME POSSIBLE TO DESIGN ELECTRONIC PRODUCTS THAT HAVE ONLY A SMALL PROBABILITY OF FAILING IN A PERIOD OF TECHNOLOGICALLY USEFUL LIFE, IF THESE PRODUCTS ARE TO BE USED IN AN ENVIRONMENT CONTROLLED FOR HUMAN COMFORT. SUCH PRODUCT DESIGNS, EVEN ONES CONTAINING CONSIDERABLE COMPLEXITY, CAN USE COMBINATIONS OF ASIC AND SEMI-CUSTOM VLSI DEVICES, DAMAGE-RESISTANT PACKAGING AND FAULT-TOLERANT TECHNIQUES TO ACHIEVE BREAKTHROUGH RELIABILITY. THE THEME OF THIS PAPER IS THAT ONCE FIELD FAILURES CAN BE REDUCED TO SMALL FRACTIONS OF THE UNITS PRODUCED, THEIR COST SAVINGS BECOME POSSIBLE.

Key Words:

AD/LD Order No:

Proprietary Code: None

Publication Date: 89/01/26 RAC Owner/Location/DAN: RAC/REF/24250-068

TITLE

HIGH RELIABILITY IN THE COMMERCIAL ARENA

Journal Name: PROCEEDINGS ANNUAL R&M SYMP Vol.: No.: 1989 Pages: 363-3567

Performing Agency Name: CODEX CORPORATION

Document No.:

ABSTRACT

MILITARY AND NASA SPACE PROGRAMS ARE NOT THE ONLY AREAS WHERE STRONG RELIABILITY PROGRAMS ARE REQUIRED. MAJOR SHIFTS IN MARKET SHARE HAVE OCCURRED IN MANY HIGH-TECHNOLOGY PRODUCTS, AND NEW SUPPLIERS ARE PERCEIVED AS PROVIDING BETTER QUALITY AND HIGHER RELIABILITY. THIS PAPER IS A DESCRIPTION OF THE RELIABILITY PROGRAM AT A MAJOR COMMERCIAL SUPPLIER AND SHOWS HOW RELIABILITY IS DEALT WITH IN THE COMMERCIAL ARENA.

AUTHORS

BRIDGERS, J. E.

Key Words:

AD/LD Order No:
Proprietary Code: None

Publication Date: 89/00/00 RAC Owner/Location/DAN: RAC/NORM/28013-000

TITLE

AN INTERACTIVE KNOWLEDGE-BASED SYSTEM FOR FORECASTING NEW PRODUCT RELIABILITY

Journal Name: COMPUTERS AND INDUSTRIAL ENGINEERING Vol.: 17 No.: Pages: 323-326

Sponsoring Agency Name: IBM/UNIV. OF PITTSBURGH Document No.: Contract Number:

Performing Agency Name: PERGAMON PRESS Document No.:

ABSTRACT

DURING THE DEVELOPMENT PHASES OF A NEW PRODUCT, SPECIAL ATTENTION IS USUALLY DIRECTED TO THE ALLOCATION OF RELIABILITY IMPROVEMENT PROGRAMS. THIS PAPER WILL PRESENT AN INTERACTIVE KNOWLEDGE-BASED DECISION SUPPORT SYSTEM (DSS) FOR OPTIMIZING THIS ALLOCATION PROCESS. THE DSS UTILIZES AN EXTENSION TO THE MODIFIED EXPONENTIAL RELIABILITY GROWTH MODEL, WHICH WAS DEVELOPED TO QUANTIFY AND MONITOR RELIABILITY DURING THE PRODUCT DEVELOPMENT PHASES. THIS PAPER ADDRESSES THE RELIABILITY OF COMPLEX ELECTRONIC SYSTEMS. IT DETERMINES THE RATE OF GROWTH, AND THE LEVEL OF INITIAL RELIABILITY REQUIRED IN ORDE

AUTHORS

NASSAR,S.M.
SOUDER,W.E.

Key Words:

AD/LD Order No:
Proprietary Code: None

Publication Date: 88/00/00 RAC Owner/Location/DAN: RAC/NORM/28012-000

TITLE

NEW DIRECTIONS FOR RELIABILITY

Journal Name: QUALITY ENGINEERING Vol.: 1 No.: 1 Pages: 79-89

Performing Agency Name: MARCEL DEKKER, INC.

Document No.:

ABSTRACT

TODAY, RELIABILITY IS NO LONGER A NUMBERS GAME. INSTEAD, MANAGEMENT AND ENGINEERING SYSTEMS MUST RESULT IN CONTINUALLY IMPROVING PRODUCT. THE REQUIRED RESULTS CAN BE OBTAINED ONLY FROM A NEW EMPHASIS ON SOUND ENGINEERING PRINCIPLES AND REALISTIC STATISTICAL CONCEPTS BY: 1) FOLLOWING CAREFUL DESIGN PRACTICES TO ENHANCE SYSTEM PERFORMANCE, 2) QUESTIONING THE CONCEPTS OF RANDOM FAILURES AND CONSTANT FAILURE RATES, 3) SELECTING AND USING ONLY THE BEST AVAILABLE PARTS, 4) CONSTANTLY MONITORING IN-PROCESS FALL-OUT AND INTENSIVE FAILURE ANALYSIS, 5) USING SIMPLE GRAPHICS TO MEASURE AND DEMONSTRATE RE

AUTHORS
KING,J.R.

Key Words:

AD/LD Order No:
Proprietary Code: None

Publication Date: 87/01/27 RAC Owner/Location/DAN: RAC/REF/19869-075

TITLE

RELIABILITY IMPROVEMENT IN THE COMMERCIAL TRUCK INDUSTRY

Journal Name: PROCEEDINGS ANNUAL R&M SYMP. Vol.: No.: 1987 Pages: 378-380

AUTHORS
QUINN,M.F.

Performing Agency Name: U.S. ARMY

Document No.:

ABSTRACT

THERE IS A CURRENT IMPRESSION THAT THE AMERICAN COMMERCIAL TRUCK INDUSTRY HAS MADE MAJOR IMPROVEMENTS IN THE RELIABILITY OF THEIR PRODUCTS. IF THIS IS FACT, ARE THEY DOING ANYTHING THAT THE ARMY COULD ADAPT TO DEFENSE SYSTEMS TO ADVANTAGE? IN ORDER TO EXPLORE THIS, A SERIES OF MEETINGS WAS ARRANGED WITH VEHICLE AND COMPONENT MANUFACTURERS.

Key Words:

AD/LD Order No:

Publication Date: 86/05/30 RAC Owner/Location/DAN: RAC/REF/24604-041

Proprietary Code: None

TITLE

THE EVALUATION OF RAS FUNCTIONS BASED ON MDT FIELD RECORDS (THE EXAMPLE OF INDUSTRIAL COMPUTER STAND ALONE SYSTEMS)

Journal Name: SYMPOSIUM ON R & M Vol.: 16TH No.: Pages: 82-83

Performing Agency Name: TOKYO UNIVERSITY OF AGRICULTURE

Document No.:

ABSTRACT

INFORMATION PROCESSING SYSTEMS AND INDUSTRIAL CONTROL SYSTEMS HAVE RAS (RELIABILITY, AVAILABILITY, SERVICEABILITY) WHICH CONTRIBUTE TO IMPROVEMENT OF SYSTEMS' RELIABILITY, AVAILABILITY AND MAINTAINABILITY. HITHERTO, THE RELATIONS BETWEEN RAS AND MAINTAINABILITY HAVE BEEN MAINLY DISCUSSED BY DESIGNERS, AND HAVE NOT BEEN DONE BY MAINTENANCE ENGINEERS. THIS REPORT GRASPS RAS'S CONTRIBUTION TO MTD DECREASING AT FIELD, I.E. THE RESULTS OF RAS EFFECTIVENESS FROM VIEW POINT OF MAINTENANCE ENGINEERS, AND EVALUATES EACH ITEM OF RAS, SELECTING FIVE KINDS OF MACHINES WITH DIFFERENT RAS FUNCTIONS.

AUTHORS
NITA,S.
TAMAKI,T.

Key Words:

AD/LD Order No:

Publication Date: 86/03/00 RAC Owner/Location/DAN: RAC/NORM/21901-000

Proprietary Code: None

TITLE

BEST PRACTICES: HOW TO AVOID SURPRISES IN THE WORLD'S MOST COMPLICATED TECHNICAL PROCESS: THE TRANSITION FROM DEVELOPMENT TO PRODUCTION

Sponsoring Agency Name: USN/NAVSO Document No.: Contract Number:

Performing Agency Name: WILLIS J. WILLOUGHBY, JR.

Document No.:

ABSTRACT

WEAPON SYSTEM DESIGN, TEST, AND PRODUCTION CONSTITUTE THE WORLD'S MOST COMPLICATED TECHNICAL PROCESS. THIS MANUAL ILLUSTRATES THAT MANY OF THE APPROACHES COMMONLY USED IN PAST AND CURRENT DEFENSE SYSTEMS ACQUISITION PROGRAMS ARE NOT BEST PRACTICES - THEY LED OR WILL LEAD TO HIGH RISK, POOR OPERATIONAL READINESS, AND HIGH SUPPORT COST IN SERVICE USE.

AUTHORS
AAKHUS,R.C.
ACCOULTI-GIL,G.
EMERSON,D.F.

Key Words:

AD/LD Order No: Publication Date: 85/01/22 RAC Owner/Location/DAN: RAC/REF/18504-035
Proprietary Code: None

RELIABILITY SELF ASSESSMENT

Journal Name: PROCEEDINGS ANNUAL R&M SYMP. Vol.: No.: 1985 Pages: 187-190
Performing Agency Name: GENERAL ELECTRIC CO. Document No.: ABSTRACT

TITLE

AUTHORS
WARR,R.E.

A RELIABILITY SELF ASSESSMENT PROGRAM IS DESCRIBED THAT WAS DEVELOPED TO HELP OPERATIONS IN THE GENERAL ELECTRIC COMPANY DRIVE THEIR PRODUCTS TO HIGHER LEVELS OF RELIABILITY. THE RELIABILITY SELF ASSESSMENT PROGRAM REPRESENTS A UNIQUE APPROACH FOR A CORPORATION TO HELP ITS DECENTRALIZED OPERATIONS IMPROVE PRODUCT RELIABILITY. THE RELIABILITY SELF ASSESSMENT PROGRAM PROVIDES A CORPORATE STRUCTURED PROCESS OF SELF ANALYSIS FOR EACH BUSINESS OPERATION TO COMPARE ITS RELIABILITY PRACTICES WITH THE BEST PRACTICES OF OTHER BUSINESS OPERATIONS OF THE COMPANY AND WITH THE BEST PRACTICES IN THE WORLD.

Key Words:

AD/LD Order No: Publication Date: 84/01/24 RAC Owner/Location/DAN: RAC/REF/18503-019
Proprietary Code: None

DOD/INDUSTRY-R&M CASE STUDY ANALYSIS

Journal Name: PROCEEDINGS ANNUAL R&M SYMP. Vol.: No.: 1984 Pages: 91-98
Performing Agency Name: INSTITUTE FOR DEFENSE ANALYSES Document No.: ABSTRACT

TITLE

AUTHORS
GOREE,P.F.
MUSSON,T.A.

THE INSTITUTE FOR DEFENSE ANALYSES WAS CHARTERED BY THE OFFICE OF THE SECRETARY OF DEFENSE TO CONDUCT A STUDY TO "IDENTIFY AND PROVIDE SUPPORT FOR HIGH PAYOFF ACTIONS WHICH THE DOD CAN TAKE TO IMPROVE THE MILITARY SYSTEM DESIGN, DEVELOPMENT AND SUPPORT PROCESS SO AS TO PROVIDE QUANTUM IMPROVEMENT IN R&M AND READINESS THROUGH INNOVATIVE USES OF ADVANCING TECHNOLOGY AND PROGRAM STRUCTURE." THE TASK WAS GIVEN A SHORT TITLE: R&M STUDY. THE CASE STUDY PORTION OF THE OVERALL IDA STUDY, WHICH FOCUSED ON THE PROGRAM STRUCTURE PORTION OF THE OBJECTIVE, IS ADDRESSED IN THIS PAPER.

Key Words:

AD/LD Order No: Publication Date: 83/08/00 RAC Owner/Location/DAN: RAC/NORM/28011-000
Proprietary Code: None

MANAGEMENT COMMITMENT TO QUALITY: XEROX CORP.

Journal Name: QUALITY PROGRESS Vol.: No.: Pages: 12-17
Sponsoring Agency Name: XEROX CORP. Document No.: Contract Number:
Performing Agency Name: ASQC Document No.:

TITLE

AUTHORS
PIPP,F.J.

ABSTRACT

XEROX CORPORATION HAS ATTEMPTED TO MEET THE CHALLENGE OF INCREASING COMPETITION BY CHANGING ITS CORPORATE CULTURE TO IMPROVE QUALITY AND PRODUCTIVITY.

Key Words:

AD/LD Order No: Publication Date: 83/03/04 RAC Owner/Location/DAN: RAC/NORM/21939-000
Proprietary Code: None

TITLE

RELIABILITY PREDICTION AND EVALUATION OF ELECTRONIC DEVICES, SUBASSEMBLIES, AND
SYSTEMS FOR AUTOMOTIVE APPLICATIONS

Performing Agency Name: FORD MOTOR CO.

Document No.:
ABSTRACT

AUTHORS
KING, J.B.

THIS PAPER WILL PRESENT SOME OF THE ACCOMPLISHMENTS ACHIEVED TO DATE BY THE SUBCOMMITTEE INCLUDING THE DEVELOPMENT OF A VIABLE RELIABILITY PREDICTIVE MODEL AND OPERATIONAL FACTORS AFFECTING ELECTRONIC COMPONENTS, SUBASSEMBLIES, AND SYSTEMS. STEPS TAKEN TO RESOLVE SOME OF THE ISSUES ASSOCIATED WITH ENHANCEMENT OF CURRENT AUTOMOTIVE RELIABILITY METHODOLOGY WILL ALSO BE PRESENTED.

Key Words:

AD/LD Order No: Publication Date: 81/02/23 RAC Owner/Location/DAN: RAC/NORM/16645-000
Proprietary Code: None

TITLE

PREDICTIVE METHODOLOGY FOR AUTOMOTIVE ELECTRONICS RELIABILITY IN THE 1980'S

Sponsoring Agency Name: SAE Document No.: 810451 Contract Number:

Performing Agency Name: FORD MOTOR CO.

Document No.: 810451
ABSTRACT

AUTHORS
KING, J.B.

GROUND, COMPONENT, GUIDE PROCEDURE, REL. MODELS/DATA/ANALYSIS, AUTOMOTIVE,

Key Words:

AD/LD Order No:
Proprietary Code: None

Publication Date: 81/01/27 RAC Owner/Location/DAN: RAC/REF/17297-051

TITLE

COMMERCIAL VS. DOD RELIABILITY PROGRAMS

Journal Name: PROCEEDINGS ANNUAL R&M SYMP. Vol.: No.: 1981 Pages: 289-292

Performing Agency Name: DIGITAL EQUIPMENT CORP. Document No.:

ABSTRACT

AFTER 20 YEARS OF INVOLVEMENT WITH THE TECHNICAL EXECUTION AND MANAGEMENT OF RELIABILITY EFFORTS ASSOCIATED WITH DEPARTMENT OF DEFENSE (DOD) PROGRAMS, THE AUTHOR HAS SWITCHED TO THE COMMERCIAL WORLD. HE NOW MANAGES RELIABILITY PROGRAM EFFORTS FOR MINICOMPUTER COMPONENTS (E.G. PERIPHERALS) USED IN COMMERCIAL APPLICATIONS. FROM THESE TWO DIVERSE EXPERIENCES COME SOME INTERESTING COMPARISONS. THE RIGID APPROACH OF MILITARY ORIENTED RELIABILITY EFFORTS PAYS DIVIDENDS; BUT SO TOO DOES THE LESS STRUCTURED APPROACH OF RELIABILITY EFFORTS APPLIED IN THE COMMERCIAL ENVIRONMENT.

AUTHORS
CARRUBBA, E.R.

Key Words:

AD/LD Order No:
Proprietary Code: None

Publication Date: 93/05/06 RAC Owner/Location/DAN: RAC/REF/27995-006

TITLE

A NEW APPROACH TO RELIABILITY OF COMMERCIAL AND MILITARY AEROSPACE PRODUCTS:
BEYOND MILITARY QUALITY/RELIABILITY STANDARDS

Journal Name: QUALITY AND RELIABILITY ENGINEERING Vol.: 9 No.: 3 Pages: 211-215

Sponsoring Agency Name: ELDEC CORPORATION Document No.: Contract Number:

Performing Agency Name: JOHN WILEY & SONS, LTD. Document No.:

ABSTRACT

RECENT CHANGES IN THE COMMERCIAL AND MILITARY AEROSPACE INDUSTRIES HAVE CAUSED US TO QUESTION THE TRADITIONAL WAYS OF MEASURING, PREDICTING AND ASSURING PRODUCT RELIABILITY. THESE INDUSTRIES HAVE BEEN UNIQUE IN THAT BOTH QUALITY AND RELIABILITY HAVE BEEN ALMOST COMPLETELY CONTROLLED BY GOVERNMENT STANDARDS, A CONDITION THAT WILL NOT SURVIVE THE CURRENT UPHEAVAL IN THESE MARKETS. TRADITIONAL RELIABILITY PREDICTION METHODS FOR MILITARY AND COMMERCIAL AEROSPACE PRODUCTS USE A PROBABILISTIC APPROACH, SUCH AS THAT OF MIL-HDBK-217, AND RELIABILITY ASSURANCE RELIES ON FIXED QUALITY LEVELS IN DESIGN.

AUTHORS
KROMHOLTZ, G.A.
CONDRA, J.W.

Key Words:

AD/LD Order No:
Proprietary Code: None

Publication Date: 93/05/06 RAC Owner/Location/DAN: RAC/REF/27995-001

TITLE

QUALITY AND RELIABILITY: ILLUSIONS AND REALITIES

Journal Name: QUALITY AND RELIABILITY ENGINEERING Vol.: 9 No.: 3 Pages: 163-168

Sponsoring Agency Name: BRITISH RAIL RESEARCH Document No.: Contract Number:

Performing Agency Name: JOHN WILEY & SONS, LTD.

Document No.:

ABSTRACT

THE PAPER REVIEWS THE ROLE OF QUANTITATIVE AND 'SYSTEMS' METHODS THAT HAVE BEEN DEVELOPED, AND IN MANY CASES STANDARDIZED, FOR APPLICATION IN QUALITY ASSURANCE AND RELIABILITY ENGINEERING. IT PROPOSES THAT THESE SHOULD BE DISCARDED IN FAVOR OF A RETURN TO TRADITIONAL ENGINEERING AND MANAGEMENT VALUES, AND EMPHASIS ON THE METHODS THAT HAVE DRIVEN THE QUALITY REVOLUTION. THESE INCLUDE THE USE OF STATISTICAL METHODS FOR PREVENTING FAILURE AND FOR OPTIMISING DESIGNS AND PROCESSES.

AUTHORS

O'CONNOR, P.D.T.

Key Words:

AD/LD Order No:

Proprietary Code: None

Publication Date: 93/11/00 RAC Owner/Location/DAN: RAC/REF/28531-001

TITLE

A QUALITY PROCESS APPROACH TO ELECTRONIC SYSTEM RELIABILITY: HANDBOOK PROCEDURE

Journal Name: Vol: No.: 1993 Pages

Sponsoring Agency Name: ROME LABORATORY

Performing Agency Name: McDonnell Douglas

Document No.: RL-TR-93-209

AUTHORS

HUGGE, P.B.

JOHNSON, R.R.

MALMBERG, E.B.

ABSTRACT

THIS HANDBOOK DEFINES A APPROACH TO RELIABILITY ASSURANCE AND CONTROL BASED ON PRINCIPLES OF TOTAL QUALITY MANAGEMENT. THE NEW APPROACH IS PROCESS ORIENTED WITH THE ELEMENTS OF THE PROCESS TAILORED TO EACH DOD ACQUISITION PHASE. THE HANDBOOK PROVIDES, FOR EACH ACQUISITION PHASE, A TIME PHASED DESCRIPTION OF ALL CRITICAL ACTIVITIES NECESSARY FOR REDUCTION AND ELIMINATION OF ALL POTENTIAL PRODUCT AND PROCESS DEFECTS. FOR EACH CRITICAL ACTIVITY, RELEVANT INPUTS, OUTPUTS, CUSTOMERS AND SUPPLIERS ARE DEFINED.

Key Words:

AD/LD Order No:
Proprietary Code: None

Publication Date: 86/03/00 RAC Owner/Location/DAN: RAC/REF/20855-000

TITLE

BEST PRACTICES - HOW TO AVOID SUPRISSES IN THE WORLD'S MOST COMPLICATED TECHNICAL PROCESS

Performing Agency Name: US NAVY

Document No.: NAVSO P-6071
ABSTRACT

AUTHORS

PATTERSON,D.O.
GILLS,L.C.
LAVERSA,M.J.

WEAPON SYSTEM DESIGN, TEST, AND PRODUCTION CONSTITUTE THE WORLD'S MOST COMPLICATED TECHNICAL PROCESS. MOST NEW WEAPON SYSTEMS WASTE OPERATOR'S TIME AND TAXPAYERS' MONEY WITH EXCESSIVE MAINTENANCE AND LOGISTICS SUPPORT, WHILE REDUCING THE READINESS OF OUR NATION'S DEFENSES. THIS SAYS THAT PROJECT MANAGERS, AND THE HIERARCHY OF MANAGEMENT ABOVE THEM, CLEAR TO THE TOP - GOVERNMENT AND CONTRACTOR ALIKE - DON'T UNDERSTAND AND PROPERLY MANAGE THE TECHNICAL PROCESS OF WEAPON SYSTEM PROCUREMENT.

Key Words:

AD/LD Order No:
Proprietary Code: None

Publication Date: 93/07/00 RAC Owner/Location/DAN: RAC/REF/28500-000

TITLE

STRATEGIC BENCHMARKING

AUTHOR

WATSON, G.H.

Journal Name: SANDVIEW EXECUTIVE SUMMARIES

Vol.: 15 No.: 7, Part 2 Pages: 1-8

Performing Agency Name:

Document No.:

ABSTRACT

IN TODAY'S FAST-PACED BUSINESS WORLD, YOUR QUALITY-IMPROVEMENT STRATEGIES MUST MAKE SENSE, WORK QUICKLY, AND PAY OFF. IF YOU'RE LOOKING FOR AN EFFECTIVE WAY TO BOOST QUALITY AND MAXIMIZE COMPETITIVENESS, LOOK NO FURTHER THAN THIS SUMMARY. IT TELLS YOU HOW THE MEASUREMENT-AND-COMPARISON PROCESS CALLED BENCHMARKING CAN DELIVER THE BOTTOM-LINE RESULTS YOU WANT.

Key Words:

AD/LD Order No: Publication Date: 93/06/00 RAC Owner/Location/DAN: RAC/REF/28495-000
Proprietary Code: None

TITLE

BENCHMARKING: THE NEXT GENERATION

AUTHOR
ETTORRE, B.

Journal Name: MANAGEMENT REVIEW Vol.: No.: 1993 Pages: 11-16
Performing Agency Name: Document No.:

ABSTRACT

EVEN AS BENCHMARKING MOMENTUM BUILDS AMONG U.S. COMPANIES, INNOVATIVE AND EXPERIENCED
BENCHMARKERS ALREADY HAVE LEFT THE CONVENTIONAL HERD IN THE DUST.

Key Words:

AD/LD Order No: Publication Date: 92/00/00 RAC Owner/Location/DAN: RAC/REF/28539
Proprietary Code: None

TITLE

INTERNATIONAL QUALITY STUDY: AUTOMOTIVE INDUSTRY REPORT

AUTHOR
ANONYMOUS

Sponsoring Agency Name: AMERICAN QUALITY FOUNDATION
Performing Agency Name: ERNST & YOUNG

Document No.: Score Retrieval File No. A49013
ABSTRACT

IDENTIFIES AREAS WHERE TRENDS SHOW SIGNIFICANT CURRENT AND FUTURE ADOPTION OF QUALITY PRACTICES WITHIN THE
AUTOMOTIVE INDUSTRY. ADDRESSES QUALITY TOOLS, STRATEGIES, PRODUCT DEVELOPMENT, AND ORGANIZATIONAL ISSUES.

Key Words:

AD/LD Order No: Publication Date: 92/05/12 RAC Owner/Location/DAN: RAC/REF/RAC 28646
Proprietary Code: None

TITLE

FIRST PRINCIPLES OF CONCURRENT ENGINEERING: A COMPETITIVE STRATEGY FOR PRODUCT DEVELOPMENT
Performing Agency Name: CALS/CONCURRENT ENGINEERING WORKING GROUP - ELECTRONIC SYSTEMS

Document No.:
ABSTRACT

AUTHOR
LINTON, LARRY ET AL

THE INTENT OF THIS DOCUMENT IS GIVE COMPANIES INTERESTED IN IMPLEMENTING CONCURRENT ENGINEERING SPECIFIC INSIGHT INTO
HOW TO GET STARTED. IT IS INTENDED TO BE A LIVING DOCUMENT AND TO BE PERIODICALLY UPDATED AS MORE INFORMATION
BECOMES AVAILABLE.

Key Words:

AD/LD Order No: Publication Date: 89/00/00 RAC Owner/Location/DAN: RAC/REF/RAC 28737-000
Proprietary Code: None

TITLE
ADVANCED QUALITY SYSTEM (AQS) FOR BOEING SUPPLIERS

Performing Agency Name: THE BOEING COMPANY

APPROVED BY: AUTHOR
BOGASH R. A.
BLUE J. A.

Document No.D1-9000

ABSTRACT

THE D1-9000 DESCRIBES A NEW STANDARD BEING INTRODUCED BY BOEING. IT REPLACES A MORE CONVENTIONAL QUALITY STANDARD AND NOW PLACES THE BURDEN OF QUALITY DIRECTLY UPON THE PRODUCING ORGANIZATION RATHER THAN INDEPENDENT INSPECTION GROUPS. QUALITY IS NO LONGER MEASURED IN TERMS OF THE PERCENTAGE OF DEFECTIVE PRODUCTS ALONE, BUT RATHER IN TERMS OF VARIATION FROM NOMINAL DIMENSIONS. THE GOAL IS TO MINIMIZE PRODUCT VARIATION.

Key Words:

AD/LD Order No: Publication Date: 91/00/00 RAC Owner/Location/DAN: RAC/REF/RAC 28738-000
Proprietary Code: None

TITLE

ADVANCED QUALITY SYSTEM (AQS) TRAINING - INTRODUCTION TO D1-9000 FOR BOEING SUPPLIERS
Performing Agency Name: THE BOEING COMPANY

AUTHOR

Document No. D6-56151

ABSTRACT

A TRAINING MANUAL FOR THE BOEING ADVANCED QUALITY SYSTEM D1-9000. MAJOR SECTIONS INCLUDE: INTRODUCING ADVANCED QUALITY, ADVANCED QUALITY CONCEPTS, D1-9000 DOCUMENT DESIGN, AQS IMPLEMENTATION PLAN, AQS PROCEDURES, APPROVAL REQUIREMENTS, AQS TRAINING, 777 DIRECTION AND STATUS, MESSAGE FROM PROCUREMENT.

Key Words:

AD/LD Order No: Publication Date: 91/00/00 RAC Owner/Location/DAN: RAC/REF/RAC 28739-000
Proprietary Code: None

TITLE

ADVANCED QUALITY SYSTEM (AQS) KEY CHARACTERISTICS - THE FIRST STEP TO ADVANCED QUALITY
Performing Agency Name: THE BOEING COMPANY

AUTHOR

Document No.D1-9000

ABSTRACT

THIS BOOKLET DISCUSSES "KEY CHARACTERISTICS," THEIR IDENTIFICATION, FLOWDOWN TO THE PART LEVEL AND THEIR ULTIMATE USE IN KEY PROCESS CONTROL TO ACHIEVE SUPERIOR QUALITY.

APPENDIX B

SECTION 2

Literature Search Summary - Selected References

Literature Search Summary - Selected References

Source	Title/Author	Summary
RAC 17297-051	Commercial vs. DoD Reliability Programs	<i>Typical Military Reliability Program:</i> <ul style="list-style-type: none">- Completeness of reliability requirements directly from customer to contractor- Emphasis on tasks which measure reliability- Concern for parts reliability- Preparation for, and participation in, customer run design reviews- Detection and correction of test failures through a closed-loop process- Minimum of involvement after product turnover to customer- Preponderance of data items
1981 RAM Symposium	Carrubba, E. R.	<i>Typical Commercial Reliability Program:</i> <ul style="list-style-type: none">- Incompleteness of reliability requirements from customer to "contractor"- Internally developed reliability requirements- Downplaying of structured front-end reliability tasks- Emphasis on informal and formal design reviews- Emphasis on rigorous design development testing, including reliability demonstration/verification testing- Maximum of post-delivery customer contact- Generation of documentation for internal use

Literature Search Summary - Selected References

- | | | |
|--|---|---|
| <p>RAC 25611</p> <p>GAO/NSIAD-91-190</p> <p>May 1991</p> | <p>US. Companies Improve Performance Through Quality Efforts</p> <p>Mendelowitz, A. I.</p> | <p>Many different kinds of companies benefited from specific TQM practices. However, none of the companies reaped those benefits immediately. Benefits reaped:</p> <ul style="list-style-type: none"> - Somewhat better employee relations were realized - Improved quality and lower cost were attained - Greater customer satisfaction was accomplished - Improved market share and profitability were attained <p>No "cookbook" approach was used in implementing a successful TQM system but they had common features:</p> <ul style="list-style-type: none"> - Corporate attention was focused on meeting customer requirements - Senior management led the way in building quality values into company operations - All employees were suitably trained, empowered, and involved in efforts to continuously improve quality and reduce costs - Systematic processes were integrated throughout the organization to foster continuous improvement <p>TQM is as useful for small companies(500< employees) as large and for service companies as well as manufacturers</p> |
| <p>RAC 26182</p> <p>SAE Second Edition 1992</p> | <p>RMS Reliability, Maintainability, and Supportability Guidebook</p> <p>SAE International</p> <p>RMS Committee (G-11)</p> <p>Stracener, J.T. Managing Editor</p> | <p>This guidebook provides a stand-alone source of general information and standardized descriptions of reliability, maintainability and supportability tasks. It establishes a forum for identification and distribution of current and emerging technologies and guidance, a roadmap to sources of "how to" information.</p> <p>Although the guidebook reflects, to a large extent, aerospace and defense specifications, standards, technology and practices, it is intended to be applicable to all industry and government sectors as well as academia. Integration and coordination of individual RMS elements is stressed.</p> |

Literature Search Summary - Selected References

RAC 27844 NASA Technical Memorandum 4322 Sept. 1991	NASA Reliability and Maintainability Steering Committee	Document summarizes reliability experience from both NASA and industry and represent the "best technical advice" that NASA has to offer. It consists of two major sections: a) Reliability Practices that have been successfully applied on previous space flight programs and b) Design Guidelines / Handbooks techniques currently applied to space flight projects.
	Design Practices Address:	
	1100 Environmental Considerations	1200 Engineering Design
	1300 Analytical Procedures	1400 Test Elements
	Design Guidelines / Handbooks Address:	
	2100 Environmental	2200 Design
	2300 Analysis	2400 Test
RAC 28152 Marcel Dekker Inc. © 1993	Reliability Improvement with Design of Experiments Condra, L. W.	<p>Purpose of the publication - To familiarize the reader with the terms and structure of a designed experiment.</p> <p>Definition: Designed Experiment - A technique to obtain and organize the maximum amount of <i>conclusive</i> information from the minimum amount of work, time, energy money, or other limited resource.</p> <p>Two main types of DOE: Classical and Taguchi Arrays.</p> <p>Basic concepts: Statistical Process Control (SPC), <i>Controllable</i> verses <i>Uncontrollable factors</i>, interactions, analysis of variance (ANOVA) and Signal-to-Noise ratio.</p> <p>Three types of experiments: one-factor-at-a-time, full factorial, and fractional factorial</p> <p>This survey of 20 electronic manufacturers in the Pacific northwest was designed to measure the perceived effectiveness of 26 reliability tasks. Development Testing, Failure Reporting and Corrective Action, Durability Analysis and Reliability Testing received the highest rating. Reliability Qualification Testing, Sneak Circuit Analysis and Reliability Prediction received the lowest rating.</p>
RAC 28228 (Private Survey)	Reliability Task Effectiveness Survey Results Lindsley, M.L., © 1993	

RAC 27257-031	Next Generation Commercial Airplanes: Reliability for Airline Economics (Panel Discussion)	Service Ready Approach to Dependability Key, L.W., Boeing Commercial Airplane Group, Seattle, WA
1993 RAM Symposium		First Step....understand the nature of maintenance actions and identify their root causes. Only flight critical messages should be displayed to the flight crew; maintenance related messages should be stored for the scheduled maintenance crew.
		New Technology Reliability Mancini, L.J., Northwest Airlines, ST. Paul, MN
		FAA Advisory Circular 120-17A "Maintenance Control by Reliability Methods" needs revision to reflect today's technology.
		Airlines and regulatory authorities must be involved in the early design stages of aircraft. An ATA sponsored working group has been formed to address reliability requirements, not just safety related, but passenger comfort and overall airline operational requirements. They are developing a new FAA advisory Circular that addresses more flexible reliability requirements.
		Third and forth generation aircraft provide us with technologies which allow us to anticipate problems and take proactive corrective action.
		An Airline's Operational Reliability Needs - Now and Tomorrow May, C.J., Delta Airlines, Inc. Atlanta, GA
		Spares costs on a unit basis have risen 100% to 200%. The consideration should be "What can I eliminate and what can I make simpler without affecting safety?" Approximately one in five of the commercial aircraft flying today has exceeded its original design life. We must also use new technology to improve older aircraft.
RAC 28012 Marcel Dekker Inc. © 1988	New Directions for Reliability King, J.R.	Discussion of assumption of constant failure rate. Ends with five "rules of thumb" which author calls conclusions: <ul style="list-style-type: none"> - Follow careful design practices - Question concepts of random failures and constant failure rate - Select and use only best available parts - Constantly monitor in-process fallout and conduct intensive failure analysis - Use simple graphics to measure and demonstrate reliability status

Literature Search Summary - Selected References

- | | | |
|-------------------------|---|--|
| RAC 18504-035 | Reliability Self Assessment
Warr, R.E. | General outline of GE, Bridgeport, internal reliability audit program. References a G E reliability practice baseline. |
| 1985 RAMS Symposium | | |
| RAC 28531-001, 002, 003 | A Quality Process Approach to Electronic System Reliability, Handbook and Vol. I & II | This handbook provides guidance for the implementation of a process for reliability assurance, incorporating the principles and practices of quality management. It gives a time-phased description of the activities, their inputs and outputs, and the tracking metrics recommended for a quality management based approach, usable by both DoD managers and DoD contractors. |
| RL-TR-93-209 | Hugge, P.B., McDonnell Aircraft & Johnson, R.R., & Malmberg, E.B., Hughes Radar Systems Group | The guide embraces the two basic principles of TQM: Customer Satisfaction and Continuous Improvement i.e., identifying the needs of the customer and translating them into product design requirements in a systematic and comprehensive manner. This requires that the design and manufacturing processes be clearly defined and understood, that employees be adequately trained and empowered to improve these processes through benchmarking. |
| | | Value-added tasks from MIL-STD-785 such as planning, supplier control, development testing, stress screening and FRACAS are retained with additional emphasis upon self-test functions and variability of parts and manufacturing processes. Requirements for quantitative predictions are also retained but expand the focus of both prediction and prevention to include defects arising from all sources. The guide is intended to be implemented by the actions of a multidiscipline team. |
| | | The Electronic Parts/Circuits Tolerance Analyses task from MIL-STD-485 has been retained and expanded to encompass variability control, both in design and manufacturing using the "Six Sigma" concept as a benchmark. |
| | | Volume One of the handbook defines the details of the reliability process while Volume Two contains certification and Audit procedures patterned after the Malcolm Baldrige Award criteria. |

<p>RAC 28206 John Wiley & Sons © 1992</p>	<p>Reliability, Availability, Maintainability and Safety Assessment</p>	<p>This publication deals with reliability from the perspective of electrical utilities and particularly nuclear power plants. It consists of two volumes: Volume 1 - Methods and Techniques, and Volume 2 - Assessment, Hardware, Software and Human Factors.</p>
<p>Villemeur, A. <i>Electricite' de France</i> Translators: Cartier, A., Lartisien, M.</p>	<p></p>	<p>The main reliability techniques discussed in Volume I include: Preliminary Hazard Analysis (PHA), FMEA, Success Diagram Method (SDM), Cause Tree Method (CTM), Truth Table Method (TTM), Gathered Fault Combination Method (GFCM), Consequence Tree Method (CQTM), Cause-Consequence Diagram Method (CCDM), and State-Space Method (SSM).</p>
<p></p>	<p></p>	<p>The specific topics discussed in Volume II include: Dependent and Common-Cause Failures, Human Factors, Mechanics, Software Domain, Assessing Safety, Computerized Methods, and Dependability Assessment.</p>
<p>RAC 28010 Zytec Quality, Reliability & Training Feb. 1991</p>	<p>Quality, Reliability, & Training Schmidt, T.R.D.</p>	<p>Overview of Zytec Quality, Reliability, & Training</p> <p>Design techniques:</p> <ul style="list-style-type: none"> - 217 Prediction, - Component quality, - Derating / stress analysis
<p></p>	<p></p>	<p>Product Quality Assurance techniques:</p> <ul style="list-style-type: none"> - Supplier program - Burn-in - ESS - ESD control - SPC - PRAT & life testing - DOE 781

Literature Search Summary - Selected References

RAC 28014 Quality Jan. 1993	Auto Industry Quality: Where are they going? Wolak, J.	Basically TQM Ranks relative importance of quality tools used in US auto industry. Relative importance is defined as percentage of companies indicating (in a survey), that a tool will be of primary importance in achieving future quality improvements. The tools are: - SPC: 55% - Histogram: 24% - Brainstorming: 20% - Scatter Diagrams: 4% - Pareto Analysis: 33% - QFD: 24% - DOE : 20% - Business Process Improvement: 33% - Cause and Effect Analysis: 22% - FMEA: 18%
RAC 28011 Quality Progress August 1983	Management Commitment to Quality: Xerox Corp. Pipp, F.J.	TQM , very general - Understand customers' existing and latent requirements - Provide both external and internal customers with products and services that meet their requirements - Employee involvement through participative problem solving - Error-free work is the most cost-effective way to improve quality
RAC 28013 Computers & Industrial Engineering Conference 1989	An Interactive, Knowledge - Based System for Forecasting New Product Reliability Nassar, S.M., Souder, W.E.	Basically a reliability growth model.
RAC 25842- 003 1992 RAMS Symposium	NASA Preferred Reliability- Practices for Design and Test Lisk , R.C.	General discussion of series of preferred practice documents. Also see 27844

Literature Search Summary - Selected References

RAC 25656-001	Benchmark Test - Typical Cases for RAM Tool Specification and Evaluation	A summary of some reliability problems facing utility engineers. Specific solutions to these problems, other than the general recommendation of benchmark testing of potential tools, are not addressed.
12th Inter RAM proceedings 1986	Yang, C.S., Miller, M.L., Long, A.B.	
RAC 18503-019	DOD / Industry - R&M Case Study Analysis	Summary of study made to identify new R&M concepts to incorporate in DOD approach or identify weakness in DOD approach
1984 RAMS Symposium	Goree, P.F., Musson, T.A.	<ul style="list-style-type: none"> - R&M requirements process weak - Development task must be properly funded as integral part of system baseline - Planned and funded maturation phase needed - Diagnostics important - Data / information. system archaic - Too much emphasis on mathematics vs. design in educational systems
RAC 22905	Automotive Electronic Reliability Prediction	MIL-HDBK-217 type model with pi factors based on automobile electronics failure data
SAE Technical Paper 870050	Denson, W.K., Priore, M.G.	Also see earlier SAE papers RAC 16645 & 21939.
RAC 27995-001	Quality and Reliability-Illusions and Realities	Criticism of AQL, Reliability Predictions, Reliability Demonstration, Reliability Models, and Quality & Reliability Standards (ISO 9000, MIL-STD-785, etc.).
Reliability Eng. & System Safety	O'Conner, P.D.T.	Emphasis should be on understanding and preventing failures.

Literature Search Summary - Selected References

RAC 27995-006	A New Approach to Reliability of Commercial and Military Aerospace Products: Beyond Military Quality / Reliability Standards	TQM	<ul style="list-style-type: none"> - Zero defects - Design-to-world-class - Process control - World class design practices
Quality & Reliability Eng. Int'l Vol. 9 1993	Kromholtz, G.A., Condra, L.W.	Eight steps of the physics-of-failure approach to product Quality and Reliability	
RAC 26335	An Introduction to Bellcore's Reliability and Quality Generic Requirements	Description of Bellcore's Reliability & Quality documents covering:	<ul style="list-style-type: none"> - Reliability program - Software R & Q - Inspection & measurement - Reliability prediction & modeling - Reliability physical design requirements. - Reliability component requirements
Technical Reference TR-NWT-000874 Issue 3, March 1991	Anonymous	Interesting historic perspective comparing the reliability techniques used in five different projects over a 30 year time span. The equipments involved include:	<ul style="list-style-type: none"> - 1936 police motorcycle radio - 1941 aircraft multichannel receiver-transmitter - 1945 Navy Lark missile - 1953 Sidewinder missile - Mercury and Gemini spacecraft - F-4 Phantom aircraft
RAC 20967-009	Winning Reliability Management Techniques - Vintage 1966		
1967 RAMS Symposium	Sumerlin, W. T. McDonnell Co.		
RAC 28233	Current Military Reliability Initiatives: An Overview	Overview of, and comparison between, various military initiatives based upon the 1983 DoD Directive 5000.40 "Reliability and Maintainability." These initiatives include:	<ul style="list-style-type: none"> - Air Force R & M 2000 - Navy's Best Practices "Transition from Development to Production" - Air Force ESD Readiness Improvements through Systems Engineering (RISE) Handbook - Air Force ASD Avionics Integrity Program (AVIP)
Test August / September 1989	Lindsley, M. L.		

RAC 28193-001	Tools of the Trade - Utility Application	A review of classical reliability engineering techniques as applied to the electrical utility industry. Techniques addressed include:
Inter-RAM Jun. 1990	Parascos, E. T. Con Edison, NY	<ul style="list-style-type: none"> - Reliability Centered Maintenance - Failure Mode & Effects Analysis - Fault Tree Analysis - Weibull Analysis - Reliability Purchase Specifications - Root Cause Analysis - Quality Function Deployment - Entropy - Minimax
RAC 24250-068	High Reliability in the Commercial Arena	Stresses a coordinated approach consisting of elements:
1989 RAMS Symposium	Bridgers, J. E. Codex Corp.	<ul style="list-style-type: none"> - Team (translation of classical parameters into usable parameters) - Technology (knowing the expected frequency of latent defects to optimize product flow and customer support) - Tools (optimum tool selection and application) - Resources (most effective utilization of available resources)
RAC 28209	Using Design of Experiments to Improve Product and Process Integrity	A prioritized listing of reliability tasks for a high reliability commercial project is also included.
1991 National Aerospace Electronics Conference	Condra, L., Lindsley, M.	The Air Force's Aviation Integrity Program (AVIP) requirements dictate that process capability and control be demonstrated, and that variability be minimized, before production can begin. Design of Experiments (DoE) is one of the few tools available to accomplish this. DoE is a structured method to obtain the maximum amount of work, time, energy, money, or other limited resource.
RAC 27257-070	Improvements in Avionics-Durability Analysis	A Taguchi experiment using inner and outer arrays is illustrated.
1993 RAMS Symposium	Followell, D., Fields, S., Liguore, S., Perez, R.	Description of testing associated with a software tool (ELIFE) designed to predict the fatigue life of solder joints, component leads and plated through holes. This is particularly important for surface mounted components since the solder joint is both the electrical interface and the main load bearing member. Both Thermal Fatigue (low cycle fatigue) and Dynamic Fatigue (high cycle fatigue) tests were used and compared to Finite Element Analysis (FEA) results.

RAC 27261-087	Design-for-Reliability Through Durability Analysis	Durability Analysis refers to a set or group of analyses that are performed to identify durability/reliability problems in avionic hardware and to predict life of the hardware for given design usage and environments. The techniques are derived from the AVIP program.
1991 RAMS Symposium	Bhagat, W.W., Tagg, B.A.	
RAC 28272	Lost in Space: Typical Benchmarking Problems	Author addresses six pertinent benchmarking questions:
Management Review Sept. 1993	Ogilvie, T.J.	<ul style="list-style-type: none"> - Is this a space that you should care about? - Are these points in the same plane? - What are the time dimensions in this space? - What are the boundaries of this space? - What is the customer dimension? - How do movements along one dimension affect related measurements? <p>Knowing certain benchmarking data are essential.</p> <ul style="list-style-type: none"> - Identify the critical processes - Define the metrics - Evaluate the process' maturity - Track historical performance trends

Literature Search Summary - Selected References

<p>RAC 28539 Ernst & Young © 1992 Score Retrieval File No. A49013</p>	<p>International Quality Study A Definitive Report on International Industry- Specific Quality Management Practices Automotive Industry Report</p>	<p>A detailed survey of the quality practices used by manufacturers in the automotive industry in four different countries: Canada, Germany, Japan and the United States. The report identifies areas where trends show significant current and future adoption of quality practices by many organizations within the industry. Some of the typical major findings include the following:</p>
		<ul style="list-style-type: none"> - Only Japanese companies are making extensive use of all process improvement techniques. Industrywide, "fewer customer complaints" is now the industry's chief measure of process improvement - In the US and Canada competitive bidding is, by far, the most frequently used selection strategy. In Germany and Japan technology considerations dominate supplier selection strategy. - The primary strategic areas in order of importance are: safety, reliability, performance and conformance to specifications. - Statistical process control is not the dominant tool used in Japan, but is the most predominantly used tool in Canada, Germany and the US.
<p>RAC 20855 NAVSO P- 6071 March 1986</p>	<p>Best Practices: How to Avoid Surprises in the World's Most Complicated Technical Process; The Transition from Development to Production Anonymous</p>	<p>Project managers must understand the technical and industrial processes involved, in terms of proven best practices. Various Critical Path "Templates" are presented each showing:</p> <ul style="list-style-type: none"> - "Traps" a brief definition of the topic - "Comparison Chart" comparing the consequences of current approaches to the benefit of best practices including both alarms and escapes - "Summary" a brief discussion of current and best practices - "Checklist" to aid in asking the right question

<p>RAC 28646 May 12, 1992</p>	<p>First Principles of Concurrent Engineering: A Competitive Strategy for Product Development</p> <p>CALS/Concurrent Engineering Working Group - Electronic Systems</p> <p>Linton, Larry et al</p>	<p>The intent of this document is give companies interested in implementing concurrent engineering specific insight into how to get started. It is intended to be a living document and to be periodically updated as more information becomes available. Specific topics in the document include:</p> <ul style="list-style-type: none"> - Recognizing the Problem - Understanding the Solution - Concurrent Engineering's Underlying first Principles - Concurrent Engineering Self-Assessment Criteria Matrix - Best Practices Templates - Evolution After Revolution: Enabling Tools and Technologies - Corporate Obstacles to CE Implementation
<p>RAC 28737 The Boeing Company © 1989</p>	<p>Advanced Quality System (AQS) for Boeing Suppliers</p> <p>D1-9000</p> <p>Approved by: Bogash R. A., Blue J. A.</p>	<p>The D1-9000 describes a new standard being introduced by Boeing. It replaces a more conventional quality standard and now places the burden of quality directly upon the producing organization rather than independent inspection groups. Quality is no longer measured in terms of the percentage of defective products alone, but rather in terms of variation from nominal dimensions. The goal is to minimize product variation. The producer must monitor quality over time by tracking the <i>key characteristics</i> that control the quality of finished products. The focus is placed on the process by which parts are made, rather than on the parts themselves. The quality of finished hardware is seen as a consequence of controlling these processes. Dependence upon mass inspection is no longer accepted as the preferred means of quality assurance.</p>
<p>RAC 28738 The Boeing Company © 1991</p>	<p>Advanced Quality System (AQS) Training - Introduction to D1-9000 for Boeing Suppliers</p> <p>D6-56151</p>	<p>A training manual for the Boeing Advanced Quality System D1-9000. Major sections include: Introducing Advanced Quality, Advanced Quality Concepts, D1-9000 Document Design, AQS Implementation Plan, AQS Procedures, Approval Requirements, AQS Training, 777 Direction and Status, Message from Procurement.</p>
<p>RAC 28739 The Boeing Company © 1991</p>	<p>Advanced Quality System (AQS) Key Characteristics - The First Step to Advanced Quality</p> <p>D6-56-55596 TN</p>	<p>The AQS focus is on reducing variation in each attribute of a product. Identification of the key characteristics of a product is an important element in the successful implementation of AQS. The identification of key characteristics enables the assurance of product quality with a much smaller commitment of resources than traditional defect detection based systems. This booklet discusses "Key Characteristics," their identification, flowdown to the part level and their ultimate use in key process control to achieve superior quality.</p>

APPENDIX C

SURVEY FORMS

This survey is being conducted by the Reliability Analysis Center (RAC), an Information Analysis Center (IAC) chartered by the Department of Defense (DoD) to serve as a government and industry focal point to improve the reliability, maintainability, and quality of manufactured components and systems.

DoD is concerned that its historic reliability and maintainability (R&M) standards, handbooks, and other documents do not adequately address the advanced R&M practices used by commercial industry. Thus, the RAC has been tasked to baseline how commercial industry, spurred by an increasingly competitive marketplace, is designing and producing systems to be reliable and easily and economically maintained.

DEFINITIONS

Terms used in this survey may not be universally defined among commercial and defense industries. For the purpose of this survey, the following definitions apply:

1. **Reliability.** The probability that a item will perform satisfactorily for at least a given time interval when used under specified conditions. May also be defined as: mission success probability (P_S), mean time between failure (MTBF), the time to failure, the rate of failure or failures per operating interval.
2. **Maintainability.** The probability that a failed item will be restored to operable condition in a specified time. It may also defined as: the time to restore a system mean time to repair (MTTR), maximum corrective down time, or the resources required to operate the system over a given time interval.
3. **Item life cycle Phases:**
 - a. **Phase 1, Development Phase** during which a concept is "translated" into a detailed design. Activities include design, trade studies, configuration management, development of technical data package, and development testing.
 - b. **Phase 2, Production Phase** during which the item is produced or manufactured. Activities include parts control, screening, process control, tooling, testing, and fabrication.
 - c. **Phase 3, Operational Phase** during which the system is used and/or maintained by the end use customer.

4. Specific R&M tasks.

- a. **FMECA.** Failure Modes, Effects, and Criticality Analysis.
- b. **FTA.** Fault Tree Analysis
- c. **TA.** Thermal Analysis.
- d. **SCA.** Sneak Circuit Analysis.
- e. **WCA.** Worst Case Analysis.
- f. **PRED.** Prediction of Reliability & Maintainability performance.
- g. **ALLOC.** Allocation of Reliability & Maintainability requirements to lower level equipments.
- h. **MODEL.** Reliability modeling (block diagrams, math models, etc.)
- i. **CENVIRON.** Characterization of Environment (operating, handling, transportation & storage)
- j. **DRs.** Design reviews.
- k. **PC.** Parts Control.
- l. **S/VC.** Subcontractor / Vendor Control
- m. **ESS.** Environmental Stress Screening.
- n. **TAAF.** Test, Analyze, and Fix.
- l. **RGT.** Reliability Growth Testing.
- p. **RQT.** Reliability Qualification Testing.
- q. **FRACAS.** Failure Reporting Analysis, and Corrective Action System.
- r. **MDEMO.** Maintainability Demonstration.

Given a choice, please indicate your selection by circling the appropriate response.

1. COMPANY NAME

2. COMPANY ADDRESS

3. COMPANY STANDARD INDUSTRIAL CODE (SIC) & MAJOR PRODUCT(S)

4. PRIMARY PRODUCT INFORMATION

a. Production volume (units per year): _____

b. Product Criticality: High (human life affected) _____

Moderate (property damage could result) _____

Low (safety not normally an issue) _____

c. Approximate Unit cost: _____

e. What governmental regulations apply regarding the sale, use, or safety of this product?

f. Are there applicable industry association (e.g. SAE, IEEE, EPRI, NEMA) guidance/policy documents. Y N

If Yes to either e or f, please explain. _____

5. PERSON COMPLETING THIS SURVEY.

a. Name _____

b. Title _____

c. Telephone No. _____ FAX No. _____

e. Mail Stop (if applicable) _____

- ## 6. R&M PROGRAM MANAGEMENT

- | | | |
|--|---|---|
| d. Are vendors and suppliers required to have a defined R&M program? | Y | N |
|--|---|---|

7. R & M TASK EFFECTIVENESS

- [illegible]

8. DoD Recognized R&M TASKS

For each of the tasks on the following page, indicate whether your company performs the task, its relative importance, whether the task is required by the customer (C) or company policy (P), and the phase(s) in which the task is performed.

TASK	PERFORMED?	IMPORTANCE Least Most	REQUIRED BY	PHASE
Failure Mode, Effects, and Criticality Analysis	Y N	1 2 3	C P	Product Develop Operat
Fault Tree Analysis	Y N	1 2 3	C P	Product Develop Operat
Thermal Analysis	Y N	1 2 3	C P	Product Develop Operat
Sneak Circuit Analysis	Y N	1 2 3	C P	Product Develop Operat
Worst Case Analysis	Y N	1 2 3	C P	Product Develop Operat
Parts Control	Y N	1 2 3	C P	Product Develop Operat
Subcontractor/Vendor Control	Y N	1 2 3	C P	Product Develop Operat
Derating	Y N	1 2 3	C P	Product Develop Operat
R & M Prediction	Y N	1 2 3	C P	Product Develop Operat
R & M Allocations	Y N	1 2 3	C P	Product Develop Operat
Reliability Modeling	Y N	1 2 3	C P	Product Develop Operat
Design Reviews	Y N	1 2 3	C P	Product Develop Operat
Failure Reporting, Analysis & Corrective Action System	Y N	1 2 3	C P	Product Develop Operat
Environmental Stress Screening	Y N	1 2 3	C P	Product Develop Operat
Test, Analyze, and Fix	Y N	1 2 3	C P	Product Develop Operat
Reliability Growth Test	Y N	1 2 3	C P	Product Develop Operat
Reliability Qualification Test	Y N	1 2 3	C P	Product Develop Operat
Maintainability Demonstration	Y N	1 2 3	C P	Product Develop Operat

9. ADDITIONAL TASKS

Section 8 listed R&M tasks frequently required by military specifications and standards. Please list and describe any other tasks your company requires and/or generally performs to ensure product R&M. Use additional sheets if needed. For each task, indicate its effectiveness (on a scale of 1 to 3, as before) and the phase(s) in which it is performed (again, circle the appropriate response).

Task 1: Description _____
Importance: 1 2 3 Phases: Development Production Operation

Task 2: Description _____
Importance: 1 2 3 Phases: Development Production Operation

Task 3: Description _____
Importance: 1 2 3 Phases: Development Production Operation

Task 4: Description _____
Importance: 1 2 3 Phases: Development Production Operation

10. TASK IMPLEMENTATION

Do you use any international, industrial or US government standards (STDs), handbooks (HDBKs), or models to implement any of the tasks from sections 8 and 9? Y N

If yes, please list the task number and corresponding applicable references.

<u>TASK No.</u>	<u>INTERNATIONAL / INDUSTRIAL / GOVERNMENT</u> <u>STD / HDBK / MODEL</u>
-----------------	---

Thank you for your help in this task by completing this survey form.

SERVICE COMPANIES

III. SURVEY QUESTIONNAIRE

Given a choice, please indicate your selection by circling the appropriate response.

1. COMPANY NAME

2. COMPANY ADDRESS

3. COMPANY STANDARD INDUSTRIAL CLASSIFICATION CODE & MAJOR PRODUCT(S)

4. PERSON COMPLETING THIS SURVEY.

a. Name _____

b. Title _____

c. Telephone No. _____

d. FAX No. _____

e. Mail Stop (if applicable) _____

f. Are **you** responsible for any or all aspects of product /service reliability? Y N ;
maintainability? Y N

5. R&M OF PRODUCT

a. Is there an organization within your company responsible for product/service R&M?

Y N

b. Do you communicate to your suppliers required levels of R&M for your equipment or specific R&M tasks that you want them to perform? Y N If you answered yes, please explain how you communicate these requirements (through specifications, interchange meetings, standards, etc.).

6. DoD Recognized R&M TASKS

If you do require that suppliers perform specific R&M tasks, please indicate which of the following are required, its relative importance, and why you require it

TASK	REQUIRED?		IMPORTANCE		
			Least		Most
FMECA	Y	N	1	2	3
FTA	Y	N	1	2	3
TA	Y	N	1	2	3
SCA	Y	N	1	2	3
WCA	Y	N	1	2	3
Parts Control	Y	N	1	2	3
Derating	Y	N	1	2	3
Predictions	Y	N	1	2	3
Allocation	Y	N	1	2	3
Modeling	Y	N	1	2	3
DRs	Y	N	1	2	3
FRACAS	Y	N	1	2	3
ESS	Y	N	1	2	3
TAAF	Y	N	1	2	3
RGT	Y	N	1	2	3
RQT	Y	N	1	2	3
MDEMO	Y	N	1	2	3
S/VC	Y	N	1	2	3

7. ADDITIONAL TASKS

Please list and describe any other tasks your company requires to address product R&M. Use additional sheets of paper if needed. For each task, indicate its performance (on a scale of 1 to 3 as before).

Task 1: Description _____
Importance 1 2 3

Task 2: Description _____
Importance 1 2 3

Task 3: Description _____
Importance 1 2 3

Task 4: Description _____
Importance 1 2 3

8. TASK EFFECTIVENESS

a. Do you measure the effectiveness or value-added of the R&M tasks or levels you require? Y N

b. If you answered Yes to 8a, please explain how you measure effectiveness or value added.

9. TASK IMPLEMENTATION

If yes, please list the task and corresponding applicable references.

INTERNATIONAL/INDUSTRIAL/GOVERNMENT
STD/HDBK/MODEL

Thank you your help in this task by completing this survey form.

APPENDIX D

INTERVIEW QUESTIONS AND NOTES

Section 1: Interview Questions

Section 2: Notes

APPENDIX D

SECTION 1

Interview Questions

INTERVIEW QUESTIONS
FOR ON-SITE VISITS IN SUPPORT OF
BENCHMARKING OF COMMERCIAL R&M PRACTICES

Section 1.-Customer Relationships

1. Broadly identify your product line. **Define "failure"** in the context of your equipment. What are the **consequences** of "failure"?
2. Do you **sell to the end user or to an intermediary** (OEM, etc.)?
3. Are your products standard catalog items, or is customization involved? To **what level of detail do customers specify** the product in their orders?
4. **Are you responsible for maintenance or repair** of products in any way? Is there an express or implied warranty? If so, who does warranty repairs? **How are warranty costs tracked?** Are repair costs factored into product pricing? **Are designers taught to consider maintenance** in their designs?
5. Discuss the typical **customer relationship**. Is your company pre-qualified by audit or other means? Does the customer inspect or audit production or design? **What documentation is required by the customer** along with the product? How is your delivered product inspected by the customer prior to acceptance? How does quality or reliability affect your status as a supplier?
6. Discuss what happens when a customer is unhappy with your product. How is the problem identified by the customer? How (who) do they notify your company ? What is expected of your company to correct the problem?
7. How much feedback do you get regarding field performance of your product? Do you have a field performance database? Do you perform failure analysis on failed units? How is this knowledge fed back to design/manufacturing?

INTERVIEW QUESTIONS
FOR ON-SITE VISITS IN SUPPORT OF
BENCHMARKING OF COMMERCIAL R&M PRACTICES

Section 2.-Product Engineering Practices

1. In your company, **who is ultimately responsible** for the quality and reliability of product? **How does this person manage** to achieve quality and reliability? What measures are used to **monitor performance**? How are these features monitored during Design? Production?
2. How does your company design its products, and the processes used to manufacture those products, to **reduce the chance or consequences** of failure during operation? What do you **name this aspect** of the system performance?
3. To what extent is your product design subject to government regulations? OSHA? FCC? UL? _____(other) Are you required, by any governmental **regulations or laws**, to address safety, quality or reliability of system performance?
4. Is this aspect of system performance **specified** by the customer?
 - a. If so, **how** and in what **terms** is it specified? **Monitored? Controlled?**
 - b. If not, what are the **incentives for addressing** this aspect of system performance?
5. How do you **communicate** reliability or quality aspects of system performance to your **design staff**? Your **manufacturing engineers**? Your **managers**? Your **customers**?
6. What **tasks** do you perform to **ensure the achievement** of this aspect of system performance?
 - a. Please explain **each task**:
 - 1) **What does the task entail?**
 - 2) **When is it done** in the product development cycle?
 - 3) **Who performs it?**
 - b. By what **criteria** are specific **tasks selected**?
 - c. **Who decides** that a specific task be performed?
 - d. How do you **measure the effectiveness** or value-added of a task or a group of tasks?
 - d. What **documentation** is generated in conjunction with these tasks?
 - e. For **what purpose** is this documentation generated?

INTERVIEW QUESTIONS
FOR ON-SITE VISITS IN SUPPORT OF
BENCHMARKING OF COMMERCIAL R&M PRACTICES

7. What area of **area of management** do these tasks fall within? Who controls the **budget** for these activities?
8. Describe the **integration of these task** with each other and with other areas of management (e.g., Design, Quality, Manufacturing, etc.)
9. Describe any system you use to obtain **failure information feedback** from your customers.
10. If any of the **tasks** you now perform are required by regulation, law, or the customer, which, if any, **would you not perform** if you had a choice (i.e., you see no value-added but perform them only because they are required)?
11. Do you **specify** this aspect of system performance **to your suppliers**?
 - a. **How** do you specify it?
 - b. How do you **measure their success** in meeting your requirements?

INTERVIEW QUESTIONS
FOR ON-SITE VISITS IN SUPPORT OF
BENCHMARKING OF COMMERCIAL R&M PRACTICES

Section 3.-Supplier Relationship and Controls

1. Explain how you manage quality and reliability of products purchased from suppliers. How is Q/R specified? measured? What happens when the quality of vendor product is unacceptable?
2. What audits or other assessments are performed in order to qualify a potential supplier?
3. What documentation is required with a product to support Q/R/Safety of the product?

APPENDIX D

SECTION 2

Notes

Summary of Interview of Company A Representative(s). This company's products are sold to distributors who sell to the end customers. The company's greatest challenge is converting the voice of the customer into a design. Specifications are developed internally based on customer surveys, warranty data, benchmarking of competitors' products, and dedicated service testing. Failures are defined as any incident that causes the customer to bring the product in for service. Reliability is a key design requirement. Warranty data resulting from such "returns" are used in evaluating reliability as are the results of customer surveys. The latter are used to determine customer tolerances to a variety of performance features. Information from the surveys and warranty data is used to develop specifications. The interviewee(s) believes that the amount of data available from warranty repairs is more than sufficient, but the data are lacking in quality (i.e., improper codes, insufficient information on causes, etc.).

The interviewee(s) sees two facets of design: deterministic and probabilistic. In converting the voice of the customer, most engineers attempt to determine the effect of every cause, and the cause of every effect. This approach is deterministic and the basis for most engineering curricula. Statisticians, on the other hand, attempt to use probability to account for chance and unknowns. This representative(s) believes that a robust design philosophy is achievable only through a "dynamic tension" between statisticians and engineers (i.e., between deterministic design and probabilistic design). The result is probabilistic design. Besides probabilistic design (i.e., robust design), the following tasks were specifically mentioned as important to the company's design approach: benchmarking, Failure Modes and Effects Analysis (FMEA), design of experiments (DOE), life testing, development testing that is similar to growth testing, computer-aided design/manufacturing (CAD/CAM), Statistical Process Control (SPC), and concurrent engineering. Failure analysis of failed parts from the field is performed but is really too late for the fielded product; the information is best used to prevent failures in the next product. Competitors' products are torn down to establish benchmarks.

Products are developed using a four-phase approach: Concept Phase (0), Prototype Phase (1), Development Phase (2), and Production Phase (3). In the Concept Phase, normally 1 year, the engineers perform an FMEA and try to understand the physics of design. In the Prototype Phase, parametric design is done. Design of Experiments is used in Phase 2, Development, to fine tune the design and validate the FMEA. Finally, the product enters Production Phase in which SPC is a key tool used to ensure quality. Products are developed by teams and are under the direction of an Engineering Director (ED). The ED is responsible for the design and cost of the design. The ED reports to the Program Manager who has total responsibility for the vehicle, including manufacturing and warranty costs.

The development teams consist of representatives from engineering, drafting, purchasing, design, and manufacturing. This team approach is the company's version of concurrent engineering. A sophisticated CAD/CAM system is used to translate "art to part." Based on interpreting the voice of the customer and from fundamental physics, a disciplined system is used to identify the control characteristics that must be a part of the design (similar to Quality Function Deployment). Control characteristics are then translated into design parameters. The team's objectives are to achieve each control characteristic at the lowest cost; these objectives are called Targets of Excellence. The team approach results in good integration of safety, reliability, and quality. Reliability and quality are key considerations in every phase. Reliability of product and process is addressed, although the latter is relatively new, not fully developed, and secondary to the former.

Reliability predictions are performed early in Phase 0, using MIL-HDBK-217 for electronics. Allocations are not made; the emphasis is on design for reliability. To respond to the voice of the customer, the reliability requirements for each part are set so high that they cannot be measured (in a practical and economical sense) using statistical demonstrations. An FMEA is done at the system and component levels. Component-level FMEAs essentially are done once, not for each successive application of a component. The operating environment of each application is reviewed to ensure that the FMEA is still applicable. Duane's theories are considered too deterministic, so growth testing, in the traditional sense, is not performed. However, testing is done during Phase 0 to learn about the physics of failures associated with the design. Understanding the design as early as possible is critical because there is never enough money during design and because the cost of failures increases as the design progresses. Partly to create a design audit trail, but for primarily for liability reasons, all tasks are thoroughly documented.

Most of the design criteria come from internal specifications and standards. However, the company's products are subject to some government regulations. Some government-witnessed testing is required. No company "Reliability and Maintainability (R&M) Standards" exist; R&M can drive the design only through

the efforts of the design team and the direction of the EDs. For products sold in Europe, International Standards Organization (ISO) 9000 requirements must be met.

During production, SPC is the primary means of controlling product quality. Incoming inspections of parts and components are made or not made depending on the part or component and the supplier.

Success of reliability efforts is "measured" using the following criteria:

1. Number of repeat customers
2. Age of buyer (i.e., reaching intended market)
3. Number of incidents per product
4. Warranty costs and frequency (the latter is considered the most important of the two)
5. Number of maintenance-induced problems

The long-term goal of the company is to reduce the number of its suppliers and to establish long-term relationships with the "best" suppliers. Suppliers are required to meet the control characteristics developed by the company for the particular part or component. The best suppliers will be those who can satisfy the control characteristics at the lowest cost (thereby meeting the Targets of Excellence). Incoming inspections are still performed for selected parts and components, depending on the supplier. An objective of the company is to eliminate incoming inspections by working with the suppliers to certify processes and by establishing a level of confidence and trust.

Summary of Interview of Company B Representative(s). This world-wide manufacturing organization sells its products directly to customers and to customers through distributorships. Products are somewhat standard, but some highly customized products are produced. Specifications are driven by marketing research (and some benchmarking of competitors' products) and the end user. No standard method is used to specify product performance other than to attempt to stay one step ahead of the competition. In addition, specifications from Underwriters Laboratory (UL) and the government govern performance requirements of the products. Specifications for equipment manufactured in Europe are linked to ISO 9000.

The product development cycle is driven by market timing for a certain product and is the absolute responsibility of a project manager. The company has no policy on procedures for the development phase. Project managers can institute any method of development that they feel will guarantee project completion within the development time schedule. Testing and reliability engineering are two phases of development that are most often eliminated to meet the product development schedule. Extensive service commitment is very often instituted for a new product line to identify and correct problem areas as they occur in the field. Although certain reliability tasks were cited as being important, they are only sporadically included in product development efforts (especially true for the custom products). It is entirely up to the product manager whether to perform a specific analysis or test (for reliability or any other purpose). Furthermore, program managers are primarily schedule-driven. Poorly performing products are fielded to meet the schedule, with the performance problems addressed through service or engineering changes in the field.

The company rates the field performance of its product lines by the service cost associated with each line. The service call rate or frequency of service calls is of a much lesser importance. This method of evaluating field performance is focused on controlling warranty and service cost, not on increasing availability and reliability. Although increased attention to reliability during design would be an effective way of controlling service costs, most managers want to minimize development time. Frequent, low-cost repairs are favored over improving reliability. Even though the service cost may be low with this approach, the availability of the machine will be low and the frequency of failures an annoyance to the customer.

Analysis of failed items is rarely performed unless the complexity of the unit and cost of the repair begin driving up the service cost. Documentation of the service calls does not provide sufficient data to determine the cause of failure, and the interviewees gave no indication that post warranty field data are analyzed to any significant degree.

The Reliability Department is part of a larger organization responsible for overall quality assurance. Two individuals are responsible for providing R&M training to design groups throughout the company. These

individuals have a through understanding of reliability engineering and have access to a comprehensive reliability library.

Many of the Reliability Department's efforts are to promote its services. Staff members advertise and explain the value of their reliability services in the training courses. These training courses range from an introduction to the basics of reliability (e.g., mathematics, terminology, FMEA, statistics) to a nine-session course on testing practices and procedures. It is the intent of the Reliability Department to interest the various project teams in the reliability discipline and then provide support by applying advanced reliability tools and techniques to specific product development efforts. The decision to implement any (or no) reliability task is made solely by each project manager; in most cases no tasks are implemented. The underlying reason that reliability tasks are not usually implemented is that the project managers feel that reliability engineering adds cost and development time to the project without adding value. The project manager is responsible for product development within a schedule that is market driven. Schedule is the driving factor and an unreliable product will be "pushed out the door" to meet the schedule. Problems will be mitigated through good servicing or, in severe cases, will be solved through redesign.

The personnel of the quality assurance organization are often asked to participate in project development reviews, but their involvement is principally from a Quality Assurance perspective rather than a reliability perspective. In many cases these reviews provide the only opportunity for representatives of the Reliability Department to present and discuss reliability issues relating to the project development.

Reliability testing, when performed, is performed at the system level and is restricted to growth testing. Vendor-supplied components and products are selected based on performance parameters but are not subject to acceptance testing. Testing of vendor products is an area that a few of the reliability engineers are strongly encouraging be increased or imposed. Environmental Stress Screening (ESS) is used if problems are uncovered in field service (i.e., in a reactive mode) but is not a standard part of the production process.

The "Robust Design" theme is promoted throughout the company. The reliability engineers expressed the concern that the project managers believe that if they produce a robust design, reliability need not be addressed. This attitude is one reason R&M tasks are not implemented. We concluded that the relationship between R&M and robust design is not understood.

The company is attempting to limit the number of its suppliers, and preferred vendors lists are kept for the primary components. It was unclear what criteria are used for developing these lists.

Summary of Interview of Company C Representative(s). Company C's products are sold to private individuals and industrial users. Sales are made through independent dealers and distributorships and, in a few cases, directly to the end user. Products are normally standard or a custom integration of standard components, although a few genuinely custom products are developed from time to time.

Design and reliability (D&R) specifications for catalog products and components are developed internally using warranty data, market and customer surveys, feedback from the sales and service organization, and some failed-part analyses. Customers usually specify system-level design performance and features for build-to-order products. They do this by including "sophisticated" clauses in the contract. These clauses impose monetary penalties for failing to meet downtime and specify service call rates, uptime ratio, and availability. Internal specifications include Mean Time Between Failure (MTBF), unit failure rates, service call rates, design life, shipping and transportation requirements, and operating envelope. Also addressed are regulatory requirements imposed by governments. Selected customers are asked to help validate D&R specifications.

Concurrent engineering is implemented using product development teams. These teams are under the direction of a general manager who is responsible for all aspects of the product. This responsibility includes the requirement to budget for warranty costs. The motivation for designing for reliability is to make production start-up easy, reduce failure rates (and warranty costs), and reduce the number of "dead-on-arrivals." Reliability engineers are part of these teams. A centralized reliability organization supports these team engineers by providing training, tools, and general requirements and managing product test laboratories. Many of the same tasks from MIL-STD-785 are used during the design but there are significant differences in their application. For example, little documentation or review accompanies the implementation of tasks. The procedures for the tasks are tailored for the company's use (predictions are made using their own data base,

testing methods are company-developed, pass-fail testing is seldom used, and FMEAs are used to prioritize areas of risk). Mechanical component reliability predictions are made using probabilistic structural methods. Reliability engineers also use finite element analysis, boundary element analysis, rapid prototyping, and knowledge-based engineering tools.

For purchased items, a two-level supplier program is used. For major or critical components, the company maintains a "partnership" with two certified suppliers. For other components, only one supplier is maintained and not all of these suppliers will be certified. Audits are used to certify suppliers and certified suppliers must "sign off" on applications of their parts or components (i.e., concur that their part or component will not be overstressed in the planned operating environment). Incoming inspections are never made of products from certified suppliers.

Summary of Interview of Company D Representative(s). Company D's products are sold directly to original equipment manufactureres (OEMs). Standard and custom products are developed; custom products are developed for major updates to OEM systems and for entirely new system models. Customers stipulate the cost and schedule requirements for a product. Few, if any, design specifications are provided by customers. Performance requirements are usually functional in nature and stated in the context of existing or prior products (i.e., we need a product similar to the one used in our 1992 system but with 5% better performance). The design specification and design are defined and evolve together.

The company receives an abundance of performance data from end users through a central OEM computer. However, the data are not precise and contain "noise" due to inaccurate data recording. Failed products are returned from the OEMs' service department that repaired the system and are analyzed to determine the cause of failure. Some electronic units have a 50% retest OK rate. In general, tear-down analysis of failed components results in 10-90% "no trouble found." A failure in a product or process is defined as not meeting a requirement.

Products are developed through a hierarchy of Business, Product, and Project Teams that guide the product through a four-phase development process: Concept Phase (0), Design Validation Phase (1), Process Validation (2), and Production (3). The Business Team has high-level representatives from sales, marketing, engineering, and manufacturing. The Business Team has cost and schedule objectives, but it was unclear from the interview how funding and budgeting are handled. Each Business Team has several Product Teams. Each Product Team can have several Project Teams, each focusing on a specific component or design element. The membership of each Project Team consists of designers, design assurance engineers, and manufacturing representatives. Each team works at a different level of product assembly.

The design assurance engineer is responsible for reliability and related assurance disciplines. Usually, there is no specification, and "system" requirements are frequently given verbally by the customer. Requirements are not allocated to lower levels of assembly. No formal process has been established for the translation of requirements to specifications. Specifications evolve from the various analyses, especially sensitivity and "what if" analyses, and testing performed during the design and development process. No specific reliability requirements are institutionalized, and no central reliability organization exists. The vision is for a central design assurance office to provide matrix management support to individual product teams. The incentive to "do R&M" is that they believe providing products with high R&M provides a competitive advantage, and they want to avoid the costs of failures. A failure is defined as not meeting the requirement.

Product Teams use a variety of reliability tools, including Fault Tree Analysis, FMECA, and predictions. Predictions are useful in developing the specification. Service analysis, criticality analysis, and warranty prediction (i.e., predicting warranty costs and frequency) are also used. Past warranty data are used to assess the evolving design. No requirements or tools are mandated by corporate policy; guidelines are available to all product and project teams.

Until recently, little if any documentation was kept on reliability tasks. More is being kept, primarily because of the change to a competitive environment. This documentation is delivered with the product. The company has general procedures for various activities.

Product development is constrained by some Federal and state government regulations. In some cases, state regulations are more severe than those of the Federal Government.

Supplier assurance activities are centered on applying internal procedures externally. A mix of certification and incoming inspection is used, with products from certified suppliers receiving the least amount of inspection. The objective of the company is to reduce the number of suppliers and to establish long-term relationships (i.e., long-term contracts) with the remaining suppliers. It is also the company's objective to eliminate all incoming inspection by working with suppliers to certify processes and by establishing a level of confidence and trust. Suppliers are certified through an auditing procedure. The company has started validating its own parts and is beginning to validate supplier parts. Performance of parts is tracked over time and must be satisfactory for a supplier to remain certified.

Other information and opinions offered were:

- Movement toward design teams and concurrent engineering is essential.
- Design teams must be given a reliability perspective (as well as a cost, schedule, and performance perspective) early in a development program.
- Military procurement is marred by excessive paperwork and by duplicative effort.
- Failure modes and effects analyses should be used in developing test plans and evaluating safety.
- Failure mechanisms must be analyzed to develop accelerated test factors.
- Use of Bayesian statistics in assessing reliability needs to be explored and developed.
- Emphasis in testing should be on validation testing using accelerated test factors.

Summary of Interview with Company E Representative(s). This company's products are used by a wide variety of government, private, and public customers. The company has a larger share of the world market than any competitor. A finite number of models are produced, but a wide range of options is available to customers.

Commercial customers do not specify reliability or specific reliability tasks. They select a product based on their needs and come to the company based on its reputation and the historical performance of its products. As long as the reliability is within an acceptable range, cost or performance is the main customer concern. Some government regulations must be met before the product may be sold; however, these do not impose the equivalent of MIL-STD-785 or MIL-STD-781. The company characterizes the performance of its own products and those of its competition to determine the level of reliability needed to meet its strategy of building the world's most reliable product. In determining the reliability required, the company distinguishes between mission and logistics reliability.

Commercial products are warranted for a maximum calendar time or operating hours (the latter is prorated after a threshold number of hours). Concurrent warranties are provided by major suppliers, but customers need only go to the company for all warranty questions and problems. Extended warranties, up to a full life warranty, are available. Design problems are covered beyond the basic warranty period, essentially for the life of the product. Operators sometimes do some of their own maintenance. During the warranty period, the company reimburses customers for repairs made by or paid for by them. For serious problems, customers call the company's service center which will take appropriate action, including sending a technician. The warranty period is used to collect field performance data that are fed back to the design engineers. Items that fail or wear out during the warranty period are analyzed to determine the cause of failure or wear-out. Results of failure analysis are used to update and revise design standards. In addition, a team meets weekly to address customer service problems. The team is composed of representatives from Product Support, project management, engineering, quality, R&M, manufacturing, and warranty administration.

Multi-disciplined design-build teams (DBTs) are used for new designs. The DBT approach is the company's way of implementing the concept of concurrent engineering. A product development committee assigns a team leader, who may be from engineering, manufacturing, etc. The DBTs have representation from engineering, manufacturing, R&M, quality, and Product Support. A complete CAD/CAM system supports the DBTs, which address both the product design and manufacturing processes. According to the individual

interviewed, **the company's number one strategy for competing in the world marketplace is to make its product the world's most reliable.** In this context, mechanical fatigue is an important design concern. The basic philosophy for designing a reliable product is to make progressive, evolutionary changes to improve successive models. Seldom does the next model represent a leap in technology, performance, or design. Field experience is heavily relied on to identify both design deficiencies and preferred designs. New materials or technology are incorporated only after extensive testing. In designing for reliability, the DBTs use techniques and approaches not dissimilar in title from those often imposed on military contractors:

- failure modes and effects analysis (required prior to release of any drawings)
- allocation and prediction (including use of the David Taylor mechanical reliability prediction models)
- failure reporting and corrective action system
- dedicated reliability testing (data from all testing are used, however)

In many ways, however, these techniques and approaches are implemented for commercial customers in a way that differs from the implementation for government customers. Much of the required format, approval, and documentation associated with the imposition of a "government standards is absent in the commercial arena.

The effect on reliability of proposed design changes to parts is evaluated by the DBTs using a metric called the Reliability Characterization Number (RCN). This company-developed metric is a cumulative measure of the effects of a design change on reliability, safety, and cost. By using the RCN, proposed design changes are subjected to a mini-cost/benefit analysis before adoption. Specifics on the metric, how it is measured or predicted, etc., were not made available.

Another key to designing a reliable product is to analyze failures, especially field failures, to determine the root causes of failure and then to use the resulting information to make engineering and manufacturing changes and to update and revise corporate practices. Standardized practices (e.g., design manuals which specify design "rules," including R&M rules) are used throughout the company, but the word standardized may not mean exactly the same thing as for a company making only products for the government. In other words, much more tailoring and project-unique application of a procedure exist than are normally provided for in government contracts. Equally noteworthy, however, is that the company's design manuals often reference MIL-STDs. The MIL-STDs are considered good guidance but are not invoked as stringently as is done on military contracts.

Based on the company's assessment of the level of reliability required, reliability goals are set at the product level and allocated down to lower-levels. Predictions are used by the DBTs to evaluate progress toward meeting these goals. The "best" source data is used in making these predictions, preferably historical data or knowledge of similar products

Another indication of its emphasis on reliability is the company's Reliability Board. Constituted of vice president/director-level representatives from all programs and chaired by the Vice President of New Product Development, this board meets every two weeks to ensure that the reliability levels expected by customers are being achieved; to find solutions to customer, design, or manufacturing problems, and to identify processes needing improvement. Issues include needed training, parts selection and application, design rules, and manufacturing processes.

The company tries to hire either mature, experienced R&M engineers or young engineers who practical design experience. Reliability training done in-house is limited and given primarily for design engineers.

The company strives to establish long-term relationships with suppliers. Five-year production options are often used to establish these relationships and to foster a team concept. A supplier qualification program is used that includes site surveys, process qualification, process specifications, and product qualification. The stringency of the qualification process varies with the criticality of the parts or supplies being purchased. Second-sourcing is used whenever possible. MTBF requirements are included for some purchased products. An MTBF guarantee is used to enforce MTBF requirements and product data are used to measure compliance

with the guarantee. Emerging or identified reliability problems due to supplier parts are investigated and solved by a DBT working with the supplier in a team approach. Penalties for failing to meet a guaranteed MTBF include providing extra spares, repairing failed units at no cost, etc.

In closing, the individual added some personal observations, including the following two: commercial reliability plans and programs are more cost-effective than the government equivalents and yield results that are at least as good; and, specifying MIL-STD parts does not guarantee good parts.

Summary of Interview with Company F Representative(s). The products of this company account for a majority of the world market. Customers are involved in the development of new products; they can observe production and perform a rigorous inspection of every design and operating detail. Customers usually have few reliability requirements, and these are stated in operational terms. The specification value of each reliability requirement is developed through technical discussions held between the company and customers. The product has a that includes a reliability guarantee. Failure to meet the guarantee results in a penalty for the company. The guaranteed reliability begins at a baseline value and gradually increases each year to some "mature" value, thereby anticipating reliability growth.

Four major process areas are designated as key to the success of the company and constitute the acquisition cycle of the company's products. These areas are:

- Business Acquisition (sales, marketing, preliminary design)
- Definition (engineering design and drawings)
- Production
- Support (after-sales service provided by the Customer Service Division)

The company's goal in re-engineering its processes is to reduce build time, reduce engineering and manufacturing costs, and to maintain a technological/performance edge over its competition. Integrated Design/Build Teams (IDBTs) are the company's approach to implementing a concurrent engineering philosophy. A CAD system facilitates the design team approach. Each IDBT is headed up by a design engineer and has the following representation:

- Customer Service
- Tooling
- Reliability Engineering
- Customer
- Operations (manufacturing)
- Material
- Safety

The primary role of the reliability engineers on the IDBTs is to collect "facts and data" from operational experience, analyze the facts and data, and provide lessons-learned to the team. This experiential information is used in trade studies to avoid past problems through design changes. The reliability engineers also do the more traditional tasks, such as performing a FMECA. No "proof" documentation is supplied to customers. The only documentation of reliability tasks maintained is that required by government regulation and what is actually needed to get the job done. The design tools and activities used are:

- Accelerated testing (temperature and vibration).
- Markov analysis (transition from one state to another).
- Robust architecture and design.
- Fault Tree Analysis (performed on "very complex" systems).
- FMECA, usually on redundant systems. FMECA is on the critical design path. The use of FMECA's is not yet widespread but is gaining acceptance.
- FRACAS (in-service and manufacturing).
- No reliability or maintainability predictions (but see later paragraph on suppliers).

- DOE (used to identify key characteristics).

The objectives of reliability engineering are:

- Ensure safety
- Ensure that the product meets government requirements
- Reduce availability costs: determine where costs are and then design to reduce or eliminate.
- Use field data to determine (predict) failure frequency and to identify failure causes.

The company has recently embraced a corporate approach to quality based on the use of SPC on the manufacturing floor; and the identification of key product characteristics (DOE is identified as a key technique for this purpose). As a result of this quality approach, hardware variability (design and manufacturing) control is a major concern. Continuous Quality Improvement (CQI) is an active goal. They realized that their initial CQI efforts were focused on improving rework processes. The emphasis is now changing to that of eliminating rework. In an attempt to remain "world-class", the company benchmarks its competitors

The company emphasizes the importance of long-term, constructive relationships with suppliers. In general, the company attempts to remove constraints from suppliers and to help "keep them in business" as long as they keep the company happy (i.e., provide high quality supplies that allow the company to meet customer needs, and remain competitive, from a cost, quality, and technological perspective). The emphasis is on qualifying processes rather than on qualifying parts or product.

Few mandates are given to suppliers. Accelerated testing guidelines are given to suppliers, and they are required to provide a report to the respective IDBT(s) that identifies the approach used for accelerated testing and the results of that testing. However, they are not directed how to perform the accelerated testing. Suppliers are usually required to provide some prediction of reliability. The company's preference is that they use actual data to do this, but MIL-HDBK-217 predictions are acceptable.

The individual provided other opinions and anecdotal information during the discussion. Those opinions and information are provided here, without comment, as accurately as possible.

- Reliability engineering is transitioning from its historical role to one of facilitator and educator/trainer.
- The acquisition process in the commercial world is less structured than in the government. This allows the commercial world's process to be more timely, less expensive, and more effective. Commercial designers have almost total autonomy with little (if any) customer direction.
- The long-term, partner-oriented relationships being established in the commercial world between the customer and the contractor, and between the contractor and its subcontractors, is difficult to imagine in the government procurement world.
- Military specifications, standards, and handbooks are very useful resources but they must not be mandated. Mandating their use and lack of tailoring drives up costs, relieves the contractor of some responsibility for the outcome, and produces results with limited utility.
- "Black" programs for the military more closely approximate the commercial world. Security restrictions force streamlined procedures and team approaches. "Black" programs are thus more cost-effective and timely than open programs.
- MIL-HDBK-217 and its underlying assumptions, such as a constant failure rate, are not the problem. The problems lie in the fact that over the years they have promoted fallacious ideas. These fallacious ideas are that failures are inevitable, that equipment fails at random times, and that reliability can only be improved by running electronics cooler or by using better parts.

- Failures are preventable during the service life of an item.

Summary of Interview with Company G Representative(s). Company G has three principal product divisions. The first two divisions sell to both government and commercial customers while the third sells only to commercial customers. The company's products (presently numbering some several hundred active products) are primarily custom-designed products rather than standard catalogue items.

A failure is defined after delivery as "something that the customer identifies as not working and is subsequently confirmed by test." Before shipment, a failure is defined as any condition that prevents the product from meeting acceptance criteria.

Due to the sophisticated nature of the test equipment, repair is "depot-level." It is typically performed under a nominal warranty (calendar years); the trend, however, is toward longer warranty periods. Most customers specify a warranty period and an MTBF. When a failure occurs during the warranty period, the user does the initial diagnosis and returns the item in question to the company for repair. Most customers request a subsequent failure analysis report on the failure. Thus, an effective failure data base has been established by the company. Warranty costs are tracked and incorporated into the pricing structure. The company does not offer service contracts; after-warranty repair costs are charged to the customer on a case-by-case basis.

Individual product design teams are used except where small, multiple-product teams are more applicable. Each of the three product divisions has a different reliability structure. An important fact is that most customers are knowledgeable regarding reliability, especially with respect to risk. Some design teams are assigned dedicated reliability engineers, while other design teams have no specific reliability engineering support. In these cases, the design engineer (who has also been trained in reliability) is responsible for the product reliability.

Each division manager is responsible for both the quality and reliability of the division's products during design, production, and warranty. Reliability is important to the division managers because it affects both sales (more reliable products sell better) and warranty costs (more reliable products reduce the cost of a warranty). Both cost (price, warranty costs, etc.) and risk (loss of customers, liability, warranty costs in excess of projected, etc.) are the key concerns. Customers are involved in the product specification and design, and they actively audit the company's manufacturing process.

The keys to reliability are:

- Using proven technology
- Using processes proven off-line
- Performing life testing of their products
- Performing step-stress testing to determine margins

More attention is typically paid to commercial design than to a comparable government design because:

- The required turn-around time for commercial products is shorter.
- Commercial customers are more demanding when it comes to field performance and the degree to which they hold the company responsible for field performance.
- In the case of government customers, you only have to "build to spec." Commercial customers do not tell you how to do the job (i.e., few if any specs) and, therefore, assume no responsibility for the performance of the product.

As stated earlier, most customers specify a warranty period and an MTBF. Reliability predictions, based upon either field data (preferred) or MIL-HDBK-217¹, are used to estimate MTBF, but they are not used to make engineering judgments.

The product design teams determine which specific reliability tasks will be performed. Only those tasks that are determined to be "value-added" will be performed. A value-added task is one that prevents a product from being returned (for rework before delivery, or by the customer after delivery) or one required by the customer. FMECAs and fault tree analysis are usually performed only when specifically requested by the customer. FMECAs, when they are done, are done "off-line" rather than using the company's CAD/CAM system. Automated MIL-HDBK-217 reliability predictions are used. DOE is an important task used to structure testing.

Environmental testing, safety, and other issues related to reliability are the responsibility of organizations other than the reliability group. The degree to which coordination and integration of efforts among reliability, environmental testing, safety, quality², etc., varies from division to division and from design team to design team. The issue of coordinating and integrating related disciplines is one that those interviewed identified as needing improvement.

The company has found that their products are sensitive to the effectiveness of the manufacturing process. Including manufacturing in the design process has been an important part of the company's design team approach. Design verification testing also is intended to bring manufacturing into the design process. Incremental process improvement in the product/process development is emphasized. This process improvement frequently involves step stress testing. Testing is based upon understanding the operating environment and good engineering judgment. As already stated, DOE is used to help structure testing.

With the significant reductions in the number of quality and reliability personnel which the company has recently experienced, internal reliability education has become a major objective of the reliability organization. Formal reliability training, including design of experiments, has been established for reliability engineers, design engineers, and test engineers and has been presented to between over a hundred employees.

Customers are now very concerned with part selection and control. The focus is on qualifying families of parts for specific applications while auditing the distributors. The intent is to encourage suppliers to "buy into a design" rather than mandating requirements. The company has observed better response from subcontractors by specifying "when, what, and how much" than by specifying "how to."

Don't mandate specifications and standards. Military specifications and standards have significant utility as resources. The problem is how they are implemented; their value is lost when they are mandated. This problem is especially true as the requirements are flowed down by the contractor to the subcontractors. While there may be some flexibility between the government and the prime contractor, this flexibility is quickly lost as the detailed requirements are levied on successive layers of subcontractors. A meaningful flow-down of the customer's needs is needed, not detailed "how to do it" direction.

By specifying a lot of detail and mandating specifications, standards, and the use of specific handbooks, the government takes much of the responsibility off the contractor, who "merely builds to spec as directed." By specifying only results and leaving the "how to" to the contractor, the customer places the burden of responsibility for the design and the field results on the contractor.

Summary of Interview with Company H Representative(s). Company H produces industrial components for OEMs. The company is organized into four major businesses. The responses to our interview questions reflect operations within the largest of those businesses and would not necessarily reflect the operations of the others.

¹The interviewees stated that it is their experience that failure rates based upon field data are typically lower than MIL-HDBK-217 based failure rates.

²The Quality Office is responsible for the quality of both design and manufacturing processes but performs only an audit function.

The product is best characterized as semi-custom, because even though each EOM has his own unique requirements, there is also a large degree of commonality among the different products. OEMs add additional equipment to the product to produce a complete "system".

The major incentive for the company to consider reliability is that they are essentially marketing a "throw-away" component. Rework or repair is extremely expensive. Products are typically sold with a multiple-year warranty. However, because the products exhibit virtually no susceptibility to wear-out mechanisms, longer warranty periods would be of little value to the customer.

Much of the company's product development process has only been recently formalized. A lack of formal procedures and consistency led the company to institute changes to formalize the process and to mandate certain procedures. Concurrent engineering is not yet fully implemented but is a goal.

A project manager, an engineer from the Engineering Department, is assigned at the beginning of initial development of a product. This engineer is responsible for all aspects of the design, including reliability. At the point at which the design goes into production, responsibility shifts to manufacturing, although an engineering liaison continues to provide support. Engineering oversees testing, but Quality Assurance (QA) is responsible for conducting the tests. QA also analyzes field failures and provides the results to Engineering. Marketing is responsible for warranty costs and repairs.

The company's approach to achieving reliability emphasizes component design. This emphasis takes the form of the use of design rules, adequate design margins, and proper derating in designing components and in qualification testing of all key components. The product test program is based upon a variation matrix to determine what parameters are to be selected for control (i.e., key design characteristics). These key design characteristics are identified by each individual component engineer. As is frequently the case in specialized component manufacturing, the characterization and the control of the critical parameters of some materials used in the product is the most important contributing factor to its ultimate performance and reliability. Supplier control is, consequently, an important part of achieving high reliability. The specific testing approach for a given component is developed by the component engineer who uses experience to balance the cost of testing against the cost of failure. Cost of failure is measured not only in the economic impact but in diminished reputation and loss of customer confidence.

A product typically has a ten to twenty year design life, and the market life of a given design is three to five years. Some specific safety-related government requirements are levied on the product. Informal FMEAs are now done to the extent needed to verify that there are no single point failures. A Fault Tree Analysis is also performed to satisfy the UL requirement for a safety report. UL, Canadian Standards Association (CSA), and ISO specifications and standards are used rather than MIL-SPECs or MIL-STDs. In the case of user safety, the interviewee stated that the UL requirements are frequently more stringent than the comparable MIL-SPECs/STDs.

The product's reliability requirement is specified in terms of an MTBF; there are also maintainability requirements dealing with accessibility, fault isolation, and the tools and personnel required to perform a specific repair. Demonstrated compliance with these requirements is based on the analysis of field data, and this analysis is delivered to the customer. The OEM is responsible for repairs, with support from the company's field service which is provided at no cost during the warranty period (for warranted items, of course) and on a case-by-case basis thereafter. The company does not deal in maintenance contracts. Field failures occur primarily in the equipment added by the OEM, not in the company's product.

Purchased critical components are qualification tested, and critical suppliers must be qualified based on their processes and past performance. Suppliers are controlled primarily through performance specifications. Material suppliers provide documentation of material properties with the product. In cases where specialized testing by a supplier would be prohibitively expensive, the company accepts materials that have passed the supplier's standard tests. The company then either does more extensive sample testing or ensures that the design margins for the component in which the material is used are sufficient to allow for variations in the material. Although the company does a limited amount of sample testing for all suppliers, the major burden of proof usually is placed directly upon the supplier. Alternative sources are maintained to provide a competitive environment, but long-term supplier relationships are also encouraged.

Other information:

- the interviewee(s) would not advocate doing away with DOD standards and handbooks.
- the company has difficulty obtaining field performance data after the warranty period. They are working with the OEMs to improve this situation.

Summary of Interview with Company I Representative(s). In its world-wide facilities, this company manufactures millions of its product each year and sells to OEMs, retailers, and end users).

The product comes with a warranty (calendar year), the length of which depends on the market and customer. A company service organization provides toll-free telephone support to end customers. Defective products can be returned during the warranty period to service points. Defective products are repaired at the service point if the problem is simple to correct. Complicated repairs are done at one of the company's manufacturing facilities.

Product requirements come from three major sources: market research, competitive equipment analysis, and focus groups of end users. Some custom requirements may also be stipulated by OEMs. Those interviewed made it clear that the company's focus is on total customer satisfaction, so product performance requirements (what is needed) are externally driven. As will be discussed in the next section, the means of meeting these requirements (how to do it) are internally driven, and customers do not play a role in defining these means. Some government and other external forces, ISO 9000, for example, do dictate some requirements. For the most part, however, the company focuses on deriving product and process specifications and requirements from their understanding of the customers' performance requirements and their evaluation of the competition.

For large developments, a "focused team" is created with members from design, manufacturing, quality, marketing, and service. This focused team represents the company's implementation of the concept of concurrent engineering. Reliability engineers are assigned to the focused teams. However, it was emphasized that the reliability engineers provide technical assistance and guidance; the design engineers do the worst case analysis, prediction, and other analyses. When asked if the design team leader or another individual was explicitly held accountable for long-term success (e.g., has responsibility for budgeting for the warranty), it was stated that the company's culture had progressed to a point where "threats" were not needed to ensure quality up-front. Instead, the motivation for doing a quality job and producing a reliable product comes from knowing the performance of the competitions' products and the now-instinctive desire to satisfy the customer. However, all analyses are subject to peer review by a group not associated with the product in question. Long-term goals, technically and financially, are derived from the company's assessment of customers and competition.

Based on the assessment of the competition and the needs of the customers, product requirements, including reliability, are set. All requirements are documented in a Product Certification Book that is approved by the Quality organization. Also included in the Product Certification Book are specific reliability tasks, such as Worst Case Analysis, MIL-HDBK-217 parts count prediction, and Accelerated Life Testing (ALT). Reliability goals are usually stated as a fraction of a percent of failures per month for the product population (i.e., a failure rate). Closely associated with reliability, quality is measured in defects per unit. To achieve the reliability goal, the team uses MIL-HDBK-217 parts count predictions, worst case analysis, and extensive development testing. Root cause analysis is important to the company and the development testing is intended to reveal any weaknesses under all conditions that could reasonably be expected during the life of the product. Testing is ALT and is required for all products. Testing is performed by the company's ALT Reliability Engineering Group to:

- subject products to extreme environments similar to what the customers may encounter
- accelerate the life of the product by compressing approximately five years of use into five weeks of testing
- uncover design flaws so development engineers can improve design margins
- precipitate parts failures and provide information on potential weaknesses to suppliers

- identify process problems so manufacturing engineers can develop efficient and controlled processes before production begins

ALT includes subjecting products to dropping, temperature extremes (hot and cold), temperature cycling (gradual change from hot to cold and cold to hot), temperature shock (sudden change from hot to cold and cold to hot), electrostatic discharge, exposure to dust, vibration, and humidity. Besides being used during the development of a product, ALT is required to be performed quarterly on a sample of in-production products. This requirement ensures that any changes in the process or other anomalies are detected early and corrected. ALT is also used to compare the company's product with those of the competition. For these comparisons, a company product and a competitor's product are placed in an ALT cycle simultaneously under identical test conditions. Finally, the design of the ALT is one input to Certification Testing (discussed in more detail in a succeeding paragraph). Major new products are also subjected to Beta site testing. It was stated that, based on the ALT, that the designers have a high confidence that the reliability goal has been met; this point was not elaborated on by those interviewed.

When questioned how the ALT test parameters are determined to ensure all possible failure modes are stimulated, the interviewee(s) cited experience as the key basis for the parameters. Asked if an FMEA or FMECA was conducted, the reply was an emphatic no (except when required by the customer. It is believed that an FMEA adds paper but no value to the engineering design process. Further probing, however, suggested that company engineers must do something analogous to an FMEA to ensure that they have accounted for all failure modes. For example, in further discussion, the interviewee(s) criticized the "formal structure and documentation" associated with an FMEA. It is the opinion of the interviewers that the interviewee(s) was equating FMEA with MIL-STD-1629. Prior interviews of individuals from other companies revealed that they too were against the "overhead" associated with the formal FMEA as described in the standard. However, these individuals stated that their analyses incorporate or include some of the essential elements of an FMEA as part of their efforts to know which failure modes are applicable to their design. Given the company's emphasis on identifying failure modes and root causes, it is likely that the essential elements of an FMEA are incorporated in their reliability engineering efforts.

Before being released for shipment, a product must be approved by Quality ("no approval, no ship"). In the case of a new model, part of the approval entails a product successfully passing a series of tests called Certification Testing (CT); CT is distinct from ALT, but many of the tests are similar. CT is specifically performed on samples of a new product to confirm that in all respects, the product represents Best-in-Class quality. The tests are prescribed in a Prototype Product Certification Guidelines document created by the ALT Reliability Engineering Department. The tests consist of:

- sudden impact testing
- endurance testing
- package drop testing (ensures packaging prevents damage during shipping)
- transport simulation
- electrical certification

The company has a form of a failure reporting and corrective action system, at least during the warranty period. All service actions are recorded, and the data used to track field reliability. As stated earlier, other than making simple repairs, customers return all failed items to the service organization. Accordingly, the company engineers are able to analyze failures in detail. Regular technical meetings are held to evaluate the field reliability, review problems, and identify actions to improve the product.

Software quality is receiving more attention because the software is becoming the main "component" of a product. Software quality is measured in terms such as defects per 1000 lines of code. The company's goal is to be certified at the Software Engineering Institute's level 3 by 1995.

The company's approach to suppliers can be summarized in eight points:

- suppliers considered Partners for Progress
- all purchased items are dual-sourced
- suppliers are expected to meet same requirements as the company (with the exception of ISO 9000 - suppliers are not required to conform to ISO 9000)
- processes must be certified
- limited number of suppliers
- suppliers must meet the Quality System Review Guidelines to be on the company's Qualified Suppliers List (QSL)
- training of suppliers is essential
- failure to meet standards results in a supplier being eliminated from the QSL
- suppliers are asked to give a time frame in which they will apply for the Malcolm Baldrige Award.

Two points bear discussion. First, by dual sourcing all purchased items, the company has allowed for periods of "surge" production, will not be forced to halt production if a process problem appears in a supplier process, and has the latitude to immediately "fire" a supplier who fails to measure up to the company's standards. Second, suppliers are expected to meet all the same standards as is the company itself.

In addition to the material already presented, the following comments and opinions were offered:

- Government requirements (imposed on its contractors) are prescriptive; customer requirements should be descriptive
- the problem with standards of any kind, regardless of the source, is that they foster bureaucracy and stifle innovation
- dual-use R&M standards as advocated by the G-11 Committee of SAE, would be of doubtful value to the company but may be useful to companies with a less mature quality culture
- the standards of value and concern to the company involve interoperability within an industry
- other than MIL-HDBK-217, no military or government standards and handbooks related to R&M are used

Summary of Interview with Company J Representative(s). This company's products are, for the most part, standard catalog items, but some customizing of products is done. Products are sold directly to end users throughout the US, Europe, and South America. Customers do not specify product performance (including reliability). The company "markets" the high reliability of its products. Products are shipped with operating and service manuals.

A failure is as any time the product does not perform its function. Products having a microprocessors perform self-test functions during power-up and operation. The products are maintained by the user who removes and replaces failed subassemblies (equivalent to Air Force Line Replaceable Units) and ships the failed subassemblies back to the company's service department. The service department provides support to the users and repairs the failed subassemblies. In the case of recurring or critical failures, failed components (i.e., Shop Replaceable Units) and Field Service Reports are subjected to failure analysis. Most failures occur in electronics, specifically in the interconnects. Shipping and handling is the severest environment to which the products are subjected.

The company is extremely conscious of the need for a safe product - this consciousness is the driving factor behind most of what they do. Products are developed using a six-phase approach called the Product Development Process (PDP). The six phases are: Idea Generation, Product Planning, Design, Validation, Production and Launch, and Customer Delivery.

Some of the key reliability tasks performed are predictions, using MIL-HDBK-217 with a mix of field data; a parts count prediction to identify problem areas; hazard analysis; life testing; and demonstration testing. The use of a hazard analysis has recently been introduced and is replacing the use of an FMEA. A hazard analysis is performed from the top down and from the bottom up and at the board level and at the component level. The purpose of this and related analyses is to identify critical components. It is similar to an FMEA and includes use/misuse analysis. The design team (DT) concept, i.e., concurrent engineering, is used to develop all products. Many of the tasks are based on DoD guidelines (e.g., MIL-STD-785, MIL-STD-781, and MIL-STD-1629) but are tailored to meet the company's needs.

Customers do not specify a required reliability. An MTBF goal was developed by evaluating the state of technology and benchmarking the competitor's products (in which competitors' products are torn down and studied). Marketing then set the MTBF goal as necessary to lead the competition. Field data and a MIL-HDBK-217 prediction are used to verify that the goal is being achieved on current products. Historical field data and parts count analysis of old equipment are used to determine historical reliability. Failure analyses of failed products are used to develop design requirements. Currently, most failures occur in interconnects on the electronics board. Based on the failure analyses performed, the boards are redesigned to eliminate these failures. New designs are overstressed to failure to determine how and where failures occur and to determine the robustness of the design. Boards are subjected to thermal cycling and are thermally mapped (using thermistors) to qualify them prior to design release. (Outside test agencies are used to perform thermal testing.) New designs are "pre-qualified" using a parts count prediction. For critical components, all tests are zero-failure. A reliability demonstration is not really needed due to the extensive component-level testing, but a system-level reliability demonstration is performed using a company-developed test design. It is an accelerated test and is based on the Chi Square method to minimize the number of test articles. Life testing is also performed.

Reliability costs are not budgeted. It was unclear from our discussions how a DT manager accounts for the costs of reliability tasks. The value of reliability tasks does not seem to be questioned, probably because of the potential life-threatening consequences of failure. Organizationally, the reliability and product assurance offices have joint responsibilities for reliability. These responsibilities are allocated as follows:

RELIABILITY

Design
Specification
Analysis
Test

PRODUCT ASSURANCE

Good Manufacturing Practices (GMPs)
Field failures

The company's products are subject to government regulations. In addition to government regulations, the company's products must comply with UL requirements, International Electrotechnical Commission (IEC) (Europe) requirements, and ISO 9000 standards.

Suppliers are chosen based on performance and reputation. The company's Quality Assurance (QA) organization checks suppliers to ensure that their QA processes are acceptable. Suppliers do all end testing; the company performs no incoming inspections other than visual. Suppliers must be qualified. The MTBF requirement is not allocated to suppliers.

Other information included:

- Commercial industry needs practical, down-to-earth, common sense guides, not theory
- MIL standards and specifications form the basis for much of what commercial industry does
- MIL standards and specifications must be tailored, not become ends in themselves, and developing organization must have latitude in their application

Summary of Interview with Company K Representative(s). Company K produces a wide range of related products. Products are standard, off-the-shelf (catalog) items with options available to meet specific customer needs. No customized products, in the true sense of the term, are made.

Design specifications are developed based on market research and surveys, knowledge of competitors' equipment performance, and technology. Benchmarking is not a key activity because benchmarking data are often too late (i.e., competition has already gained a competitive edge). However, some performance benchmarking is used to determine the performance of the company's products relative to competitors' products. Competitive benchmarking, in which competitors' products are torn down, is not performed because few, if any, differences exist in most areas.

Customers are offered a selection of one of several levels of after-sales support (after-sales support is not the responsibility of the designers or product development teams but a service division). Basically, these levels differ by the guaranteed response time in the event of a problem. The cost of the various levels is the same regardless of the cost and type of system purchased. Customers call a toll-free number that is answered by company personnel. Based on their assessment of the problem, they dispatch a service representative to fix the equipment (usually a remove and replace action). Service representatives are called "change engineers," and service is often subcontracted out within the United States. In Europe, service is done primarily through messengers. European customers who have a problem with a product call a toll-free number; the company representative assesses the problem based on information provided by the customer and dispatches a messenger with a replacement part.

From its records on maintenance of its products while under warranty, the company tracks response times and parts usage fairly accurately for products sold to end users. However, reliability and failure data are difficult to obtain. This difficulty results from the lack of complete configuration control after the product is sold and an inability to accurately track operating hours. It is also difficult to obtain any data on products sold through resellers, although quality assurance forms are used to collect feedback from OEMs. These difficulties are not significant to the company because its goal is not to determine root causes of failures but to do trending and identify problem areas.

Customers are primarily interested in performance and product availability. The rather recent emphasis on availability is creating a new concern by company designers in the maintainability of their products. Selected customers are asked to participate in evaluating designs of current products and projected specifications for new products. Customers, DoD, and major OEMs, regularly audit the company's processes and qualify its products. Considerable amounts of design and test data are made available to these customers in conjunction with these audits and qualification activities.

The company has a New Product Introduction process consisting of seven phases: Exploration; Initiation of Approval; Specification, Planning, and Design; First Prototype; Pre-Pilot (Beta testing); Pre-Launch (qualification of manufacturing processes); Sustaining Production; and End of Life. The cycle time from Exploration to Pre-Launch for a completely new product ranges from 8 months to 2 years. Design teams are designated to develop products under the leadership of project managers (i.e., this process is the company's implementation of a concurrent engineering approach).

The interviewee(s) defined failure as noncompliance with the specification definition of operational performance. The focus of reliability engineering within the company is on qualification of the design. Product reliability is the responsibility of the project managers and design teams. The reliability organization provides support and guidance to the design teams. Project managers are evaluated and awarded bonuses on the basis of the number of units sold; time-to-market and time-to-volume are the drivers. At first glance, with this emphasis on schedule, one might conclude that reliability is not a key concern of the project managers. However, manufacturing, which has responsibility for after-sales reliability, is a member of the design team and must sign off on the product release. The design teams seek consensus on the design approach, requirements, and activities/tools used in the design.

Marketing research is used to develop the product specifications. Requests for quote (RFQs) received from potential customers usually include a reliability requirement (either an MTBF, an availability or an allowable downtime requirement). In its response to an RFQ, the company includes a MIL-HDBK-217

prediction to support its claim regarding the product reliability. If the customer challenges the prediction, the company's approach is to educate the customer regarding the meaning, underlying assumptions, and limitations of the prediction. Because the company's products are catalog items, the reliability cannot be "changed" to quiet a customer's concern. The greatest source of this concern are the claims by the company's competitors of having equivalent products with higher reliability, claims that are based on other, sometimes questionable means of predicting or measuring reliability. The company uses MIL-HDBK-217 rather than other methods because the MIL-HDBK-217 methodology is universally known or accepted and addresses key design factors (for example, the Bellcore methodology is not well accepted overseas and does not adequately address thermal considerations). These MIL-HDBK-217 failure rate predictions are considered conservative, usually 1.2 to 3.6 lower than what will be experienced in service. In fact, the Japanese will multiply the MIL-HDBK-217 MTBF prediction by 3 and specify the result as the reliability value to be demonstrated (the Japanese usually require a complete reliability demonstration). Based on predictions, the reliability staff recommends design changes to design teams, develops test plans, and so forth.

Along with reliability prediction, thermal analysis and evaluation (using a thermal scanner on prototypes) are key reliability tasks. Neither a FMECA nor a fault tree analysis (FTA) is performed: they became "victims" of downsizing (i.e., not feasible given the present staff). Reliability growth is just now being introduced into the company. It is used if a product does not meet the reliability requirement. Environmental evaluation (humidity, temperature, vibration, shock, etc.) is done by an organization other than the reliability department to ensure that a product meets minimum military and IEC specifications. Accelerated testing (a modified Highly Accelerated Life Test [HALT] method) is used. Early involvement in the design concept and development phases is considered essential to the success of a product in the marketplace. Some use is made of DOE (Design of Experiments) to determine key design characteristics and to develop test plans. Step stress testing is first done using operational levels of stresses to prove out the design; it is then performed at higher levels, until the product fails, to determine design margins. No maintainability analysis has been done in the past; it is now being added in light of customer emphasis on availability. The current maintainability requirement was subjectively and somewhat arbitrarily determined. The value-added and cost of reliability activities (i.e., the return on investment) is difficult to quantify. Activities are selected by design teams based on engineering judgment and experience. Activities and testing are documented to satisfy internal requirements and business partners or to allay the concerns of certifying bodies, such as UL.

Software reliability is a major concern and is considered the major issue for the future. Its importance lies in the fact that most hardware becoming extremely reliable. Therefore, hardware reliability will become a moot point within 5 years; thus reliability will become totally software driven. Little distinction, in terms of definition or approach, is made between hardware and software reliability. The key is to emphasize the design process and on reducing the frequency with which the software fails to perform as required (or planned).

The reliability staff provides guidelines to the supplier engineers (who are part of the design teams) regarding supplier specifications for reliability. These supplier engineers track supplier compliance. Two levels of suppliers are used: Preferred Suppliers and Partner Suppliers. The production processes of Preferred Suppliers are qualified by the company. In the case of Partner Suppliers, the company becomes very involved with the details of the suppliers' designs. Extensive documentation regarding the performance and testing of supplier products is required. The company ensures that its suppliers' equipment is electrostatic discharge (ESD) qualified.

Other information offered included:

- The creativity of design engineers is limited by standard processes and mandated procedures.
- The company's management priorities are, in order: price, performance, then reliability.
- Because the cost of ownership is difficult to measure, price still dominates.

APPENDIX E

TERMS AND DEFINITIONS

TERMS AND DEFINITIONS

AAMI	Association for the Advancement of Medical Instrumentation
Acceptance Testing	Any testing required by customers prior to their acceptance of a product. Can be done before committing to production (see RQT) or during production to "ensure" that the designed reliability is not degraded by the manufacturing processes (see PRAT).
ASME	American Society of Mechanical Engineers
Benchmarking	Benchmarking is the continuous process of measuring products, services, and practices against the toughest competitors or those companies recognized as industry leaders. (David T. Kearns, Former Chief Executive Officer, Xerox Corporation)
CAD/CAM	Computer-aided design/computer-aided manufacturing
CAFTA	Computer-aided Fault Tree Analysis
Competitive Benchmarking	Benchmarking done against direct competitors (<i>Benchmarking</i> by Robert C. Camp, ASQC Quality Press, Milwaukee, WI, 1989.) Sometimes referred to as strategic or corporate benchmarking.
CSA	Canadian Standards Association
Demonstration Testing	Testing done to demonstrate that a specified reliability has been made (i.e., determine compliance). Acceptance testing (see), PRAT (see), and RQT (see) are demonstration tests.
DOE	Design of Experiments. A branch of applied statistics dealing with planning, conducting, analyzing, and interpreting controlled tests to evaluate the factors that control the value of a parameter or group of parameters. (<i>Quality Progress</i> , February 1992, page 22)
DOT	Department of Transportation
DTIC	Defense Technical Information Center
EPA	Environmental Protection Agency
ESS	Environmental Stress Screening. A series of tests conducted under environmental stresses to disclose weak parts and workmanship defects for correction. (MIL-STD-721C)
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FMEA	Failure Modes and Effects Analysis. A procedure by which each potential failure mode in a system is analyzed to determine the results or effects thereof on the system and to classify each potential failure mode according to its severity.
FMECA	Failure Modes, Effects, and Criticality Analysis. See FMEA.
FRACAS	Failure Reporting and Corrective Action System. A closed-loop system for reporting failures, analyzing the failures to determine cause, and recording the corrective action taken. (MIL-STD-785B)
FTA	Fault Tree Analysis. An analytical method to identify the effects of faults on a system. It is a top-down approach in contrast to the FMECA which is a bottom-up approach. (<i>Reliability Toolkit</i> , RL, April 1993)
Functional Benchmarking	Benchmarking of a function using for comparison a company in a dissimilar industry (i.e., not a direct competitor). (<i>Benchmarking</i> by Camp) Also defined as benchmarking of functions, rather than strategic measures of company performance, using either direct competitors or companies in dissimilar industries.

GAO	General Accounting Office
Growth Testing	See RGT.
IBC	International Benchmarking Clearinghouse
IEC	International Electrotechnical Commission
IITRI	Illinois Institute of Technology Research Institute
Internal Benchmarking	Benchmarking of a function by a company organization using another operating unit within the company for comparison.
ISO	International Standards Organization
Maintainability	The measure of the ability of an item to be retained in or restored to a specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair. (MIL-STD-721C)
MIL-HDBK	Military Handbook
MIL-SPEC	Military Specification
MIL-STD	Military Standard
Normative Benchmarking	Benchmarking done for a cooperating group of companies by a third-party consultant. Results and data are aggregated (they cannot be traced or attributed to a specific company) and then distributed to all companies
NUREG	Nuclear Regulatory Commission
OASD (ES)	Office of the Assistant Secretary of Defense, Economic Security
OSHA	Occupational Safety and Health Administration
Physics of Failure	An approach to developing robust designs and manufacturing processes based on understanding the root-cause failure mechanisms.
POC	Point of Contact
PRAT	Production Reliability Acceptance Test. See Acceptance Testing.
Quality	The degree of excellence possessed by a product, service, or other output of a business activity or business process. (Anon) Fitness for use. (J. M. Juran) Meeting the customer's requirements the first time and every time. (Federal Quality Institute) Cost to society and robustness. (Genichi Taguchi)
Qualification Test	See RQT.
RAAF	Royal Australian Air Force
R&M	Reliability and Maintainability
RAC	Reliability Analysis Center. A DoD-sponsored Information Analysis Center administratively managed and funded by the Defense Technical Information Center. The RAC's technical areas of responsibility are reliability, maintainability, and quality.
Reliability	(1) The duration or probability of failure-free performance under stated conditions. (2) The probability that an item can perform its intended function for a specified interval under stated conditions. (For non-redundant item, this is equivalent to definition (1). For redundant items, this is equivalent to the definition of mission reliability.) (MIL-STD-721C)

RGT	Reliability Growth Testing. Testing performed to improve reliability by uncovering and correcting deficiencies in design or manufacture.
RQT	Reliability Qualification Testing. Testing performed for the purpose of demonstrating, or measuring, the reliability of an item. The testing is used to determine contractual compliance with pre-established acceptance-reject criteria. (MIL-HDBK-781)
SIC	Standard Industrial Code
Strategic Benchmarking	Benchmarking of direct competitors using corporate-level indicators. (Kersi F. Munshi, Consultant) Also called corporate or competitive benchmarking.
TAAF	Test, Analyze, and Fix. See RGT.
Tailoring	The inclusion, deletion, and modification of specific requirements of a military standard or specification to match program and product requirements and constraints.
TQM	Total Quality Management
UL	Underwriter's Laboratory
WCCA	Worst-case Circuit Analysis. An analysis performed to evaluate the simultaneous existence and effect of all unfavorable parameter tolerances on a circuit. (<i>Reliability Toolkit</i> , RL, 1993)
WSIG	Weapon Support Improvement Group

APPENDIX E

RAC PRODUCT ORDER FORM

RAC Product Order Form

Ordering
Code

Title

Page #

U.S.
Price

Non-US
Price

Qty.

Item
Total

Data Publications

NPRD	Nonelectronic Parts Reliability Data	3	\$195	\$215		
ECDS	Environmental Characterization Device Sourcebook	3	\$100	\$120		
RDSC-2	The Reliability Sourcebook - "How and Where to Obtain R&M Data and Information"	3	\$50	\$60		
VZAP	Electrostatic Discharge Susceptibility Data	3	\$195	\$215		
NONOP-1	Nonoperating Reliability Databook	3	\$50	\$60		
FMD	Failure Mode/Mechanism Distributions	3	\$100	\$120		

Application Guides

CPE	Reliability Toolkit: Commercial Practices Edition	4	\$25	\$35		
SLEA	Service Life Extension Assessment	4	\$50	\$60		
SOAR-2	Practical Statistical Analysis for the Reliability Engineer	4	\$50	\$60		
BENCH	Benchmarking Commercial Reliability Practices	4	\$50	\$60		
RMST	Reliability & Maintainability Software Tools	4	\$50	\$60		
TEST	Testability Design and Assessment Tools	4	\$50	\$60		
RTMG	RAC Thermal Management Guidebook	5	\$75	\$85		
NPS	Mechanical Applications in Reliability Engineering *Price Reduced*	5	\$75	\$85		
QREF	RAC Quick Reference Guides	5	\$25	\$35		
SOAR-6	ESD Control in the Manufacturing Environment	5	\$50	\$60		
SOAR-4	Confidence Bounds for System Reliability	5	\$50	\$60		
WHDK	New Weibull Handbook	6	\$79	\$94		

Reliable Application of Components

PSAC	Parts Selection, Application and Control	6	\$75	\$85		
EOES	EOS/ESD Guidelines	6	\$50	\$60		
CAP	Reliable Application of Capacitors	6	\$50	\$60		
PEM2	Reliable Application of Plastic Encapsulated Microcircuits	6	\$75	\$85		
MCM	Reliable Application of Multichip Modules	6	\$50	\$60		

Component Publications

MFAT-1	Microelectronics Failure Analysis Techniques: A Procedural Guide	7	\$70	\$80		
MFAT-2	GaAs Microcircuit Characterization and Failure Analysis Techniques: A Procedural Guide	7	\$50	\$60		
MFAT 1 & 2	Combined set of MFAT-1 and MFAT-2	7	\$100	\$120		
QML	Qualified Manufacturer's List: New Device Manufacturing and Procurement Technique	7	\$50	\$60		
GAAS	An Assessment of Gallium Arsenide Device Quality and Reliability	7	\$50	\$60		
ATH	Analog Testing Handbook	7	\$100	\$120		
PRIM	A Primer for DoD Reliability, Maintainability, Safety and Logistics Standards *Price Reduced*	7	\$50	\$60		

Quality Improvement

SPAT	Software Engineering Process Group Handbook	8	\$30	\$40		
BPRQ	Business Process Reengineering for Quality Improvement	8	\$75	\$85		
TQM	TQM Toolkit	8	\$75	\$85		
SOAR-7	A Guide for Implementing Total Quality Management	8	\$75	\$85		
SOAR-8	Process Action Team Handbook *Price Reduced*	8	\$30	\$40		

Computer Products

CART	RAC Computer-Aided Reliability Training Course	9	\$300	\$340		
217N2	MIL-HDBK-217F, Notice 2 (Macintosh Format) *Price Reduced*	9	\$50	\$60		
338D	MIL-HDBK-338B (Draft) (Macintosh Format) *Price Reduced*	9	\$50	\$60		
NPRD-P	NPRD-95 PC Version (with Informix run-time module and hard copy of book also included)	9	\$475	\$515		
NPRD-P	NPRD-95 PC Version (without run-time module for those owning NPRD-95 software - hard copy of book also included)	9	\$275	\$315		
NRPS	Nonoperating Reliability Prediction System *Price Reduced*	9	\$350	\$390		
VPRED	VHSIC Reliability Prediction Software	9	\$100	\$120		

Concurrent Engineering Series

ITCE	Introduction to Concurrent Engineering	10	\$75	\$85		
WCCA	Worst Case Circuit Analysis Application Guidelines	10	\$75	\$85		
FMECA	Failure Mode, Effects and Criticality Analysis	10	\$75	\$85		
FTA	Fault Tree Analysis Application Guide	10	\$75	\$85		

Shipping and Handling (Note: Different postal rates for NPRD and VZAP) - See Back
Quantity Discount - See Back

☐ ZRG RAC Journal (Free)

Order Total

RCode: BENCH

Ordering Information

Ordering

Fax to (315) 337-9932 or mail to **Reliability Analysis Center, P.O. Box 4700, Rome, NY, 13442-4700**. Prepayment is preferred. Credit cards (VISA, AMEX, MasterCard) are accepted for purchases of \$25 and up. All Non-US orders must be accompanied by a check drawn on a US bank. Make checks payable to IITRI/RAC.

Shipping & Handling

US orders add \$4.00 per book, \$6.00 for First Class. Non-US add \$10.00 per book (allow 8-10 weeks delivery) for surface mail, \$15.00 per book for air mail (\$25.00 for NPRD or VZAP).

Quantity Discounts

Discounts are available for 10+ copies. For discount prices call (800) 526-4802 or (315) 339-7047.

Military Agencies

Blanket Purchase Agreement, DD Form 1155, may be used for ordering RAC products and services. Indicate the maximum amount authorized and cutoff date and specify products and services to be provided. **Identify vendor as IIT Research Institute/Reliability Analysis Center.**

To place an order

Write to: Reliability Analysis Center, P.O. Box 4700, Rome, NY 13442-4700

Call: (800) 526-4802, (315) 339-7047

Fax: (315) 337-9932

E-mail: rac@mail.iitri.com

Please return with RAC Product Order Form

Name _____

Company _____

Division _____

Address _____

City _____ State _____ Zip _____

Country _____ Phone _____ Ext. _____

Method of Payment

☐ Personal check enclosed

☐ Company check enclosed (Make checks payable to IITRI/RAC)

☐ Credit Card # _____ Expiration Date _____

Type (circle): AMERICAN EXPRESS VISA MASTERCARD

Name on card: _____

Billing Address: _____

☐ DD1155 (Government personnel)

☐ Company Purchase Order

☐ Place my name on the distribution list for the free RAC Journal

RCode: BENCH