

# **The New Weibull Handbook Student Version**

**An Introduction to Reliability & Statistical Analysis  
Including Failure Forecasting and Software  
Extracted from The New Weibull Handbook  
And The SuperSMITH Software**

**First Edition by Dr. Robert B. Abernethy**

## **The New Weibull Handbook Student Version**

**Copyright** © 2005 by Robert B. Abernethy

All rights reserved. Reproduction or translation of any part of this work beyond that permitted by Section 107 or 108 of the 1976 United States Copyright Act without permission of the copyright author is unlawful. Requests for permission should be addressed to the author.

**ISBN** 0-9653062-2-4

### **Published and distributed by Robert B. Abernethy**

536 Oyster Road, North Palm Beach, Florida 33408-4328

Phone/Fax: 1-561-842-4082, E-mail: [weibull@att.net](mailto:weibull@att.net)

### **Also distributed by:**

1. Wes Fulton, Phone/Fax: 310-548-6358, Web page: <http://www.weibullnews.com>
2. Paul Barringer, Phone: 281-852-6810, E-mail: [hpaul@barringer1.com](mailto:hpaul@barringer1.com) and <http://www.barringer1.com>

**Copyrights and Trademarks:** Windows is trademarked by Microsoft, Inc. The New Weibull Handbook Student Version copyright belongs to Dr. Robert B. Abernethy. Copyrights for SuperSMITH software Student Version WSWS and "Playtime with SuperSMITH" belong to Fulton Findings.

### **Printing History**

First Edition November 2005, December 4, 2005

## ***DEDICATION:***

This book is dedicated to the reader with the hope it will have "some utility," to use Professor Weibull's words and further, that it will help spread the application of these methods to engineering students as well as practicing engineers, scientists, doctors and dentists everywhere.

## ***PREFACE:***

**The New Weibull Handbook Students Version** is largely extracted from *The New Weibull Handbook* covering the basic material for introductory courses in reliability and statistics. The chapter numbers and appendixes have the same designation as in *The New Weibull Handbook*. The Student's Version was suggested by Jim Breneman, an adjunct professor at the University of Hartford who provided significant help. Dr. Bob is indebted to him for his encouragement and suggestions.

**WinSMITH Weibull Student's software** is included to reduce much of the drudgery of hand calculations and produce probability plots for the most useful distributions. It is similarly extracted from the **SuperSMITH WinSMITH Weibull** software thanks to Wes Fulton. It is hoped the student's handbook with the student's software will provide an affordable package for reliability and statistics courses everywhere. To make the Handbook more readable, all the heavy mathematics will be found in the appendixes. Asterisks on section subtitles indicate advanced topics that are covered in detail in *The New Weibull Handbook* and *SuperSMITH software*. The novice reader may skip these sections. The format includes much white space for notes and calculations. Case studies are employed to present the methodology. On the CD with the software there is a PowerPoint presentation to introduce the WinSMITH Weibull Student's software with case studies.

**Background** More than two decades have passed since the *USAF Weibull Analysis Handbook* was published. In the years that followed, the author frequently taught Weibull analysis using the USAF Handbook as the text, encouraged by both the United States Air Force and Pratt & Whitney. In 1987, the author retired early to devote full time to research and lecturing in Weibull Analysis. It has been most enjoyable and interesting. The best part has been meeting outstanding engineers and scientists from many industries with new and different applications for Weibull methods. The students inspire additional research and methods development. This in turn required rewriting and updating the USAF Handbook producing *The New Weibull Handbook*. This document is now in its fourth edition has become the national and international standard for Weibull analysis. It is in daily use throughout the world. Thousands of copies have been distributed. Users include military, automotive, medical, electronics, materials & composites research, aerospace, electrical power, nuclear power, dental research, advertising, bearings, compressors, v-belts, chain drives and on and on. Many organizations have adopted the Handbook and software implementing its methods as standard including the Federal Aviation Administration, Harley Davidson, Motorola, TVA, Honeywell, BICC General, GKN Automotive, Dupont, Siemens, Behr, Teleflex, Guidant Cardiac Pacemaker (CPI), Daimler Chrysler, General Electric, Rolls Royce, Gates Rubber, the US Naval Air Arm (NAVAIR), the US Air Force at SAALC and WPAFB, and Dow Chemical. The author has provided free copies of the Handbook to universities in Europe, North and South America, Japan, and Australia. In addition, Wes Fulton provides free demonstration copies of the SuperSMITH software on our web sites.

Please call or write with questions, comments, and constructive criticism about *The Student's Weibull Handbook*. I would like to hear from you:

Dr. Robert B. Abernethy  
536 Oyster Road  
North Palm Beach, Florida 33408-4328  
Summertime Tennessee 865-408-0541  
Wintertime Florida 561-842-4082  
E-mail: [weibull@att.net](mailto:weibull@att.net)

## *Table of Contents*

*This Student Version has the same Chapter Numbers and Appendixes as The New Weibull Handbook but some are missing such as: Chapters 5, 7-10, and several Appendixes .....*

<b>CHAPTER 1 AN OVERVIEW OF WEIBULL ANALYSIS</b>	<b>1-1</b>
1.1 OBJECTIVE	1-1
1.2 BACKGROUND	1-1
1.3 EXAMPLES	1-2
1.4 SCOPE	1-2
1.5 ADVANTAGES OF WEIBULL ANALYSIS	1-3
1.6 DATA, DISCRETE VERSUS LIFE DATA, EXACT VERSUS INTERVAL	1-3
1.7 FAILURE DISTRIBUTION	1-4
1.8 FAILURE FORECASTS AND PREDICTIONS	1-5
1.9 ENGINEERING CHANGE TEST SUBSTANTIATION	1-6
1.10 MAINTENANCE PLANNING	1-6
1.11 SYSTEM ANALYSIS AND MATH MODELS	1-7
1.12 WEIBULLS WITH CURVED DATA	1-7
1.13 WEIBULLS WITH CORNERS AND DOGLEGS	1-8
1.14 WEIBAYES	1-9
1.15 SMALL SAMPLE WEIBULLS	1-9
1.16 UPDATING WEIBULLS	1-9
1.17 DEFICIENT (DIRTY) DATA	1-9
1.18 ESTABLISHING THE WEIBULL LINE, CHOOSING THE FIT METHOD	1-9
1.19 RELATED METHODS AND PROBLEMS	1-10
1.20 SUMMARY	1-10
 <b>CHAPTER 2 PLOTTING THE DATA AND INTERPRETING THE PLOT</b>	 <b>2-1</b>
2.1 FOREWORD	2-1
2.2 WEIBULL DATA	2-1
2.3 THE WEIBULL PLOT	2-1
2.4 THE WEIBULL PARAMTERS: (ETA) AND (BETA)	2-3
2.5 WEIBULL ANALYSIS - AN EXAMPLE	2-5
2.6 MEDIAN RANKS	2-5
2.7 THE WEIBULL PLOT	2-6
2.8 "B" LIFE	2-6
2.9 SUSPENDED TEST ITEMS	2-7
2.10 BERNARD'S APPROXIMATION	2-7
2.11 STEPS TO PLOT THE WEIBULL	2-8
2.12 INTERPRETING THE WEIBULL PLOT	2-8
2.13 BETA < 1 IMPLIES INFANT MORTALITY	2-9
2.14 BETA = 1.0 IMPLIES RANDOM FAILURES	2-10
2.15 1.0 < BETA < 4.0 IMPLIES EARLY WEAR OUT	2-11
2.16 BETA > 4.0 IMPLIES OLD AGE (RAPID) WEAR OUT	2-11
2.17 UNKNOWN WEIBULL MODES MAY BE "COVERED"	2-12
2.18 WEIBULL PAPER AND ITS CONSTRUCTION	2-12
2.19 WEIBULL ANALYSIS - THE STANDARD METHOD	2-14
2.20 PROBLEMS	2-14

<b>CHAPTER 3 DIRTY DATA, "BAD" WEIBULLS, AND UNCERTAINTIES</b>	<b>3-1</b>
3.1 FOREWORD	3-1
3.2 SMALL SAMPLE UNCERTAINTIES	
3.3 GOODNESS OF FIT	3-3
3.4 SUSPENSIONS	3-7
3.5 CURVED WEIBULLS AND THE $T_0$ CORRECTION AND THE THREE PARAMETER WEIBULL	3-7
3.6 DATA INCONSISTENCIES AND MULTIMODE FAILURES	3-11
3.6.1 LOW-TIME FAILURES	3-12
3.6.2 CLOSE SERIAL NUMBERS	3-12
3.6.3 MIXTURES OF FAILURE MODES	3-13
3.7 INTERPRETING THE PLOT	3-15
3.8 CONCLUSION	3-16
3.9 PROBLEMS	3-16
<b>CHAPTER 4 FAILURE FORECASTING = RISK ANALYSIS</b>	<b>4-1</b>
4.1 SITUATION	4-1
4.2 DEFINITION	4-1
4.3 FORECASTING TECHNIQUES	4-1
4.4 CALCULATING FAILURE FORECASTS	4-1
4.4.1 EXPECTED FAILURES NOW	55
4.4.2 FAILURE FORECAST WHEN FAILED UNITS ARE NOT REPLACED	4-3
4.4.3 FAILURE FORECASTS WHEN FAILED UNITS ARE REPLACED, PRODUCTION RATES, USAGE RATES, WARRANTY CLAIMS	4-3
4.5 FAILURE FORECAST ANALYSIS-SUMMARY	4-4
4.5.1 CASE STUDY 1: BEARING CAGE FRACTURE	4-4
4.5.2 CASE STUDY 2: BLEED SYSTEM FAILURES	4-7
4.6 PROBLEMS	4-12
<b>CHAPTER 6 WEIBAYES AND WEIBAYES SUBSTANTIATION TESTING</b>	<b>6-1</b>
6.1 FOREWORD	6-1
6.2 WEIBAYES METHOD	6-2
6.3 WEIBAYES - NO FAILURES	6-2
6.4 WEIBAYES WITH FAILURES	6-3
6.5 UNKNOWN FAILURE TIMES	6-4
6.6 WEIBAYES WORRIES AND CONCERNS	6-4
6.7 WEIBAYES CASE STUDIES	6-4
6.8 SUBSTANTIATION AND RELIABILITY TESTING	6-9
6.9 ZERO-FAILURE TEST PLANS FOR SUBSTANTIATION TESTING	6-10
6.10 ZERO-FAILURE TEST PLANS FOR RELIABILITY TESTING	6-12
6.10.1 RE-EXPRESSION OF RELIABILITY GOAL TO DETERMINE	6-12
6.10.2 DESIGNING TEST PLANS	6-13
6.11 TOTAL TEST TIME	6-14
6.12 TEST-TO-FAILURE VERSUS WEIBAYES ZERO-FAILURE TESTS	6-14
6.13 WEIBULL LIBRARIES	6-16
6.14 PROBLEMS	6-17

**APPENDIX A: GLOSSARY            A-1**

**APPENDIX B: RANK REGRESSION AND CORRELATION METHODS    B-1**

B.1 METHOD    B-1

B.2 EXAMPLE AND STEP-BY-STEP PROCEDURE    B-1

**APPENDIX E: WEIBAYES ANALYSIS            E-1**

E.1 FOREWORD            E-1

E.2 WEIBAYES EQUATION WIT NO FAILURES    E-1

E.3 WEIBAYES WITH FAILURES            E-2

**APPENDIX G: WEIBULL AND LOG NORMAL MEAN AND VARIANCE G-1**

G.1 RTH MOMENTS            G-1

G.2 WEIBULL MEAN            G-2

G.3 WEIBULL VARIANCE G-3

G.4 WEIBULL MODE            G-3

G.5 WEIBULL MEDIAN        G-3

**APPENDIX H: WEIBULL GRAPH PAPER    H-1**

**APPENDIX I: MEDIAN RANKS, 5% Ranks, & 95% Ranks    I-1**

**APPENDIX K: ANSWERS TO PROBLEMS    K-1**

**REFERENCES            R-1**

**INDEX            I-1**