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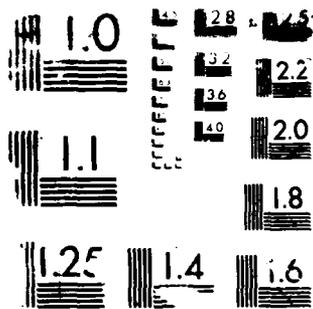
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USAAVSCOM
TECHNICAL REPORT 87-F-3

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WARRANTY MODEL (WARM) USER'S GUIDE

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20. Abstract (continued)

→ The model helps to prepare the Army should cost position for contract negotiations, to study cost effectiveness of a proposed warranty and to assess risk to the Government of not purchasing a warranty. Keywords: input; output; instructions.

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11 SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

PREFACE

This report is the user's guide for the latest version of the Warranty Model (WARM), the purpose of which is to determine the cost effectiveness of warranties on weapon system procurements. It supersedes all previous versions. The latest version of the model is called PCWARM3, is designed to run on an IBM compatible personal computer (PC), and is the September 1987 version. PCWARM3 performs essentially the same mathematical analysis as the earlier versions of WARM. The principal changes to the model are to clarify the treatment of the threshold warranty case, make some cosmetic changes to the input and output, and to revise the user's guide.

This latest version was undertaken at the behest of the Army Materiel Command (AMC) based on suggestions from each of the Major Subordinate Commands (MSCs) and from Headquarters, AMC Cost Analysis (AMCRM-E). Under the guidance of AMC Cost Analysis, many of these suggestions and comments were incorporated into this update. Headquarters, AMC Cost Analysis (AMCRM-E) released and approved this revision for distribution and use throughout AMC.

The original model was developed by Mr. William Bodden and Mr. Ronald Crosier of the U.S. Army Aviation Systems Command (AVSCOM), Directorate for Systems and Cost Analysis under the guidance of an AMC working group. Dr. Seki Choo' of the same directorate updated the model and prepared a version of the user's guide. The present model update and user's guide revisions were made by Ms. Marcella Gordon and Dr. Frank Fox.

TABLE OF CONTENTS

	<u>PAGE</u>
I. INTRODUCTION	1
II. INSTRUCTIONS FOR RUNNING WARM ON A PERSONAL COMPUTER	3
III. INPUT INSTRUCTIONS AND TERMINOLOGY	4
IV. OUTPUT	15
V. EXAMPLES	19
VI. ADDITIONAL MODEL USAGE NOTES	92
APPENDIX A LIST OF MAIN PROGRAM VARIABLES	A-1
APPENDIX B DESCRIPTION OF METHODOLOGY AND SUBROUTINES	B-1
APPENDIX C EXAMPLE OF MAINFRAME GRAPHICS	C-1

I. INTRODUCTION

Under certain circumstances, Army policy requires that an economic analysis be performed to determine whether the purchase of a warranty is cost effective. The Warranty Model (WARM) is an AMC approved model for performing such analyses. WARM analyzes two types of warranties, the failure-free and the threshold. In a failure-free warranty, the Government buys a warranty from the contractor, paying a price equal to the cost of repairing the expected number of failures. All failures under the warranty are then at no cost to the Government (thus the name "failure free"). In the threshold warranty, the Government pays nothing to the contractor for the warranty. Instead, the expected number of failures is set as a threshold. If the number of failures is below the threshold, the Government pays the cost of the failures. The contractor pays the costs for the number of failures which exceed the threshold.

The following types of data are required to run the model. A detailed description is given in section III.

1. Data describing the warranted equipment and its usage
 - a. Number of systems and spares delivered
 - b. Economic life
 - c. Usage hours
 - d. Failure rate of the equipment expressed as a MTBF
2. Data on the cost and value of money:
 - a. Discount rate
 - b. Escalation indices
3. Data describing the warranty
 - a. Length of the warranty in time periods (e.g., years)

- b. Length of the warranty in usage hours
 - c. Percent of failures that result in valid claims for warranted repair.
4. Cost data (expressed as fixed and variable cost).
- a. Costs for repairs under the warranty alternative.
 - (1) In-house costs
 - (2) Costs associated with non-warranted alternative
 - b. Costs for repairs under the non-warranted alternatives

The purpose of WARM is to provide the user with an approved standardized analytical approach for quantitatively assessing the cost effectiveness of warranties. Using the information described above, WARM provides an analysis consisting of three types of information.

For failure-free warranties, WARM determines a "should cost" price for the purchase of a warranty.

For both types of warranties, it compares the total cost of repairs for the two alternatives of purchasing an item with or without a warranty over a range of MTBFs.

Provides some probability distributions which can be used for sensitivity and risk analysis. A detailed description of the WARM output is given in section IV.

This manual provides the user detailed input instructions and instructions for the analysis and interpretation of the model results. Examples are provided to better explain the features of the model. Appendix A contains a description of the variables used in the main sections of WARM and Appendix B contains a description of the subroutines used in WARM.

II. Instructions for Running WARM on a Personal Computer

A copy of the September 1987 PC version of the WARM model on a floppy disk and a copy of this user's guide can be obtained by sending a request to: Commander, USAAVSCOM, ATTN: AMSAV-BB, 4300 Goodfellow Blvd, St. Louis, MO 63120-1798.

In order to have storage space for more than one data file, WARM should be copied to the hard disk of the PC. To obtain a copy of the WARM input and output on the printer, depress CONTROL and PRINT SCREEN before beginning the WARM program. When ready to run the program, enter PCWARM3. Thereafter, enter the data in response to the program prompts. All input is free-format; this means that blanks or commas separate numbers and decimal points are optional on whole numbers. Percentages are entered as percentages and not as decimals, e.g., 80 for 80 percent, not .8.

When using a PC without a hard disk and either one or two disk drives, the following directions apply: First, you will need to have a system disk to boot or start up the PC, a copy of PCWARM3, and a formatted disk if you plan on saving or retrieving files.

For one-disk drive: After you boot up the PC with the system disk, remove the disk and insert the PCWARM3 Disk. At the A> prompt, type PCWARM3. When the information on the Warranty Program appears, remove the PCWARM3 disk and insert the formatted disk. You can now save your file which will be created, as well as retrieve any files which you have saved previously.

For two-disk drive: After you boot up the PC by inserting the system disk in drive A, change the drive to B by typing B: after the A> prompt (e.g., A>B:). The prompt B> is now displayed. You will now be able to save your created files or retrieve created files from this disk drive. Insert the PCWARM3 disk in drive A and the formatted disk on which you will save files in drive B. You now type A:PCWARM3 to begin running the Warranty Program. When you are ready to save your file which you have created, type a name with an extension (e.g., EXMPL1.DAT). Do not type the disk drive designation.

III. INPUT INSTRUCTIONS AND TERMINOLOGY

1. TWO LINES OF HEADER INFORMATION

Each of the lines may be up to 80 characters in length. Whatever is entered in these two lines will be printed as two header lines at the beginning of the WARM output and can be used to identify individual runs.

example: Flying Fortress - Threshold Case

19 June 1987

2. ECONOMIC LIFE IN TIME PERIODS (WHOLE NUMBER BETWEEN 1 AND 240)

The economic life, together with the number of time periods over which deliveries are made, determines the length of time over which the economic analysis is performed. For example, if deliveries are made during the first time period and the economic life is three time periods, the economic analysis will be for three time periods. However, if deliveries are made over four time periods and the economic life is again three time periods, the economic analysis will be for six time periods. The economic analysis extends for three time periods (economic life) beyond the last delivery period, counting the last period as the first of the three. See the illustration in figure 1.

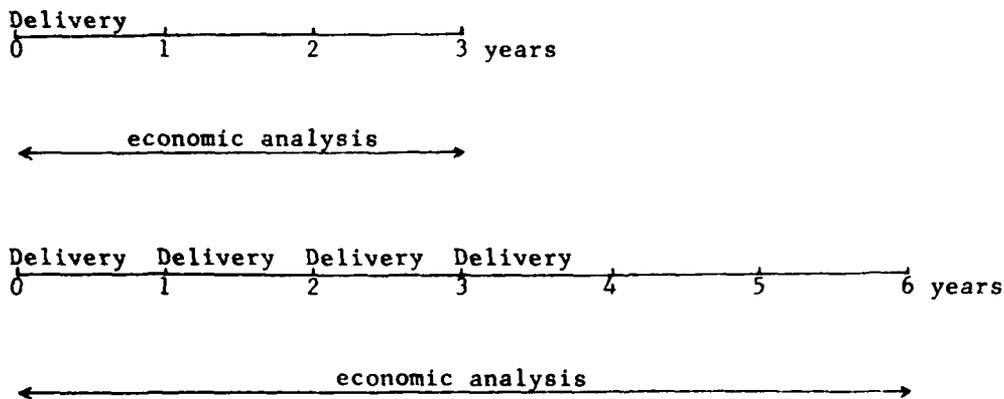


Figure 1. Economic Analysis Period.

3. NUMBER OF TIME PERIODS DELIVERIES ARE MADE (MUST BE A WHOLE NUMBER FROM 1 TO 240)

For example, if delivery of 50 items is made in time periods one, two, and four; and no deliveries are made in time period three, the number of time periods deliveries are made would be four, not three, and the systems delivered each period (next paragraph) would be 50 50 0 50.

4. NUMBER OF SYSTEMS DELIVERED EACH PERIOD

If 13 systems are delivered each time period for 5 time periods, it could be entered as 13 13 13 13 13 or as 5*13.

5. NUMBER OF SPARES DELIVERED EACH PERIOD

Similar to item 4.

6. USAGE HOURS PER SYSTEM PER TIME PERIOD

The usage hours per system should be entered for each time period over which the economic analysis takes place. That will be a number of time periods equal to the economic life plus the number of delivery periods minus one (see item 2). The computer program will prompt the user with the number of time periods for which usage hours must be input. The usage hours are input as a free format list. Suppose that 25 items are introduced during the first year and each item is used 200 hours in the initial year and 300 hours each year thereafter. Suppose that in the second year an additional 75 items are introduced and each of them is used 200 hours in their initial year (second year of the program) and 300 hours each year thereafter. The usage in the second year does not refer to the usage the second year of the systems introduction, which would be 300 hours. Rather, it must be computed, in this example, by taking a weighted average of the 300 hours usage of the 25 items and the 200 hours usage of the 75 items.

Specifically

$$\text{usage} = 300(25/100) + 200(75/100) = 225 \text{ h urs}$$

The usage hours per system for the first four years would be 200 225 300 300.

7. DISCOUNT RATE AS PERCENT PER TIME PERIOD

DOD specifies a yearly discount rate of 10% for economic analysis.

The discount rate per time period is entered as a percent, not as a decimal. For example, if the discount rate is 10% a year and the time periods are years, enter 10. A discount rate of 10% a year is equivalent to a discount rate of 0.797% a month. If the discount rate is 10% a year and the time periods are months, enter 0.797. The formula for converting a yearly discount rate D to a monthly discount rate M is:

$$M = 100 (\sqrt[12]{1 + D/100} - 1)$$
, where D and M are in percent. If the time periods are quarters or semiannual periods, the discount rate should be computed accordingly.

8. ESCALATION INDICES PER TIME PERIOD

An escalation index must be entered for each time period under consideration. Note that while the discount rate is a percent, the escalation index is a factor. For example, if costs are escalated by 10%, an index of 1.1 is entered rather than 10. The indices are factors used to multiply the costs in the corresponding time periods. AMC has advised that escalation is inappropriate for an economic analysis. If no escalation is desired, enter an escalation index of 1 for each time period. Even though escalation is inappropriate for economic analysis, the capability to escalate costs has been retained in WARM in case the model is used for some other purpose which requires escalation. The indices are not used cumulatively. If 1.08 is entered for 10 years, the costs in all ten years are escalated by the same amount. To escalate by 8% each year, enter

1.00 (no escalation in the first year) for the first year, 1.08 for the second year, $1.1664 = (1.08)(1.08)$ for the third year, etc., If the time periods are months, not years, then the yearly index should be entered 12 times. This is easily done using the occurrence indicator, e.g., $12*1.0, 12*1.08, 12*1.1664,$ etc.

9. INHERENT FAILURE RATE (IN %), VALID CLAIM RATE (IN %) AND PERCENT WHICH REQUIRE REPAIR AT THE GS-OR-ABOVE LEVEL

For example, enter 85% as 85. Failures are classified as either being inherent to the item which fails or being induced by improper handling or use. For example, if a car has a flat tire, the flat is an inherent failure. If, in replacing the flat tire with a spare, the mechanic damages a lug on the wheel, then the damage to the lug is induced. WARM uses the inherent failure rate (percentage) which is the percent of all failures which are inherent as opposed to induced. Thus if the inherent failure rate is 85% and the total number of failures which occur due to all causes is 100, then 85 of the failures would be inherent and 15 would be induced. When a warranted item fails in the field, in order to have the contractor honor the warranty, the warranty claim must be processed properly (paper work filled out properly). WARM allows for the possibility that not all claims are properly filled out. The valid claim rate is the percentage of claims which are properly processed. For example, if the valid claim rate is 95%, then 95% of the claims are properly processed and 5% are not, and those 5% would not be honored by the contractor. Items often can fail in more than one way. Some of the failures may be repairable at field level and others may be repairable only at higher levels. In general, only those repairs which are done at the level of GS or above are warranted

and those done at field level are not. Therefore, WARM makes use of the percent of repairs to an item at the GS or above level. If the percent at GS or above level is 60%, then only 60% of the failures of an item are of the type which would be covered by the warranty.

10. INHERENT MTBF

The inherent MTBF (mean time between failure) describes how often an item experiences failures. The difference between inherent and induced failures is explained in section 9. In most cases, the MTBF value specified in the contract is the inherent MTBF. If the inherent MTBF is 100 hours, on the average, there will be one inherent failure every 100 hours of usage. If induced failures are also included, the failures will be more frequent (the MTBF will be less). In fact, if the inherent failure rate is 85%, the MTBF for both inherent and induced failures would be $100 \times .85 = 85$ hours. If the percent repaired at GS or above is 60%, then only 60% of the failures are of the type which are warranted. Therefore, warrantable failures occur less frequently (the MTBF is greater) than all failures. In fact, the MTBF for all failures both inherent and induced, which are repaired at GS or above would be $85/.60 = 141.7$ hours. In WARM, the MTBF for all failures, both inherent and induced, which are repaired at GS or above is called the modified MTBF. The concept represented by the modified MTBF is of importance in WARM, because it is the MTBF for all failures which actually occur (induced as well as inherent) of the type covered by the warranty. Since it could be described in those words, it was called the warranted MTBF in previous versions of WARM. However, that was not a desirable name for it, because the number of warranted failures was not computed directly from it. (The number of warranted failures is obtained by multiplying the

number of failures computed from the modified MTBF by the valid claim rate and the inherent failure rate. Therefore, the expression warranted MTBF has been replaced by the modified MTBF.

11. RANGE OF MTBF VALUES: BEGINNING MTBF, ENDING MTBF, STEP SIZE, AND AND MODE (MOST LIKELY MTBF)

In Part 2 of the output, the total cost of repairing all failures is compared over a range of MTBFs for the two alternatives of purchasing an item with or without a warranty. The range of inherent MTBF over which that comparison is made is indicated by entering a beginning MTBF (smallest), ending MTBF (largest), step size, and mode MTBF (a logical choice for the mode is the inherent MTBF). Note that the range of MTBFs is a range of inherent MTBFs, each of which corresponds to a modified MTBF. Part 2 of the output shows the range of modified MTBFs, not inherent MTBFs.

12. MTBF FACTORS FOR THE WARRANTY ALTERNATIVE

These factors can be used to multiply the MTBF to provide the capability to vary the MTBF by time period. For example, suppose the item under warranty has a given inherent MTBF. Furthermore, suppose that if a warranty is purchased with the item, the inherent MTBF would be 10% greater than it would be without the warranty. That can be entered in the model by entering a factor of 1.1 for each time period. As another example, suppose that the inherent MTBF increases by 5% each year over what it was the previous year for three years and then remains constant thereafter. If the time periods are years and the economic analysis is performed over a six year period, then the MTBF factors would be 1.0 1.05 1.1025 1.1576 1.1576 1.1576. Note that the factors are input as a free format list and are not used cumulatively. Note also that these

factors apply to calendar time, not usage time. A system operating in the third time period has a MTBF adjusted by the MTBF factor for the third time period; whether the system was delivered in the first, second, or third period is irrelevant. In usual practice, the analyst will probably not want to vary the MTBF by time period. In that case a factor of 1 must be entered for each time period. That can be done for 18 time periods, for example, by 18*1.

13. MTBF FACTORS FOR THE NO WARRANTY ALTERNATIVE

Remember that the main purpose of the model is to compare the two alternatives of purchasing an item with or without a warranty. Here the model provides the same capability for the no warranty case as is provided in section 12 for the warranty case. Again, in most standard analyses, the user will want to enter a factor of 1 for each time period.

14. DURATION OF THE WARRANTY IN TIME PERIODS AND IN USAGE HOURS

The duration of the warranty refers to how long the items are warranted. WARM considers warranties of the type length in time periods or usage hours, whichever comes first. For example, the duration of a warranty might be for one year or 100 hours of usage, whichever occurs first. The length of the warranty must be in whole numbers. If the length of a warranty happened to be 1.5 years, then time periods such as months, quarters, or semiannual periods should be used instead of years. Then the length of the warranty would be 18 months, 6 quarters, or 3 semiannual periods.

15. COSTS FOR WARRANTED REPAIRS BY COST ELEMENT

In order to perform an economic analysis comparing the warranty and no warranty alternatives, it is necessary to enter the costs of repairing failures for four separate cases, three for the warranty alternative and one for the no warranty alternative (see section 19). The warranty alternative requires

three cases to account for three separate possibilities. First, there are warranted failures (this section). Of course, these occur only during the warranty period. Second, there are unwarranted failures during the warranty period (see section 17). Examples of unwarranted failures during the warranty period are induced failures and invalidly claimed failures. Third, there are post warranty failures (see section 18). Of course, post warranty failures are possible only for the warranty alternative. These four separate cases are illustrated in figure 2, assuming a warranty period of 2 years and an economic analysis over 3 years. Even if the cost data is the same for some of the four cases, it must be entered separately for each case.

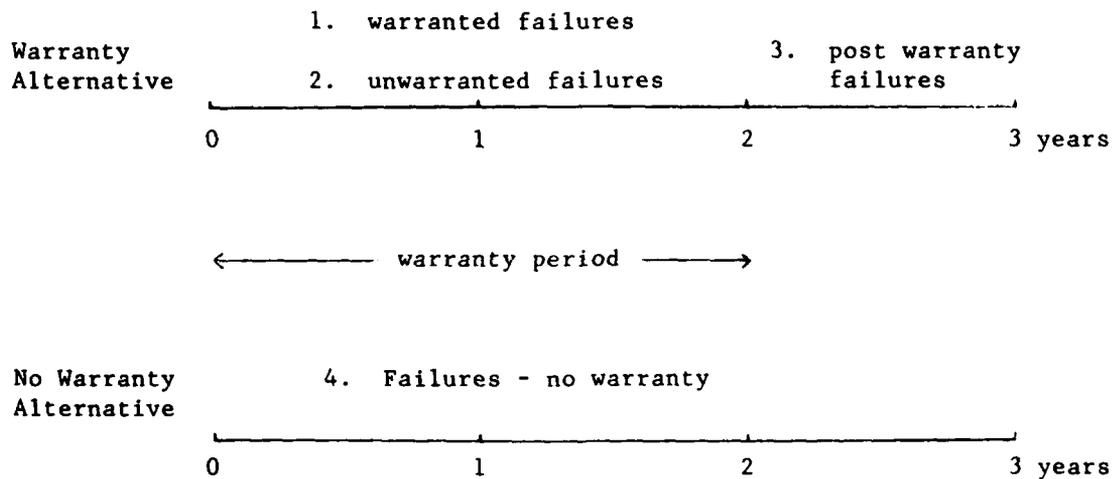


Figure 2. Cost Data Is Necessary for Four Separate Cases

For each of the four separate cases there are three options for entering repair cost data by cost element. The option selected by the analyst depends on the detail to which the analyst can input cost data. The most detailed option is to enter data for any subset of the following ten elements: 1/

- 1 - 2.01/3.02, NON-RECURRING PRODUCTION
- 2 - 2.02, RECURRING PRODUCTION
- 3 - 2.03, ENGINEERING CHANGES
- 4 - 2.04, DATA
- 5 - 2.05/4.01, SYSTEMS TEST AND EVALUATION
- 6 - 2.06/4.02, ILS TRAINING, SERVICE AND EQUIPMENT
- 7 - 2.07/4.04, INITIAL SPARES/REPAIR PARTS
- 8 - 2.08/3.03/3.04, OPERATIONAL/SITE ACTIVATION
- 9 - 2.09/4.06, OTHER
- 10 - 4.03, TRANSPORTATION

A second option is to enter cost data for the following four cost elements:

- 1 - material
- 2 - labor
- 3 - overhead
- 4 - other

The third option is a single cost element in which all costs are lumped together. For whichever option is chosen, the cost for each element must be divided into fixed and variable costs. Furthermore, for the warranted failure only, percentages must be given for the portions of the fixed and variable costs borne by the contractor. For example, suppose that the analyst chooses to enter data for element 7, Initial Spares/Repair Parts. If the data entered

1/ Cost element reference numbers are obtained from the "Big Five" - DCA-P-92(R), Directorate for Cost Analysis, Office of the Comptroller of the Army, 15 May 1984.

is 500 10 70 90, it means that for cost element 7, the fixed cost of repairing a warranted failure is 500, the variable cost of repairing a warranted failure is 10, 70% of the fixed cost of 500 is borne by the contractor (30% by the government), and 90% of the variable cost of 10 is borne by the contractor (10% by the government). An assumption of the model is that the contractor is responsible for the cost of the warranted repairs. However, the government may also have some cost, such as transportation costs, for warranted repairs. Percentages of costs borne by the contractor are not given for the three remaining cases (unwarranted repairs, post warranty repairs, and no-warranty repairs) because all those costs are government costs.

16. EXCLUSIONS TO WARRANTY PRICE FOR COMPARISON PURPOSES

This amount is subtracted from the warranty price when comparing the warranty and no warranty alternative. The exclusions may represent, for example, prorating of one-time, up front costs to purchase a warranty (e.g., stamping equipment that would not be spent in subsequent warranty purchases). Because of the flexibility in what the exclusion may represent, it is not discounted or escalated by the model. If appropriate, that should be done by the analyst before entering the value in the model.

17. COST FOR NONWARRANTED REPAIRS DURING THE WARRANTY PERIOD

This is one of the cases described in section 15. The data descriptions are similar to those in section 15 except that no percentages are required, only fixed and variable costs for each cost element used.

18. COSTS FOR REPAIRS AFTER THE WARRANTY EXPIRES

This is one of the cases described in section 15. The data descriptions are similar to those in section 15 except that no percentages are required, only fixed and variable costs for each cost element used.

19. COST FOR REPAIRS FOR THE NO-WARRANTY ALTERNATIVE

This is one of the cases described in section 15. The data descriptions are similar to those in section 15 except that no percentages are required, only fixed and variable costs for each cost element used.

20. IMPORTANT DISTINCTION BETWEEN THE FAILURE-FREE CASE AND THE THRESHOLD CASE

In the Failure-Free case the government purchases a warranty from a contractor and then all covered failures are repaired by the contractor at no cost to the government, hence the terminology "failure-free" (no cost). In the threshold case, a threshold (expected number of failures) is established. For a number of failures which is below the threshold, the government pays for the failures. For the number of failures in excess of the threshold, the contractor pays. In both the Failure-Free and Threshold cases, the WARM model computes an expected number of warranted failures. It is this value that is the threshold for the Threshold case. Note that in the Failure-Free case, the contractor pays for the expected number of warranted failures (in other words those below the threshold); while in the Threshold case, the government pays for the failures below the threshold (termed warranted failures in the model). Therefore, in the Failure-Free case, costs for warranted repairs should be assigned to the contractor by the percentages; and in the threshold case, the costs for warranted repairs should be assigned to the government by the percentages (see examples 1 and 2).

IV. OUTPUT

The output consists of three parts. Part 1 analyzes warranted failures only. The model computes and displays the expected number of warranted failures and the amount that should be paid to the contractor to fix the expected number of validly claimed warranted failures (called the warranty price). Part 2 is a cost comparison of the two alternatives of purchasing an item with and without a warranty. The comparison is made over the specified range of MTBFs. All failures, not just warranted failures, are included in the determination of the costs of the two alternatives. Part 3 provides two probability distributions which can be used to determine confidence intervals.

A. Part 1: An Analysis of Warranty Price Based on Warranted Analysis

The first table prints:

1. The modified MTBF - this is the MTBF of all failures, both inherent and induced, which are repaired at the GS or above level. (The modified MTBF was called the warranted MTBF in earlier versions of WARM.) The modified MTBF is the MTBF actually experienced for the type of failures which are warrantable.
2. The expected number of warranted failures - This number is computed by determining the number of failures from the modified MTBF and adjusting for inherent and validly claimed failures.
3. Cost for warranted repairs are apportioned between the contractor and government (in house) based on the percentages for fixed and variable costs for each cost element. The costs borne by the contractor are then totaled. It is the total of the contractor's costs to repair the warranted failures that is called the warranty price or "should cost" price of the warranty.

The government's in-house costs do not include costs for induced or invalidly claimed failures, since part 1 is concerned only with warranted failures.

The second table in part 1 is a distribution of warranted failures about the expected number of warranted failures computed in the first table of part 1. If the expected number of failures is 50 or greater, it is assumed that the warranted failures are normally distributed about the expected number. If there are fewer than 50, it is assumed that the number of warranted failures is a Poisson distribution. The number of warranted failures is computed at 5% intervals from 5% to 95%. There will always be nineteen values. Since the Poisson distribution is discrete, rather than continuous, the 5% steps are not exact; and occasionally a line in the distribution is repeated when the Poisson jumps two steps instead of one. Note that the distribution of warranted failures is either normal or Poisson. The input distribution of MTBFs is not used until part 2. For each line in the distribution of warranted failures, the warranty value and in-house costs (both computed as above) are shown.

B. Part 2: Comparison of Alternatives (Based on All Failures)

If the Failure-Free case is being analyzed, the input value of the exclusion and the amount by which the warranty price is to be reduced due to discounting are displayed and then subtracted from the warranty price to give the value of the warranty for comparison purposes. That value is then shown as the Warranty Cost in the table. For the threshold case, there is no warranty price. Instead, there is a possible administrative cost to the government, which is the only cost of the warranty. For the threshold case, the administrative cost is shown in place of the warranty cost.

In the table, a comparison of the total costs for all failures is made for the warranty and no warranty alternatives over the range of input MTBFs. The input MTBFs were inherent. Those shown in the table are the corresponding modified MTBFs. For each modified MTBF, there are two lines in the table, one for the warranty alternative and for the no warranty alternative. Also for each modified MTBF, the corresponding expected number of warranted failures is shown. "Other" contains the cost to the government of repairing all the failures repaired at GS or above that occur during the warranty period. "Post Warranty" contains the cost to the government of repairing all the failures (warranted and unwarranted) repaired at GS or above that occur from the time the warranty expires until the end of the economic analysis period. If the range of modified MTBFs in the table is large enough, there will be a crossover point at which the total cost for the warranty alternative and no warranty alternatives are equal (interpolation might be necessary to determine the crossover point). The modified MTBF at the crossover point is the MTBF which would have to be experienced in order for the warranty to be cost effective. For all modified MTBFs greater than that at the crossover point, the warranty is not cost effective.

C. Part 3: Probability Distribution

Part 3 contains two probability distributions. The first is a probability and cumulative probability distribution for the modified MTBF. The distribution is determined by the range of inherent MTBFs which were input and the type (triangular or Weibull) of distribution selected.

The second table is a cumulative probability distribution for the total cost of repairing all failures (warranted and unwarranted) of the type repaired

at GS or above for both the warranty and no warranty alternatives. The table can be used to determine the probability that the cost will not exceed a certain amount. Note that these probabilities are only as accurate as the input distribution.

V. Examples

In order to see how to use PCWARM3 and to see how the model does some of its calculations, consider the following examples:

A. Example 1: Failure-Free Case

The easiest way to see how the model works is with a simple example. Suppose that the Army is going to buy a quantity of items and also purchase a failure-free warranty for them (the Army pays a certain amount for the warranty and all covered failures are repaired at no charge to the government, thus the name failure-free).

The first information asked for in running WARM is whether the data is to be input from the terminal or a file. The file is a permanent data set which can be created from input data and to which changes can be made by responding to prompts. Let's select the terminal since it is more instructive, enter a T.

Next the user is asked for two lines of header (title) information which can be used to describe the warranty being analyzed or merely to name it. Let's call our analysis EXAMPLE, enter EXAMPLE and press the RETURN key twice (the second time enters the second line which is blank).

The first data element to be entered in the WARM model is the economic life. In this example, the economic life is the period of time over which the analyst chooses to make a cost comparison of the warranty/no-warranty alternatives. In our example, let the economic life be three years, enter 3 for the model.

It is now established that there are going to be three time periods. The next data to be entered is the number of periods in which deliveries are made.

Let's assume that deliveries are made only during the first year, enter 1.

Next enter the number of systems delivered in the first year. Let's assume that 100 items are to be delivered, enter 100.

Next enter the number of spares delivered in the first year. Let's assume there are no spares enter 0.

The next data element to be entered is the number of hours a single item is expected to be used in each of the three years. Let's assume that each item will be used 50 hours a year for each of the three years, enter 50 50 50.

Next enter the discount rate. In this example, let's assume there will be no discounting, enter 0.

Similarly assume there is no escalation in any of the three years, so enter 1 1 1.

By the inherent failure rate is meant the percent of all failures of the item which are considered to be inherent in contrast to induced failures which are caused by mishandling of the item. Let's assume that the inherent failure rate is 85%. That means that if there are 100 failures of the item, 85 of them are inherent and 15 of them are induced. The valid claim rate is the percent of failures which have the paper work for the warranty claims filled out correctly. In our example, let's assume that the valid claim rate is 95 percent, i.e., only 95 percent of the claims presented to the contractor are accepted by the contractor. An item can fail in several different ways, some of which would be repaired in the field and some of which would be repaired at GS or depot level. Only the failures which are repaired at GS or depot are considered for warranty coverage. Therefore the model asks for the percent

of failures which are repaired at GS or depot level. Let's assume in our example that 50 percent are repaired at that level. For the inherent failure rate, valid claim rate, and percent repaired at GS or above level, enter 85 95 50.

Enter the inherent mean time between failure. This is the mean time between failure caused by defects which are inherent to the item as opposed to failures which are induced by mishandling of the equipment. In our example, assume that the inherent MTBF = 50 hours, i.e., on the average a single item will fail every 50 hours of use.

The next data elements are a range of MTBFs and a step size for the range. This is the range of values over which the model compares the costs of the warranty/no warranty alternatives. That comparison is shown in part 2 of the output for each step in the range of MTBFs. For our example let's use a range of inherent MTBFs given by beginning (smallest) MTBF = 30, ending (largest) MTBF = 60, step size = 2, and mode (most likely) = 50, enter 30 60 2 50. In our example the mode was chosen to be the same as the inherent MTBF. That's a logical choice but it's not necessary.

The next two data elements allow the user to specify that the MTBF is different in any of the time periods or different if a warranty is purchased or not. In our example, assume the MTBF does not change under these circumstances, enter 1 1 1 for the warranty alternative and 1 1 1 for the no-warranty alternative.

Next, the duration of the warranty is entered. In WARM the type of warranty is length or usage, whichever comes first. In our example, let's suppose that the warranty proposal to be evaluated is for the first 2 years or 100 hours of usage, whichever comes first, enter 2 100. The warranty can last no longer than two years and could last for less than 2 years if 100 hours of usage occur before the two years are up. In our example, the item is being used at the

rate of 50 hours a year for each of the three years. So two years of usage would be exactly 100 hours. Therefore the 100 hours of usage expires at the same time as the two years. That need not be the case in this type of warranty as we will see later.

Next, the costs associated with repairs are entered. Remember that the purpose of the model is to make a comparison between the costs associated with repairing an item when a warranty exists including the cost of the warranty and when a warranty does not exist. We have to enter the costs for both of those cases, since they could be different. In the case of the no warranty alternative, there is only one set of costs (simply the costs when no warranty exists, a three year time period in our example). The warranty alternative is more complicated. First the warranty is for only two of the three year economic life. Thus we have a two year warranty period and a one year post warranty period. Furthermore, during the warranty period a failure may be warranted or unwarranted. Reasons why failures during the warranty period would not be warranted are that they are induced by improper handling or that warranty paper work to claim the failure is improperly filled out or that the warranted usage had expired. For the warranty alternative there are three sets of costs to enter in the model: the costs of warranted failures (these occur only during the warranty period), the costs of unwarranted failures during the warranty period, and the costs of post warranty failures.

Including the warranty and no warranty alternatives, there are four sets of repair costs to enter. Each of those sets of costs can be entered in one of three ways at the option of the WARM user. The simplest of these is to enter merely a fixed and a variable cost for a repair. Another alternative is to enter four cost elements for each repair: material, labor, overhead, and other. The third alternative is to enter any of the following ten cost elements for a repair: nonrecurring production; recurring production;

engineering changes; data; systems test and evaluation; ILS training; service and equipment; initial spares/repair parts; operational/site activation; other; and transportation. In our example, let's use simplest way of entering costs, merely fixed and variable, for each of the four sets of repair costs.

For warranted repairs, select choice 13 from the menu to enter fixed and variable costs.

For our example, suppose that the fixed costs associated with warranted repairs are 650 and the variable costs are 10 for each repair. Furthermore, there may be costs to both the government and the contractor for a warranted repair. So for warranted repairs only, the user must enter the percent of the fixed costs and the percent of the variable costs which are borne by the contractor. In our example let's assume that 100 percent of the fixed and 100 percent of the variable costs are borne by the contractor, enter 650 10 100 100.

For exclusions to warranty price, enter 0 for this example.

Next are the repair costs for unwarranted repairs during the warranty period. To enter only fixed and variable costs, enter 13 from the menu. Let's assume that the fixed and variable costs for unwarranted repairs are 650 and 10, respectively; enter 650 and 10. Here and in the next two cases, all the costs are borne by the government, so no percentages can be entered.

For the post warranty period, let's assume that the fixed costs have already been paid to handle the unwarranted repairs during the warranty period, and are therefore 0 here, and that the variable costs are again 10 for each repair, enter 0 10.

Finally, for the no-warranty alternative, let's assume that the fixed and variable costs are again 650 and 10, enter 650 and 10.

Figure 3 illustrates the four different sets of costs necessary to compare the warranty and no warranty alternatives. Of course in our example we could have chosen the economic life (time period over which the comparison is made) to be equal to the warranty length. Then there would be no post warranty period. However, the model would still ask for post warranty costs, but they would not be used.

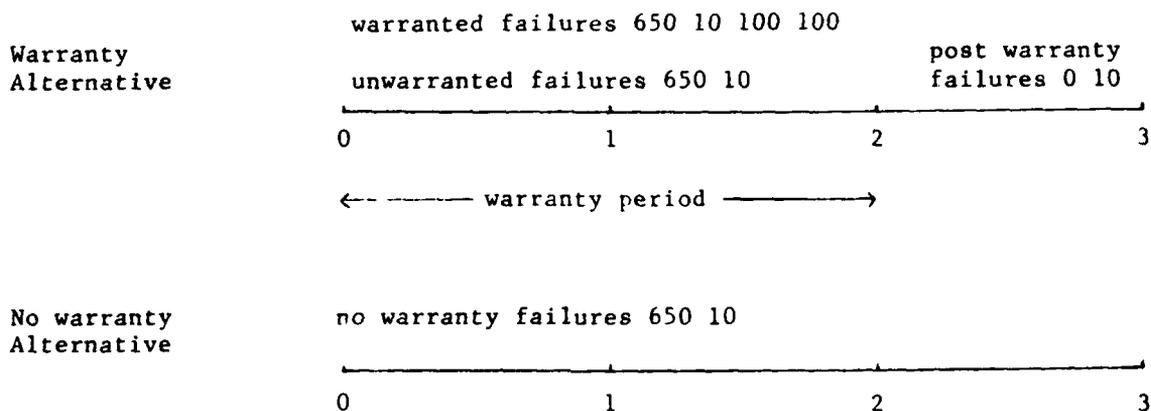


Figure 3. Illustration of WARM Input Costs

All the input data has now been entered and we can now examine the model's output which is in three parts. Part 1 is concerned with warranted failures, Part 2 compares the warranty/no warranty alternatives over a range of input MTBFs, and Part 3 gives some distributions.

Keep in mind that Part 1 deals only with warranted failures. The first value displayed in Part 1 is the modified MTBF by which is meant the MTBF for

both inherent and induced failures which are repaired at GS or depot level. This is the MTBF of interest, because it includes all failures of an item which actually occur (the failures actually experienced) which are of the type that could be warranted. The equation for computing the modified MTBF is

$$\text{modified MTBF} = \text{inherent MTBF} \times \frac{\text{inherent failure rate}}{\text{percent repaired at GS or depot}}$$

In our example,

$$\text{modified MTBF} = 50(85/50) = 85 \text{ hours}$$

The next item in the output is the expected number of warranted failures, the actual number of failures during the warranty period which are warranted. In our example, the warranty period is 2 years, there are 50 hours of usage in each of the first 2 years, and there are 100 items. That means that there are

$$\frac{100 \text{ items} \times 50 \text{ hours} \times 2 \text{ years}}{85} = 117.6 \text{ failures of}$$

the type of repair covered by the warranty. However, these still include the induced and invalid claims. Multiplying by the inherent failure rate and the valid claim rate gives

$$\text{warranted failures} = 117.6 \times .85 \times .95 = 95$$

Next is given the cost breakout for these 95 failures by cost element. Here we have only one element, fixed and variable. The first column is the contractor's cost for the 95 failures = $650 + (95 \times 10) = 1600$. The second column is the government's cost for the 95 failures which is 0, because we assigned 100% of the warranted costs to the contractor. The third column is the total of the first two. The warranty price is the total of cost elements (only one in our example) paid to contractor. Therefore the warranty price is the contractor's cost for repairing the 95 failures.

The next section in Part I shows the same total costs as the first section in Part I except that they are computed for warranted failures which are assumed to be normally distributed about the expected number of warranted failures computed in the first section of Part I. There are 19 lines in the table corresponding to 5 percent intervals from 5 percent to 95 percent in the normal distribution. If the expected number of warranted failures is less than 50, the Poisson distribution is used instead of the normal.

For the line with 100 failures, the warranty value is the contractor's cost to repair 100 warranted failures.

$$\text{warranty value} = 650 + 100 (10) = 1650$$

The benefit of this distribution is that it gives the warranty value (warranty price) for various numbers of warranted failures which are different from the expected number, and it also provides probabilities of those numbers of failures occurring. Using the lines from the table in our example for 90 and 100 failures corresponding to cumulative probabilities of 30 and 70 percent, respectively, gives that there is a 40 percent probability that the warranty value is between 1550 and 1650.

The in-house costs are the government's cost for 100 warranted failures. Those costs are 0, because 100 percent of the warranted failure costs are borne by the contractor. The third column is the sum of the first two.

The user then has the option to have a cost breakout (rather than just totals as in the table) for another number of warranted failures. In our example, let's enter N.

Since this is a failure-free warranty, enter F-FREE when prompted, to indicate the type of warranty being analyzed.

At the beginning of Part 2, a warranty cost for comparison purposes is computed by starting with the warranty price from Part 1 (which can be escalated but not discounted), subtracting the exclusions (which must be escalated and discounted outside the model), and subtracting an amount for discounting (based on discounting failures). Therefore, the warranty cost which is shown in column 3 of the comparison table can be escalated and discounted. In this example, it is not escalated or discounted.

The table in Part 2 is one of the most important outputs of WARM. It shows the comparison of the total cost over the entire economic life of the warranty/no warranty alternatives for a range of MTBFs. It is from this table that the analyst can determine the crossover point at which the total cost for the warranty and no warranty alternatives are the same. In our example they are never equal, but they are close when the modified MTBF=51 which corresponds to an inherent MTBF=30. Therefore the crossover point occurs when the inherent MTBF is slightly less than 30.

In the table in Part 2, the warranty cost is discounted and escalated. The "other" column which contains the government's costs for unwarranted failures is discounted and escalated. However, the fixed costs (which are assumed to occur in the first year) are not discounted. The post warranty costs are discounted and escalated. The fixed costs for them are assumed to occur in the first year after the warranty expires and are discounted and escalated accordingly. The total column is the sum of the three previous columns.

In Part 3, the WARM model displays two probability distributions. The first probability distribution in Part 3 is based on the range of inherent

MTBFs input by the user and the choice of whether the distribution is triangular or Weibull. In our example, we choose a triangular distribution with a range of inherent MTBFs from 30 to 60 with a mode of 50 and step size of 2, enter TRIANG. The model converts these values to corresponding modified MTBFs. The range of modified MTBFs corresponding to our input inherent MTBFs is 51 to 102 with a mode of 85 and step size 2 (the step size is always unchanged). WARM begins the table in Part 3 with MTBF=51 and continues in steps of 2 past the larger endpoint 102. Therefore the modified MTBF 85 will be in the table, but 102 will not since it is even. In this case the values of 101 and 103 appear.

The expected value is computed from the range of modified MTBFs. In our example a triangular distribution was selected. The expected value of a triangular distribution is given by

expected value = $1/3 (51 + 85 + 103) = 79.7$. The WARM printout shows 80.0. Note that in the computation the endpoint of 103 is used rather than 102.

The probability and cumulative values shown in the first table of Part 3 are based on the triangular distribution. For example, when MTBF=55, the PROB=.009. That means that the probability of the MTBF falling in the preceding step interval (53 to 55) is .009. The third column is the accumulation of column two.

The second table in Part 3 is based on the table in Part 2 and the first table in Part 3. It is a cumulative distribution for total costs (last column of the table in Part 2) for the warranty and the no-warranty alternatives. Each step in the table in Part 2 is associated with a probability from column two of the first table in Part 3. In particular, 103 to 105 has PROB = .004, 101 to 103 has PROB = .012, etc. Starting with the MTBF = 103 the costs in

the last column of the table in Part 2 are listed in increasing value and cumulative distributions are computed for the warranty and no warranty cases separately based on the associated probabilities in the first table of Part 3.

After the program has finished running, a menu (figure 3) is displayed presenting the analyst with several choices. For the example we have just completed, enter 18 to save the data on a file. Call the file EXAMPL1.DAT.

C:\>cd\pcwarm

C:\PCWARM>PCWARM3

WARRANTY PROGRAM UPDATED SEPTEMBER 1987

TYPE T TO INPUT DATA AT TERMINAL; TYPE F TO RETRIEVE DATA STORED ON FILE
T

ENTER TWO LINES OF HEADER INFORMATION
EXAMPLE

ENTER ECONOMIC LIFE IN TIME PERIODS (WHOLE NUMBER BETWEEN 1 AND 240)
3

ENTER NUMBER OF TIME PERIODS DELIVERIES ARE MADE (MUST BE A
WHOLE NUMBER FROM 1 TO 240)
1

ENTER NUMBER OF SYSTEMS DELIVERED EACH PERIOD FOR 1 TIME PERIODS
100

ENTER NUMBER OF SPARES DELIVERED EACH PERIOD FOR 1 TIME PERIODS
0

ENTER USAGE HOURS PER SYSTEM PER TIME PERIOD, FOR 3 PERIODS
50 50 50

ENTER DISCOUNT RATE AS PERCENT PER TIME PERIOD, E.G., 10. FOR 10%
0

ENTER ESCALATION INDICES PER TIME PERIOD, FOR 3 PERIODS
1 1 1

ENTER INHERENT FAILURE RATE, VALID CLAIM RATE
AND PERCENT WHICH REQUIRES GS OR ABOVE LEVEL REPAIR
85 95 50

ENTER INHERENT MTBF
50

ENTER RANGE OF MTBF VALUES AS BEGINNING MTBF, ENDING MTBF, STEP SIZE
AND THE MODE(=MOST LIKELY MTBF)
30 60 2 50

ENTER MTBF FACTORS FOR WARRANTY ALTERNATIVE; ONE FOR EACH PERIOD, FOR
3 TIME PERIODS. TO INPUT A VALUE N TIMES USE N*VALUE; FOR EXAMPLE,
3*1.2 BECOMES 1.2,1.2,1.2
1 1 1

ENTER MTBF FACTORS FOR NO WARRANTY ALTERNATIVE; ONE FOR EACH PERIOD, FOR
3 TIME PERIODS. TO INPUT A VALUE N TIMES USE N*VALUE; FOR EXAMPLE,
3*.99 BECOMES .99,.99,.99
3*1.0

ENTER LENGTH OF WARRANTY IN TIME PERIODS (MUST BE A WHOLE NUMBER) AND IN
USAGE HOURS

COSTS FOR WARRANTED REPAIRS BY COST ELEMENT:

- 1. THESE COSTS ARE INITIALIZED TO ZERO.
- 2. A FIXED COST, A VARIABLE COST, AND PERCENTAGES OF THESE COSTS PAID TO THE CONTRACTOR ARE REQUIRED FOR EACH COST ELEMENT TO BE ENTERED.
- 3. USE SUBMENU TO SELECT COST ELEMENTS TO BE INPUT.
- 4. VARIABLE COSTS FOR COST ELEMENTS OTHER THAN 2.02 (RECURRING PRODUCTION) MAY BE ENTERED AS A PERCENT OF THE VARIABLE COST FOR 2.02, BY ENTERING THE PERCENTAGE AS A NEGATIVE NUMBER, E.G., -10.0 FOR 10%.

AFTER MESSAGE IS NOTED HIT RETURN.

SUBMENU FOR COSTS OF WARRANTED REPAIRS:

ENTER ON 1 LINE NUMBERS FOR ALL COST ELEMENTS YOU WISH TO INPUT, OR ENTER 0 (ZERO) TO SKIP INPUTTING ANY COSTS

- 1 - TO ENTER COSTS FOR 2.01/3.02, NONRECURRING PRODUCTION
- 2 - TO ENTER COSTS FOR 2.02, RECURRING PRODUCTION
- 3 - TO ENTER COSTS FOR 2.03, ENGINEERING CHANGES
- 4 - TO ENTER COSTS FOR 2.04, DATA
- 5 - TO ENTER COSTS FOR 2.05/4.01, SYSTEMS TEST AND EVALUATION
- 6 - TO ENTER COSTS FOR 2.06/4.02 ILS TRAINING, SERVICE AND EQUIPMENT
- 7 - TO ENTER COSTS FOR 2.07/4.04, INITIAL SPARES/REPAIR PARTS
- 8 - TO ENTER COSTS FOR 2.08/3.03/3.04, OPERATIONAL/SITE ACTIVATION
- 9 - TO ENTER COSTS FOR 2.09/4.06, OTHER
- 10 - TO ENTER COSTS FOR 4.03, TRANSPORTATION

YOU MAY CHOOSE DIFFERENT COST ELEMENTS SUCH AS:

- 12 - TO SELECT 4 COST ELEMENTS, MATERIAL, LABOR, OVERHEAD, OTHER
- 13 - OR TO SELECT JUST FIXED COSTS AND VARIABLE COSTS

13

ENTER FIXED COSTS AND VARIABLE COSTS,
PERCENT OF FIXED COSTS PAID TO CONTRACTOR
AND PERCENT OF VARIABLE COSTS PAID TO CONTRACTOR
650 10 100 100

ENTER EXCLUSIONS TO WARRANTY PRICE TO BE USED WHEN COMPARING WARRANTY AND NO WARRANTY ALTERNATIVES

0

COSTS FOR NONWARRANTED REPAIRS DURING WARRANTY PERIOD:

- 1. THESE COSTS ARE INITIALIZED TO ZERO.
- 2. USE SUBMENU TO SELECT COST ELEMENTS TO BE INPUT.
- 3. A FIXED COST AND A VARIABLE COST ARE REQUIRED FOR ANY COST ELEMENT ENTERED.
- 4. VARIABLE COSTS FOR COST ELEMENTS OTHER THAN 2.02 (RECURRING PRODUCTION) MAY BE ENTERED AS A PERCENT OF THE VARIABLE COST FOR 2.02, BY ENTERING THE PERCENTAGE AS A NEGATIVE NUMBER, E.G., -10.0 FOR 10%.

AFTER MESSAGE IS NOTED HIT RETURN.

SUBMENU FOR COSTS OF NONWARRANTED REPAIRS DURING WARRANTY PERIOD:

ENTER ON 1 LINE NUMBERS OF ALL COSTS ELEMENTS TO BE INPUT, OR
ENTER 0 (ZERO) TO SKIP INPUTTING COSTS

- 1 - TO ENTER COSTS FOR 2.01/3.02, NONRECURRING PRODUCTION
- 2 - TO ENTER COSTS FOR 2.02, RECURRING PRODUCTION
- 3 - TO ENTER COSTS FOR 2.03, ENGINEERING CHANGES
- 4 - TO ENTER COSTS FOR 2.04, DATA
- 5 - TO ENTER COSTS FOR 2.05/4.01, SYSTEMS TEST AND EVALUATION
- 6 - TO ENTER COSTS FOR 2.06/4.02, ILS TRAINING, SERVICE AND EQUIPMENT
- 7 - TO ENTER COSTS FOR 2.07/4.04, INITIAL SPARES/REPAIR PARTS
- 8 - TO ENTER COSTS FOR 2.08/3.03/3.04, OPERATIONAL/SITE ACTIVATION
- 9 - TO ENTER COSTS FOR 2.09/4.06, OTHER
- 10 - TO ENTER COSTS FOR 4.03, TRANSPORTATION

YOU MAY CHOOSE DIFFERENT COST ELEMENTS SUCH AS:

- 12 - TO SELECT 4 COST ELEMENTS, MATERIAL, LABOR, OVERHEAD, OTHER
- 13 - OR TO SELECT JUST FIXED COSTS AND VARIABLE COSTS

13

ENTER FIXED COSTS AND VARIABLE COSTS
650 10

COSTS FOR NONWARRANTED REPAIRS AFTER WARRANTY EXPIRES:

- 1. THESE COSTS ARE INITIALIZED TO ZERO.
- 2. A FIXED AND A VARIABLE COST ARE REQUIRED FOR A COST ELEMENT.
- 3. USE SUBMENU TO SELECT COST ELEMENTS TO BE INPUT.
- 4. VARIABLE COSTS FOR COST ELEMENTS OTHER THAN 2.02 (RECURRING PRODUCTION) MAY BE ENTERED AS A PERCENT OF THE VARIABLE COST FOR 2.02, BY ENTERING THE PERCENTAGE AS A NEGATIVE NUMBER, E.G., -10.0 FOR 10%.

AFTER MESSAGE IS NOTED HIT RETURN.

SUBMENU FOR COSTS OF REPAIRS AFTER THE WARRANTY EXPIRES:

ENTER ON 1 LINE NUMBERS OF COSTS ELEMENTS TO BE INPUT, OR
ENTER 0 (ZERO) TO SKIP INPUTTING DATA

- 1 - TO ENTER COSTS FOR 2.01/3.02, NONRECURRING PRODUCTION
- 2 - TO ENTER COSTS FOR 2.02, RECURRING PRODUCTION
- 3 - TO ENTER COSTS FOR 2.03, ENGINEERING CHANGES
- 4 - TO ENTER COSTS FOR 2.04, DATA
- 5 - TO ENTER COSTS FOR 2.05/4.01, SYSTEMS TEST AND EVALUATION
- 6 - TO ENTER COSTS FOR 2.06/4.02, ILS TRAINING, SERVICE AND EQUIPMENT
- 7 - TO ENTER COSTS FOR 2.07/4.04, INITIAL SPARES/REPAIR PARTS
- 8 - TO ENTER COSTS FOR 2.08/3.03/3.04, OPERATIONAL/SITE ACTIVATION
- 9 - TO ENTER COSTS FOR 2.09/4.06, OTHER
- 10 - TO ENTER COSTS FOR 4.03, TRANSPORTATION

YOU MAY CHOOSE DIFFERENT COST ELEMENTS SUCH AS:

- 12 - TO SELECT 4 COST ELEMENTS, MATERIAL, LABOR, OVERHEAD, OTHER
- 13 - OR TO SELECT JUST FIXED COSTS AND VARIABLE COSTS

13

ENTER FIXED COSTS AND VARIABLE COSTS
0 10

COSTS FOR REPAIRS FOR NO WARRANTY ALTERNATIVE:

1. THESE COSTS ARE INITIALIZED TO ZERO.
2. A FIXED AND A VARIABLE COST ARE REQUIRED FOR A COST ELEMENT.
3. USE SUBMENU TO SELECT COST ELEMENTS TO BE INPUT.
4. VARIABLE COSTS FOR COST ELEMENTS OTHER THAN 2.02 MAY BE ENTERED AS A PERCENT OF THE VARIABLE COST FOR 2.02 BY ENTERING THE PERCENTAGE AS A NEGATIVE NUMBER, E.G., -10.0 FOR 10%.

AFTER MESSAGE IS NOTED HIT RETURN.

SUBMENU FOR COSTS OF REPAIRS FOR NO WARRANTY CASE:

ENTER ON 1 LINE NUMBERS FOR ALL COST ELEMENTS TO BE INPUT
ENTER 0 (ZERO) TO SKIP INPUTTING ANY VALUES

- 1 - TO ENTER COSTS FOR 2.01/3.02, NONRECURRING PRODUCTION
- 2 - TO ENTER COSTS FOR 2.02, RECURRING PRODUCTION
- 3 - TO ENTER COSTS FOR 2.03, ENGINEERING CHANGES
- 4 - TO ENTER COSTS FOR 2.04, DATA
- 5 - TO ENTER COSTS FOR 2.05/4.01, SYSTEMS TEST AND EVALUATION
- 6 - TO ENTER COSTS FOR 2.06/4.02 ILS TRAINING, SERVICE AND EQUIPMENT
- 7 - TO ENTER COSTS FOR 2.07/4.04 INITIAL SPARES/REPAIR PARTS
- 8 - TO ENTER COSTS FOR 2.08/3.03/3.04, OPERATIONAL/SITE ACTIVATION
- 9 - TO ENTER COSTS FOR 2.09/4.06, OTHER
- 10 - TO ENTER COSTS FOR 4.03, TRANSPORTATION

YOU MAY CHOOSE DIFFERENT COST ELEMENTS SUCH AS:

- 12 - TO SELECT 4 COST ELEMENTS, MATERIAL, LABOR, OVERHEAD, OTHER
- 13 - OR TO SELECT JUST FIXED COSTS AND VARIABLE COSTS

13

ENTER FIXED COSTS AND VARIABLE COSTS
650 10

TO GET NEW PAGE, TAKE PRINTER OFF LINE, ADVANCE PAPER TO TOP OF PAGE.
TO PROCEED, RETURN PRINTER ON LINE AND HIT RETURN.

EXAMPLE

PART 1: ANALYSIS OF WARRANTY PRICE (BASED ON WARRANTED FAILURES ONLY)

THE MODIFIED MTBF IS 85.0
(THE MODIFIED MTBF IS THE MTBF
OF ALL FAILURES INHERENT AND INDUCED
WHICH ARE REPAIRED AT GS OR ABOVE.)

EXPECTED NUMBER OF WARRANTED FAILURES IS 95

BREAKOUT OF COST OF 95.00 WARRANTED FAILURES:

COST ELEMENT	PAID TO CONTRACTOR	IN-HOUSE	TOTAL
FIXED & VARIAB	1600	0	1600
TOTALS:	1600	0	1600
WARRANTY PRICE=	1600		

TO GET NEW PAGE, TAKE PRINTER OFF LINE, ADVANCE PAPER TO TOP OF PAGE.
TO PROCEED, RETURN PRINTER ON LINE AND HIT RETURN.

EXAMPLE

DISTRIBUTION OF WARRANTED FAILURES (GIVEN WARRANTED MTBF)		COSTS OF WARRANTED FAILURES		
NUMBER OF FAILURES	CUMULATIVE PROBABILITY	WARRANTY VALUE	IN-HOUSE	TOTAL
79	.05	1440	0	1440
83	.10	1480	0	1480
85	.15	1500	0	1500
87	.20	1520	0	1520
88	.25	1530	0	1530
90	.30	1550	0	1550
91	.35	1560	0	1560
93	.40	1580	0	1580
94	.45	1590	0	1590
95	.50	1600	0	1600
96	.55	1610	0	1610
97	.60	1620	0	1620
99	.65	1640	0	1640
100	.70	1650	0	1650
102	.75	1670	0	1670
103	.80	1680	0	1680
105	.85	1700	0	1700
107	.90	1720	0	1720
111	.95	1760	0	1760

DO YOU WANT A COST BREAKOUT FOR ANOTHER NUMBER OF
WARRANTED FAILURES (THAT YOU ENTER)? (ANSWER Y OR N)
N

TO GET NEW PAGE, TAKE PRINTER OFF LINE, ADVANCE PAPER TO TOP OF PAGE.
TO PROCEED, RETURN PRINTER ON LINE AND HIT RETURN.

EXAMPLE

IS THIS A FAILURE-FREE OR THRESHOLD WARRANTY ?
 TYPE "F-FREE" FOR FAILURE-FREE OR "THRESH"
 FOR THRESHOLD WARRANTY
 IF THRESHOLD, ENTER THE ADMIN COST
 PAID TO THE CONTRACTOR
 F-FREE

PART 2: COMPARISON OF ALTERNATIVES (BASED ON ALL FAILURES)-FAILURE FREE

WARRANTY PRICE = 1600
 EXCLUSIONS FOR COMPARISON PURPOSES = 0
 AMOUNT EXCLUDED DUE TO DISCOUNTING = 0
 VALUE USED FOR COMPARISON PURPOSES = 1600

MODIFIED MTBF	EXP NO. OF WARRANTD FAIL	WARRANTY ?	WARRANTY COST	OTHER	POST WARRANTY	TOTAL
51.0	158	YES	1600	1027	980	3608
51.0	158	NO		2611	980	3591
53.0	152	YES	1600	1013	943	3557
53.0	152	NO		2537	943	3480
55.0	147	YES	1600	1000	909	3509
55.0	147	NO		2468	909	3377
57.0	142	YES	1600	988	877	3465
57.0	142	NO		2404	877	3282
59.0	137	YES	1600	976	847	3424
59.0	137	NO		2345	847	3192
61.0	132	YES	1600	966	820	3385
61.0	132	NO		2289	820	3109
63.0	128	YES	1600	956	794	3349
63.0	128	NO		2237	794	3031
65.0	124	YES	1600	946	769	3315
65.0	124	NO		2188	769	2958
67.0	121	YES	1600	937	746	3284
67.0	121	NO		2143	746	2889
69.0	117	YES	1600	929	725	3254
69.0	117	NO		2099	725	2824
71.0	114	YES	1600	921	704	3225
71.0	114	NO		2058	704	2763
73.0	111	YES	1600	914	685	3199
73.0	111	NO		2020	685	2705
75.0	108	YES	1600	907	667	3173
75.0	108	NO		1983	667	2650
77.0	105	YES	1600	900	649	3149
77.0	105	NO		1949	649	2598

79.0	102	YES	1600	894	633	3127
79.0	102	NO		1916	633	2549
81.0	100	YES	1600	888	617	3105
81.0	100	NO		1885	617	2502
83.0	97	YES	1600	882	602	3084
83.0	97	NO		1855	602	2457
85.0	95	YES	1600	876	588	3065
85.0	95	NO		1826	588	2415
87.0	93	YES	1600	871	575	3046
87.0	93	NO		1799	575	2374
89.0	91	YES	1600	866	562	3028
89.0	91	NO		1774	562	2335
91.0	89	YES	1600	862	549	3011
91.0	89	NO		1749	549	2298
93.0	87	YES	1600	857	538	2995
93.0	87	NO		1725	538	2263
95.0	85	YES	1600	853	526	2979
95.0	85	NO		1703	526	2229
97.0	83	YES	1600	848	515	2964
97.0	83	NO		1681	515	2196
99.0	82	YES	1600	844	505	2949
99.0	82	NO		1660	505	2165
101.0	80	YES	1600	841	495	2936
101.0	80	NO		1640	495	2135
103.0	78	YES	1600	837	485	2922
103.0	78	NO		1621	485	2106
105.0	77	YES	1600	833	476	2910
105.0	77	NO		1602	476	2079

DO YOU WISH TO ASSUME YOUR DISTRIBUTION
OF MTBFS IS TRIANGULAR OR WEIBUL ?

TYPE "TRIANG" FOR TRIANGULAR OR "WEIBUL"
FOR WEIBULL DISTRIBUTION

NOTE: IN SOME CASES, WEIBULL DISTRIBUTION MIGHT NOT BE
SUITABLE AND MUELLER ITERATION MIGHT NOT CONVERGE.

IN GENERAL TRIANGULAR DISTRIBUTION WILL GIVE YOU
A GOOD APPROXIMATION

TRIANG

TO GET NEW PAGE, TAKE PRINTER OFF LINE, ADVANCE PAPER TO TOP OF PAGE.
TO PROCEED, RETURN PRINTER ON LINE AND HIT RETURN.

PART 3: PROBABILITY DISTRIBUTION

PROBABILITY DISTRIBUTION OF MODIFIED MTBF

THE EXPECTED MODIFIED MTBF = 80.0

MODIFIED MTBF	PROB.	CUM. PROB.
51	.000	.000
53	.004	.004
55	.009	.013
57	.013	.027
59	.018	.044
61	.022	.067
63	.027	.093
65	.031	.124
67	.036	.160
69	.040	.200
71	.044	.244
73	.049	.293
75	.053	.346
77	.058	.404
79	.062	.466
81	.067	.533
83	.071	.604
85	.075	.679
87	.068	.747
89	.060	.806
91	.052	.858
93	.044	.902
95	.036	.937
97	.028	.965
99	.020	.985
101	.012	.997
103	.004	1.001

TO GET NEW PAGE, TAKE PRINTER OFF LINE, ADVANCE PAPER TO TOP OF PAGE
TO PROCEED, RETURN PRINTER ON LINE AND HIT RETURN.

DISTRIBUTION OF TOTAL COSTS

TOTAL COSTS	CUM. PROB. WARRANTY	CUM. PROB. NO WARRANTY
2106	.000	.004
2135	.000	.016
2165	.000	.036
2196	.000	.064
2229	.000	.099
2263	.000	.143
2298	.000	.195
2335	.000	.254
2374	.000	.322
2415	.000	.397
2457	.000	.468
2502	.000	.535
2549	.000	.597
2598	.000	.655
2650	.000	.708
2705	.000	.757
2763	.000	.801
2824	.000	.841
2889	.000	.877
2922	.004	.892
2936	.016	.898
2949	.036	.904
2958	.052	.908
2964	.064	.910
2979	.099	.915
2995	.143	.921
3011	.195	.927
3028	.254	.933
3031	.265	.934
3046	.322	.939
3065	.397	.944
3084	.468	.950
3105	.535	.955
3109	.547	.957
3127	.597	.960
3149	.655	.965
3173	.708	.970
3192	.745	.974
3199	.757	.975
3225	.801	.979
3254	.841	.984
3282	.874	.988
3284	.877	.988
3315	.908	.991
3349	.934	.994
3377	.952	.997
3385	.957	.997
3424	.974	.999
3465	.988	1.000
3480	.991	1.000
3509	.997	1.001
3557	1.001	1.001
3591	1.001	1.001
3608	1.001	1.001

ENTER APPROPRIATE NUMBER TO STOP OR TO REENTER DATA, OR TO RERUN ANALYSIS

- 1 - REENTER EVERYTHING
 - 2 - HEADER INFORMATION
 - 3 - ECONOMIC LIFE
 - 4 - DELIVERY SCHEDULES (FOR SYSTEMS AND SPARES)
 - 5 - USAGE HOURS PER SYSTEM PER TIME PERIOD
 - 6 - DISCOUNT RATE
 - 7 - ESCALATION INDICES
 - 8 - MTBF VALUES AND PERCENT OF FAILURES COVERED BY WARRANTY
 - 9 - LENGTH OF WARRANTY
 - 10 - COSTS FOR WARRANTED REPAIRS
 - 11 - EXCLUSIONS TO WARRANTY PRICE FOR COMPARISON PURPOSES
 - 12 - COSTS FOR NONWARRANTED REPAIRS
 - 13 - COSTS OF REPAIRS AFTER WARRANTY EXPIRES
 - 14 - COSTS UNDER NO WARRANTY ALTERNATIVE
 - 15 - RERUN ANALYSIS
 - 16 - PRINT THIS MENU
 - 17 - PRINT CURRENT VALUES OF INPUT DATA
 - 18 - TO SAVE INPUT DATA ON FILE
 - 19 - TO RETRIEVE SAVED DATA FROM FILE
 - 20 - STOP
- 18

ENTER THE NAME OF THE OUTPUT FILE
EXMPL1.DAT

ENTER APPROPRIATE NUMBER TO STOP OR TO REENTER DATA, OR TO RERUN ANALYSIS

- 1 - REENTER EVERYTHING
 - 2 - HEADER INFORMATION
 - 3 - ECONOMIC LIFE
 - 4 - DELIVERY SCHEDULES (FOR SYSTEMS AND SPARES)
 - 5 - USAGE HOURS PER SYSTEM PER TIME PERIOD
 - 6 - DISCOUNT RATE
 - 7 - ESCALATION INDICES
 - 8 - MTBF VALUES AND PERCENT OF FAILURES COVERED BY WARRANTY
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 - 15 - RERUN ANALYSIS
 - 16 - PRINT THIS MENU
 - 17 - PRINT CURRENT VALUES OF INPUT DATA
 - 18 - TO SAVE INPUT DATA ON FILE
 - 19 - TO RETRIEVE SAVED DATA FROM FILE
 - 20 - STOP
- 20

Stop - Program terminated.

B. Example 2: Threshold Case

In this example, let's use the data we stored on the file EXMPL1.DAT at the end of example 1. Of course, the data had to be stored to retrieve it. If that wasn't done, enter the data again as in example 1. Enter 19 to retrieve saved data from the menu if still logged on from example 1. If logging on again, enter F to indicate that data on a file is to be used. When prompted for the name of the input file, enter EXAMPL1.DAT.

From the menu enter 2 to change the header information. Then enter the new header EXAMPLE 2 - THRESHOLD CASE.

From the menu, enter 10 to change the costs for warranted repairs. The difference between the failure-free warranty and the threshold warranty is in who pays for the failures below the expected value (threshold). In the failure-free warranty, those failures are paid for by the contractor, since the government has purchased their warranty. In the threshold warranty, they are the expected number of failures. Since the government doesn't purchase a warranty, it must pay for these expected failures. Therefore, the costs for warranted repairs should be changed from 650 10 100 100 for the failure-free warranty to 650 10 0 0 for the threshold case. Note that the percentages have been changed assigning these costs to the government rather than the contractor. As before, we are using only one cost element, fixed and variable.

From the menu, enter a 12 to change the cost for unwarranted repairs during the warranty period. Previously, we had fixed costs of 650 and variable costs of 10 for this case. The fixed cost of 650 was necessary because at this point in the failure-free case, no fixed cost for the government had been entered. However, in the threshold case, a fixed cost of 650 has already been entered for the government in the warranted failures section. Therefore, change the costs for unwarranted repairs from 650 10 in the failure-free warranty to 0 10 in the threshold warranty.

It is not necessary to change the costs for post warranty repairs and the no warranty alternative. In fact, no other data needs to be changed, so enter a 15 from the menu to run the analysis. The main purpose of Part 1 of the output is to compute the threshold value. Since only the cost data was changed, we get the same value for the modified MTBF, 85, and the expected number of warranted failures, 95, as in example 1. These are the threshold values. If there are 95 or fewer failures (inherent, validly claimed, and repaired at GS or above) during the warranty period, the government pays their repair costs. If there are more than 95, the contractor must pay for the amount by which the number exceeds 95.

When the program asks for the type of warranty to be analyzed, enter THRESH for threshold. Suppose the administrative costs to the government are 55, enter 55 for the administrative costs. Part 2 displays the administrative costs, which, if appropriate, must be escalated and discounted outside the model, in place of the warranty cost. The table in Part 2 again shows a comparison of the total government cost of all failures for the warranty/no warranty alternatives. However, note that when the modified MTBF is less than

the threshold modified MTBF of 85 (i.e., the number of failures is greater than the threshold of 95), the government's cost is capped by the threshold cost of 2470 for the warranty alternative. Under the warranty alternative, the contractor pays for all the failures in excess of the threshold. So the government has no costs for warranted failures once the threshold is reached. For the no warranty case, there is no cap and the government's cost continues to rise as the expected number of warranted failures increases. By comparing the total cost for the warranty and no warranty cases, it can be seen that for a modified MTBF somewhere between 81 and 83 the total costs are the same. By interpolating, this crossover point can be determined exactly to be 82.4. If the modified MTBF is less than 82.4, it would be beneficial from a cost standpoint to have a warranty. If the modified MTBF is greater than 82.4, it would be beneficial to not have the warranty.

For the distributions in Part 3, again select the triangular distribution. The first table in Part 3 is the distribution and cumulative distribution of the input triangular distribution. The second table is the cumulative distribution for both the warranty and the no warranty cases. Since both cases are shown on the same table, the entry for the threshold cost is repeated several times until the cumulative probability has reached 100% for the warranty case.

WARRANTY PROGRAM UPDATED SEPTEMBER 1987

TYPE T TO INPUT DATA AT TERMINAL; TYPE F TO RETRIEVE DATA STORED ON FILE
F

ENTER THE NAME OF THE INPUT FILE
EXMPL1.DAT

ENTER APPROPRIATE NUMBER TO STOP OR TO REENTER DATA, OR TO RERUN ANALYSIS

- 1 - REENTER EVERYTHING
- 2 - HEADER INFORMATION
- 3 - ECONOMIC LIFE
- 4 - DELIVERY SCHEDULES (FOR SYSTEMS AND SPARES)
- 5 - USAGE HOURS PER SYSTEM PER TIME PERIOD
- 6 - DISCOUNT RATE
- 7 - ESCALATION INDICES
- 8 - MTBF VALUES AND PERCENT OF FAILURES COVERED BY WARRANTY
- 9 - LENGTH OF WARRANTY
- 10 - COSTS FOR WARRANTED REPAIRS
- 11 - EXCLUSIONS TO WARRANTY PRICE FOR COMPARISON PURPOSES
- 12 - COSTS FOR NONWARRANTED REPAIRS
- 13 - COSTS OF REPAIRS AFTER WARRANTY EXPIRES
- 14 - COSTS UNDER NO WARRANTY ALTERNATIVE
- 15 - RERUN ANALYSIS
- 16 - PRINT THIS MENU
- 17 - PRINT CURRENT VALUES OF INPUT DATA
- 18 - TO SAVE INPUT DATA ON FILE
- 19 - TO RETRIEVE SAVED DATA FROM FILE
- 20 - STOP

2

ENTER TWO LINES OF HEADER INFORMATION
EXAMPLE 2 - THRESHOLD CASE

ENTER APPROPRIATE NUMBER TO STOP OR TO REENTER DATA, OR TO RERUN ANALYSIS

- 1 - REENTER EVERYTHING
- 2 - HEADER INFORMATION
- 3 - ECONOMIC LIFE
- 4 - DELIVERY SCHEDULES (FOR SYSTEMS AND SPARES)
- 5 - USAGE HOURS PER SYSTEM PER TIME PERIOD
- 6 - DISCOUNT RATE
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- 15 - RERUN ANALYSIS
- 16 - PRINT THIS MENU
- 17 - PRINT CURRENT VALUES OF INPUT DATA
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- 19 - TO RETRIEVE SAVED DATA FROM FILE
- 20 - STOP

SUBMENU FOR COSTS OF WARRANTED REPAIRS:

ENTER ON 1 LINE NUMBERS FOR ALL COST ELEMENTS YOU WISH TO INPUT, OR
ENTER 0 (ZERO) TO SKIP INPUTTING ANY COSTS

- 1 - TO ENTER COSTS FOR 2.01/3.02, NONRECURRING PRODUCTION
- 2 - TO ENTER COSTS FOR 2.02, RECURRING PRODUCTION
- 3 - TO ENTER COSTS FOR 2.03, ENGINEERING CHANGES
- 4 - TO ENTER COSTS FOR 2.04, DATA
- 5 - TO ENTER COSTS FOR 2.05/4.01, SYSTEMS TEST AND EVALUATION
- 6 - TO ENTER COSTS FOR 2.06/4.02 ILS TRAINING, SERVICE AND EQUIPMENT
- 7 - TO ENTER COSTS FOR 2.07/4.04, INITIAL SPARES/REPAIR PARTS
- 8 - TO ENTER COSTS FOR 2.08/3.03/3.04, OPERATIONAL/SITE ACTIVATION
- 9 - TO ENTER COSTS FOR 2.09/4.06, OTHER
- 10 - TO ENTER COSTS FOR 4.03, TRANSPORTATION

YOU MAY CHOOSE DIFFERENT COST ELEMENTS SUCH AS:

- 12 - TO SELECT 4 COST ELEMENTS, MATERIAL, LABOR, OVERHEAD, OTHER
- 13 - OR TO SELECT JUST FIXED COSTS AND VARIABLE COSTS

13

ENTER FIXED COSTS AND VARIABLE COSTS,
PERCENT OF FIXED COSTS PAID TO CONTRACTOR
AND PERCENT OF VARIABLE COSTS PAID TO CONTRACTOR
650 10 0 0

ENTER APPROPRIATE NUMBER TO STOP OR TO REENTER DATA, OR TO RERUN ANALYSIS

- 1 - REENTER EVERYTHING
- 2 - HEADER INFORMATION
- 3 - ECONOMIC LIFE
- 4 - DELIVERY SCHEDULES (FOR SYSTEMS AND SPARES)
- 5 - USAGE HOURS PER SYSTEM PER TIME PERIOD
- 6 - DISCOUNT RATE
- 7 - ESCALATION INDICES
- 8 - MTBF VALUES AND PERCENT OF FAILURES COVERED BY WARRANTY
- 9 - LENGTH OF WARRANTY
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- 15 - RERUN ANALYSIS
- 16 - PRINT THIS MENU
- 17 - PRINT CURRENT VALUES OF INPUT DATA
- 18 - TO SAVE INPUT DATA ON FILE
- 19 - TO RETRIEVE SAVED DATA FROM FILE
- 20 - STOP

SUBMENU FOR COSTS OF NONWARRANTED REPAIRS DURING WARRANTY PERIOD:

ENTER ON 1 LINE NUMBERS OF ALL COSTS ELEMENTS TO BE INPUT, OR
ENTER 0 (ZERO) TO SKIP INPUTTING COSTS

- 1 - TO ENTER COSTS FOR 2.01/3.02, NONRECURRING PRODUCTION
- 2 - TO ENTER COSTS FOR 2.02, RECURRING PRODUCTION
- 3 - TO ENTER COSTS FOR 2.03, ENGINEERING CHANGES
- 4 - TO ENTER COSTS FOR 2.04, DATA
- 5 - TO ENTER COSTS FOR 2.05/4.01, SYSTEMS TEST AND EVALUATION
- 6 - TO ENTER COSTS FOR 2.06/4.02, ILS TRAINING, SERVICE AND EQUIPMENT
- 7 - TO ENTER COSTS FOR 2.07/4.04, INITIAL SPARES/REPAIR PARTS
- 8 - TO ENTER COSTS FOR 2.08/3.03/3.04, OPERATIONAL/SITE ACTIVATION
- 9 - TO ENTER COSTS FOR 2.09/4.06, OTHER
- 10 - TO ENTER COSTS FOR 4.03, TRANSPORTATION

YOU MAY CHOOSE DIFFERENT COST ELEMENTS SUCH AS:

- 12 - TO SELECT 4 COST ELEMENTS, MATERIAL, LABOR, OVERHEAD, OTHER
- 13 - OR TO SELECT JUST FIXED COSTS AND VARIABLE COSTS

13

ENTER FIXED COSTS AND VARIABLE COSTS
0 10

ENTER APPROPRIATE NUMBER TO STOP OR TO REENTER DATA, OR TO RERUN ANALYSIS

- 1 - REENTER EVERYTHING
- 2 - HEADER INFORMATION
- 3 - ECONOMIC LIFE
- 4 - DELIVERY SCHEDULES (FOR SYSTEMS AND SPARES)
- 5 - USAGE HOURS PER SYSTEM PER TIME PERIOD
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- 15 - RERUN ANALYSIS
- 16 - PRINT THIS MENU
- 17 - PRINT CURRENT VALUES OF INPUT DATA
- 18 - TO SAVE INPUT DATA ON FILE
- 19 - TO RETRIEVE SAVED DATA FROM FILE
- 20 - STOP

TO GET NEW PAGE, TAKE PRINTER OFF LINE, ADVANCE PAPER TO TOP OF PAGE.
TO PROCEED, RETURN PRINTER ON LINE AND HIT RETURN.

EXAMPLE 2 - THRESHOLD CASE

PART 1: ANALYSIS OF WARRANTY PRICE (BASED ON WARRANTED FAILURES ONLY)

THE MODIFIED MTBF IS 85.0

(THE MODIFIED MTBF IS THE MTBF
OF ALL FAILURES INHERENT AND INDUCED
WHICH ARE REPAIRED AT GS OR ABOVE.)

EXPECTED NUMBER OF WARRANTED FAILURES IS 95

BREAKOUT OF COST OF 95.00 WARRANTED FAILURES:

COST ELEMENT	PAID TO CONTRACTOR	IN-HOUSE	TOTAL
FIXED & VARIAB	0	1600	1600
TOTALS:	0	1600	1600
WARRANTY PRICE=	0		

TO GET NEW PAGE, TAKE PRINTER OFF LINE, ADVANCE PAPER TO TOP OF PAGE.
TO PROCEED, RETURN PRINTER ON LINE AND HIT RETURN.

EXAMPLE 2 - THRESHOLD CASE

DISTRIBUTION OF WARRANTED FAILURES
(GIVEN WARRANTED MTBF)

COSTS OF WARRANTED FAILURES

NUMBER OF FAILURES	CUMULATIVE PROBABILITY	WARRANTY VALUE	IN-HOUSE	TOTAL
79	.05	0	1440	1440
83	.10	0	1480	1480
85	.15	0	1500	1500
87	.20	0	1520	1520
88	.25	0	1530	1530
90	.30	0	1550	1550
91	.35	0	1560	1560
93	.40	0	1580	1580
94	.45	0	1590	1590
95	.50	0	1600	1600
96	.55	0	1610	1610
97	.60	0	1620	1620
99	.65	0	1640	1640
100	.70	0	1650	1650
102	.75	0	1670	1670
103	.80	0	1680	1680
105	.85	0	1700	1700
107	.90	0	1720	1720
111	.95	0	1760	1760

DO YOU WANT A COST BREAKOUT FOR ANOTHER NUMBER OF
WARRANTED FAILURES (THAT YOU ENTER)? (ANSWER Y OR N)
N

TO GET NEW PAGE, TAKE PRINTER OFF LINE, ADVANCE PAPER TO TOP OF PAGE.
TO PROCEED, RETURN PRINTER ON LINE AND HIT RETURN.

EXAMPLE 2 - THRESHOLD CASE

IS THIS A FAILURE-FREE OR THRESHOLD WARRANTY ?
 TYPE "F-FREE" FOR FAILURE-FREE OR "THRESH"
 FOR THRESHOLD WARRANTY
 IF THRESHOLD, ENTER THE ADMIN COST
 PAID TO THE CONTRACTOR
 THRESH

ENTER ADMINISTRATIVE COST
 55

PART 2: COMPARISON OF ALTERNATIVES (BASED ON ALL FAILURES)-THRESHOLD CASE

REMEMBER THAT IN THE THRESHOLD CASE THE FAILURES
 BELOW THE THRESHOLD ARE IDENTIFIED AS WARRANTED
 FAILURES AND THEIR COSTS SHOULD HAVE BEEN ASSIGNED
 TO THE GOVERNMENT

AMOUNT OF ADMINISTRATIVE COST
 GOVERNMENT PAID TO CONTR = 55

MODIFIED MTBF	EXP NO. OF WARRANTD FAIL	WARRANTY ?	ADMIN COST	OTHER	POST WARRANTY	TOTAL
51.0	95	YES	55	1826	588	2470
51.0	158	NO		2611	980	3591
53.0	95	YES	55	1826	588	2470
53.0	152	NO		2537	943	3480
55.0	95	YES	55	1826	588	2470
55.0	147	NO		2468	909	3377
57.0	95	YES	55	1826	588	2470
57.0	142	NO		2404	877	3282
59.0	95	YES	55	1826	588	2470
59.0	137	NO		2345	847	3192
61.0	95	YES	55	1826	588	2470
61.0	132	NO		2289	820	3109
63.0	95	YES	55	1826	588	2470
63.0	128	NO		2237	794	3031
65.0	95	YES	55	1826	588	2470
65.0	124	NO		2188	769	2958
67.0	95	YES	55	1826	588	2470
67.0	121	NO		2143	746	2889
69.0	95	YES	55	1826	588	2470
69.0	117	NO		2099	725	2824
71.0	95	YES	55	1826	588	2470
71.0	114	NO		2058	704	2763

73.0	95	YES	55	1826	588	2470
73.0	111	NO		2020	685	2705
75.0	95	YES	55	1826	588	2470
75.0	108	NO		1983	667	2650
77.0	95	YES	55	1826	588	2470
77.0	105	NO		1949	649	2598
79.0	95	YES	55	1826	588	2470
79.0	102	NO		1916	633	2549
81.0	95	YES	55	1826	588	2470
81.0	100	NO		1885	617	2502
83.0	95	YES	55	1826	588	2470
83.0	97	NO		1855	602	2457
85.0	95	YES	55	1826	588	2470
85.0	95	NO		1826	588	2415
87.0	93	YES	55	1799	575	2429
87.0	93	NO		1799	575	2374
89.0	91	YES	55	1774	562	2390
89.0	91	NO		1774	562	2335
91.0	89	YES	55	1749	549	2353
91.0	89	NO		1749	549	2298
93.0	87	YES	55	1725	538	2318
93.0	87	NO		1725	538	2263
95.0	85	YES	55	1703	526	2284
95.0	85	NO		1703	526	2229
97.0	83	YES	55	1681	515	2251
97.0	83	NO		1681	515	2196
99.0	82	YES	55	1660	505	2220
99.0	82	NO		1660	505	2165
101.0	80	YES	55	1640	495	2190
101.0	80	NO		1640	495	2135
103.0	78	YES	55	1621	485	2161
103.0	78	NO		1621	485	2106
105.0	77	YES	55	1602	476	2134
105.0	77	NO		1602	476	2079

DO YOU WISH TO ASSUME YOUR DISTRIBUTION
OF MTBFS IS TRIANGULAR OR WEIBUL. ?

TYPE "TRIANG" FOR TRIANGULAR OR "WEIBUL"
FOR WEIBULL DISTRIBUTION

NOTE: IN SOME CASES, WEIBULL DISTRIBUTION MIGHT NOT BE
SUITABLE AND MUELLER ITERATION MIGHT NOT CONVERGE.

IN GENERAL TRIANGULAR DISTRIBUTION WILL GIVE YOU
A GOOD APPROXIMATION

TRIANG

PART 3: PROBABILITY DISTRIBUTION

PROBABILITY DISTRIBUTION OF MODIFIED MTBF

THE EXPECTED MODIFIED MTBF = 80.0

MODIFIED MTBF	PROB.	CUM. PROB.
51	.000	.000
53	.004	.004
55	.009	.013
57	.013	.027
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61	.022	.067
63	.027	.093
65	.031	.124
67	.036	.160
69	.040	.200
71	.044	.244
73	.049	.293
75	.053	.346
77	.058	.404
79	.062	.466
81	.067	.533
83	.071	.604
85	.075	.679
87	.068	.747
89	.060	.806
91	.052	.858
93	.044	.902
95	.036	.937
97	.028	.965
99	.020	.985
101	.012	.997
103	.004	1.001

TO GET NEW PAGE, TAKE PRINTER OFF LINE, ADVANCE PAPER TO TOP OF PAGE
 TO PROCEED, RETURN PRINTER ON LINE AND HIT RETURN.

DISTRIBUTION OF TOTAL COSTS

TOTAL COSTS	CUM. PROB. WARRANTY	CUM. PROB. NO WARRANTY
2106	.000	.004
2135	.000	.016
2161	.004	.033
2165	.006	.036
2190	.016	.058
2196	.020	.064
2220	.036	.090
2229	.044	.099
2251	.064	.128
2263	.076	.143
2284	.099	.174
2298	.118	.195
2318	.143	.226
2335	.168	.254
2353	.195	.286
2374	.228	.322
2390	.254	.352
2415	.297	.397
2429	.322	.421
2457	.374	.468
2470	.397	.487
2470	.468	.487
2470	.535	.487
2470	.597	.487
2470	.655	.487
2470	.708	.487
2470	.757	.487
2470	.801	.487
2470	.841	.487
2470	.877	.487
2470	.908	.487
2470	.934	.487
2470	.957	.487
2470	.974	.487
2470	.988	.487
2470	.997	.487
2470	1.000	.487
2470	1.000	.487
2502	1.000	.535
2549	1.000	.597
2598	1.000	.655
2650	1.000	.708
2705	1.000	.757
2763	1.000	.801
2824	1.000	.841
2889	1.000	.877
2958	1.000	.908
3031	1.000	.934
3109	1.000	.957
3192	1.000	.974
3282	1.000	.988
3377	1.000	.997
3480	1.001	1.001
3591	1.001	1.001

C. Example 3: Treatment of Spares

In this example the treatment of spares in WARM will be examined. It is not possible for WARM to keep track of individual items separately, clocking their usage over time. Indeed, WARM doesn't know whether an item is being used or is in storage waiting to be used. WARM treats the items under warranty in the aggregate. As a result, the treatment of spares is not exact. However, the model does try to give some credit for the existence of spares. It does so only when the duration of the warranty in usage hours is less than the duration in time periods. To illustrate that, use the data stored on EXMPL1.DAT. Keep all the data the same except for the number of spares delivered which should be changed to 15 for these illustrations and the duration of the warranty which will be varied in the illustrations. First, keep the duration of the warranty unchanged from the value of 2 years or 100 hours of usage. (At this point the only change from example 1 is in the number of spares which has increased from 0 to 15.) Run the model with this data and compare the results with those from example 1. Notice that the results are exactly the same. In other words, the model gives no credit for the 15 spares which were purchased. That is because the duration of the warranty in usage, 100 hours, is not less than the duration of the warranty in time periods, 2 years (2 years at a usage rate of 50 hours a year equates to 100 hours of usage).

Now rerun the data from EXMPL1.DAT again. Only this time change the number of spares to 15 and change the duration of the warranty to 2 years or 60 hours. Notice that the expected number of warranted failures has changed from 95 to 62.7. The expected number of warranted failures is the sum of

the warranted failures of the 100 items over the 60-hour warranty period (100 hours were warranted in the previous illustration) and the warranted failures of the 15 spares for the 40-hour period from the end of the 60-hour period to the end of the 2 year period (100 hours of usage). See figure 4.

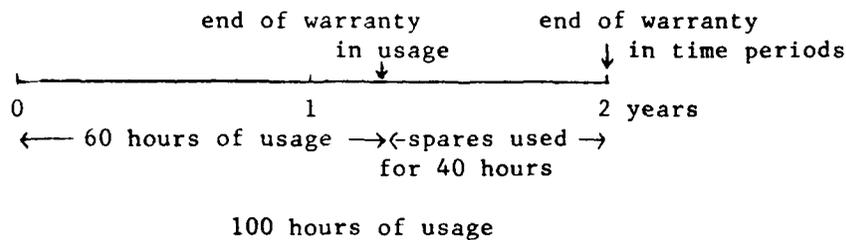


Figure 4. Usage Periods for Spares Computation

The formula for computing warranted failures is

$$\text{warranted failures} = \frac{\text{no. of items} \times \text{usage} \times \text{inherent fail. rate} \times \text{valid claim rate}}{\text{modified MTBF}}$$

For 100 items for 60 hours,

$$\text{warranted failures} = \frac{100 \times 60 \times .85 \times .95}{85} = 57$$

For 15 spares for 40 hours,

$$\text{warranted failures} = \frac{15 \times 40 \times .85 \times .95}{85} = 5.7$$

The total number of warranted failures is 62.7.

Another limitation on the computation of warranted failures occurring from the use of spares is that the usage period for spares cannot exceed the duration of the warranty in usage hours. For example, if the duration of the warranty in the previous illustration had been 2 years or 40 hours of usage, the spares would only be used from the 40-hour point to the 80-hour point even though the 2-year period would not expire until the 100-hour point. For this data the expected number of warranted failures would be 43.7.

WARRANTY PROGRAM UPDATED SEPTEMBER 1987

TYPE T TO INPUT DATA AT TERMINAL; TYPE F TO RETRIEVE DATA STORED ON FILE

F

ENTER THE NAME OF THE INPUT FILE
EXMPL1.DAT

ENTER APPROPRIATE NUMBER TO STOP OR TO REENTER DATA, OR TO RERUN ANALYSIS

- 1 - REENTER EVERYTHING
- 2 - HEADER INFORMATION
- 3 - ECONOMIC LIFE
- 4 - DELIVERY SCHEDULES (FOR SYSTEMS AND SPARES)
- 5 - USAGE HOURS PER SYSTEM PER TIME PERIOD
- 6 - DISCOUNT RATE
- 7 - ESCALATION INDICES
- 8 - MTBF VALUES AND PERCENT OF FAILURES COVERED BY WARRANTY
- 9 - LENGTH OF WARRANTY
- 10 - COSTS FOR WARRANTED REPAIRS
- 11 - EXCLUSIONS TO WARRANTY PRICE FOR COMPARISON PURPOSES
- 12 - COSTS FOR NONWARRANTED REPAIRS
- 13 - COSTS OF REPAIRS AFTER WARRANTY EXPIRES
- 14 - COSTS UNDER NO WARRANTY ALTERNATIVE
- 15 - RERUN ANALYSIS
- 16 - PRINT THIS MENU
- 17 - PRINT CURRENT VALUES OF INPUT DATA
- 18 - TO SAVE INPUT DATA ON FILE
- 19 - TO RETRIEVE SAVED DATA FROM FILE
- 20 - STOP

2

ENTER TWO LINES OF HEADER INFORMATION

EXAMPLE 3
TREATMENT OF SPARES

ENTER APPROPRIATE NUMBER TO STOP OR TO REENTER DATA, OR TO RERUN ANALYSIS

- 1 - REENTER EVERYTHING
- 2 - HEADER INFORMATION
- 3 - ECONOMIC LIFE
- 4 - DELIVERY SCHEDULES (FOR SYSTEMS AND SPARES)
- 5 - USAGE HOURS PER SYSTEM PER TIME PERIOD
- 6 - DISCOUNT RATE
- 7 - ESCALATION INDICES
- 8 - MTBF VALUES AND PERCENT OF FAILURES COVERED BY WARRANTY
- 9 - LENGTH OF WARRANTY
- 10 - COSTS FOR WARRANTED REPAIRS
- 11 - EXCLUSIONS TO WARRANTY PRICE FOR COMPARISON PURPOSES
- 12 - COSTS FOR NONWARRANTED REPAIRS
- 13 - COSTS OF REPAIRS AFTER WARRANTY EXPIRES
- 14 - COSTS UNDER NO WARRANTY ALTERNATIVE
- 15 - RERUN ANALYSIS
- 16 - PRINT THIS MENU
- 17 - PRINT CURRENT VALUES OF INPUT DATA
- 18 - TO SAVE INPUT DATA ON FILE
- 19 - TO RETRIEVE SAVED DATA FROM FILE
- 20 - STOP

4

ENTER NUMBER OF TIME PERIODS DELIVERIES ARE MADE (MUST BE A WHOLE NUMBER FROM 1 TO 240)

1

ENTER NUMBER OF SYSTEMS DELIVERED EACH PERIOD FOR 1 TIME PERIODS
100

ENTER NUMBER OF SPARES DELIVERED EACH PERIOD FOR 1 TIME PERIODS
15

ENTER APPROPRIATE NUMBER TO STOP OR TO REENTER DATA, OR TO RERUN ANALYSIS

- 1 - REENTER EVERYTHING
- 2 - HEADER INFORMATION
- 3 - ECONOMIC LIFE
- 4 - DELIVERY SCHEDULES (FOR SYSTEMS AND SPARES)
- 5 - USAGE HOURS PER SYSTEM PER TIME PERIOD
- 6 - DISCOUNT RATE
- 7 - ESCALATION INDICES
- 8 - MTBF VALUES AND PERCENT OF FAILURES COVERED BY WARRANTY
- 9 - LENGTH OF WARRANTY
- 10 - COSTS FOR WARRANTED REPAIRS
- 11 - EXCLUSIONS TO WARRANTY PRICE FOR COMPARISON PURPOSES
- 12 - COSTS FOR NONWARRANTED REPAIRS
- 13 - COSTS OF REPAIRS AFTER WARRANTY EXPIRES
- 14 - COSTS UNDER NO WARRANTY ALTERNATIVE
- 15 - RERUN ANALYSIS
- 16 - PRINT THIS MENU
- 17 - PRINT CURRENT VALUES OF INPUT DATA
- 18 - TO SAVE INPUT DATA ON FILE
- 19 - TO RETRIEVE SAVED DATA FROM FILE
- 20 - STOP

15

EXAMPLE 3
TREATMENT OF SPARES

PART 1: ANALYSIS OF WARRANTY PRICE (BASED ON WARRANTED FAILURES ONLY)

THE MODIFIED MTBF IS 85.0
(THE MODIFIED MTBF IS THE MTBF
OF ALL FAILURES INHERENT AND INDUCED
WHICH ARE REPAIRED AT GS OR ABOVE.)

EXPECTED NUMBER OF WARRANTED FAILURES IS 95

BREAKOUT OF COST OF 95.00 WARRANTED FAILURES:

COST ELEMENT	PAID TO CONTRACTOR	IN-HOUSE	TOTAL
FIXED & VARIAB	1600	0	1600
TOTALS:	1600	0	1600
WARRANTY PRICE=	1600		

TO GET NEW PAGE, TAKE PRINTER OFF LINE, ADVANCE PAPER TO TOP OF PAGE.
TO PROCEED, RETURN PRINTER ON LINE AND HIT RETURN.

ENTER APPROPRIATE NUMBER TO STOP OR TO REENTER DATA, OR TO RERUN ANALYSIS

- 1 - REENTER EVERYTHING
 - 2 - HEADER INFORMATION
 - 3 - ECONOMIC LIFE
 - 4 - DELIVERY SCHEDULES (FOR SYSTEMS AND SPARES)
 - 5 - USAGE HOURS PER SYSTEM PER TIME PERIOD
 - 6 - DISCOUNT RATE
 - 7 - ESCALATION INDICES
 - 8 - MTBF VALUES AND PERCENT OF FAILURES COVERED BY WARRANTY
 - 9 - LENGTH OF WARRANTY
 - 10 - COSTS FOR WARRANTED REPAIRS
 - 11 - EXCLUSIONS TO WARRANTY PRICE FOR COMPARISON PURPOSES
 - 12 - COSTS FOR NONWARRANTED REPAIRS
 - 13 - COSTS OF REPAIRS AFTER WARRANTY EXPIRES
 - 14 - COSTS UNDER NO WARRANTY ALTERNATIVE
 - 15 - RERUN ANALYSIS
 - 16 - PRINT THIS MENU
 - 17 - PRINT CURRENT VALUES OF INPUT DATA
 - 18 - TO SAVE INPUT DATA ON FILE
 - 19 - TO RETRIEVE SAVED DATA FROM FILE
 - 20 - STOP
- 19

ENTER THE NAME OF THE INPUT FILE
EXMPL1.DAT

ENTER APPROPRIATE NUMBER TO STOP OR TO REENTER DATA, OR TO RERUN ANALYSIS

- 1 - REENTER EVERYTHING
 - 2 - HEADER INFORMATION
 - 3 - ECONOMIC LIFE
 - 4 - DELIVERY SCHEDULES (FOR SYSTEMS AND SPARES)
 - 5 - USAGE HOURS PER SYSTEM PER TIME PERIOD
 - 6 - DISCOUNT RATE
 - 7 - ESCALATION INDICES
 - 8 - MTBF VALUES AND PERCENT OF FAILURES COVERED BY WARRANTY
 - 9 - LENGTH OF WARRANTY
 - 10 - COSTS FOR WARRANTED REPAIRS
 - 11 - EXCLUSIONS TO WARRANTY PRICE FOR COMPARISON PURPOSES
 - 12 - COSTS FOR NONWARRANTED REPAIRS
 - 13 - COSTS OF REPAIRS AFTER WARRANTY EXPIRES
 - 14 - COSTS UNDER NO WARRANTY ALTERNATIVE
 - 15 - RERUN ANALYSIS
 - 16 - PRINT THIS MENU
 - 17 - PRINT CURRENT VALUES OF INPUT DATA
 - 18 - TO SAVE INPUT DATA ON FILE
 - 19 - TO RETRIEVE SAVED DATA FROM FILE
 - 20 - STOP
- 2

ENTER TWO LINES OF HEADER INFORMATION
EXAMPLE 3 - NUMBER 2

SPARES - CHANGE IN LENGTH OF WARRANTY

ENTER APPROPRIATE NUMBER TO STOP OR TO REENTER DATA, OR TO RERUN ANALYSIS

- 1 - REENTER EVERYTHING
 - 2 - HEADER INFORMATION
 - 3 - ECONOMIC LIFE
 - 4 - DELIVERY SCHEDULES (FOR SYSTEMS AND SPARES)
 - 5 - USAGE HOURS PER SYSTEM PER TIME PERIOD
 - 6 - DISCOUNT RATE
 - 7 - ESCALATION INDICES
 - 8 - MTBF VALUES AND PERCENT OF FAILURES COVERED BY WARRANTY
 - 9 - LENGTH OF WARRANTY
 - 10 - COSTS FOR WARRANTED REPAIRS
 - 11 - EXCLUSIONS TO WARRANTY PRICE FOR COMPARISON PURPOSES
 - 12 - COSTS FOR NONWARRANTED REPAIRS
 - 13 - COSTS OF REPAIRS AFTER WARRANTY EXPIRES
 - 14 - COSTS UNDER NO WARRANTY ALTERNATIVE
 - 15 - RERUN ANALYSIS
 - 16 - PRINT THIS MENU
 - 17 - PRINT CURRENT VALUES OF INPUT DATA
 - 18 - TO SAVE INPUT DATA ON FILE
 - 19 - TO RETRIEVE SAVED DATA FROM FILE
 - 20 - STOP
- 4

ENTER NUMBER OF TIME PERIODS DELIVERIES ARE MADE (MUST BE A WHOLE NUMBER FROM 1 TO 240)

1

ENTER NUMBER OF SYSTEMS DELIVERED EACH PERIOD FOR 1 TIME PERIODS
100

ENTER NUMBER OF SPARES DELIVERED EACH PERIOD FOR 1 TIME PERIODS
15

ENTER APPROPRIATE NUMBER TO STOP OR TO REENTER DATA, OR TO RERUN ANALYSIS

- 1 - REENTER EVERYTHING
- 2 - HEADER INFORMATION
- 3 - ECONOMIC LIFE
- 4 - DELIVERY SCHEDULES (FOR SYSTEMS AND SPARES)
- 5 - USAGE HOURS PER SYSTEM PER TIME PERIOD
- 6 - DISCOUNT RATE
- 7 - ESCALATION INDICES
- 8 - MTBF VALUES AND PERCENT OF FAILURES COVERED BY WARRANTY
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- 12 - COSTS FOR NONWARRANTED REPAIRS
- 13 - COSTS OF REPAIRS AFTER WARRANTY EXPIRES
- 14 - COSTS UNDER NO WARRANTY ALTERNATIVE
- 15 - RERUN ANALYSIS
- 16 - PRINT THIS MENU
- 17 - PRINT CURRENT VALUES OF INPUT DATA
- 18 - TO SAVE INPUT DATA ON FILE
- 19 - TO RETRIEVE SAVED DATA FROM FILE
- 20 - STOP

9

ENTER LENGTH OF WARRANTY IN TIME PERIODS (MUST BE A WHOLE NUMBER) AND IN
USAGE HOURS
2 60

ENTER APPROPRIATE NUMBER TO STOP OR TO REENTER DATA, OR TO RERUN ANALYSIS

- 1 - REENTER EVERYTHING
 - 2 - HEADER INFORMATION
 - 3 - ECONOMIC LIFE
 - 4 - DELIVERY SCHEDULES (FOR SYSTEMS AND SPARES)
 - 5 - USAGE HOURS PER SYSTEM PER TIME PERIOD
 - 6 - DISCOUNT RATE
 - 7 - ESCALATION INDICES
 - 8 - MTBF VALUES AND PERCENT OF FAILURES COVERED BY WARRANTY
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 - 10 - COSTS FOR WARRANTED REPAIRS
 - 11 - EXCLUSIONS TO WARRANTY PRICE FOR COMPARISON PURPOSES
 - 12 - COSTS FOR NONWARRANTED REPAIRS
 - 13 - COSTS OF REPAIRS AFTER WARRANTY EXPIRES
 - 14 - COSTS UNDER NO WARRANTY ALTERNATIVE
 - 15 - RERUN ANALYSIS
 - 16 - PRINT THIS MENU
 - 17 - PRINT CURRENT VALUES OF INPUT DATA
 - 18 - TO SAVE INPUT DATA ON FILE
 - 19 - TO RETRIEVE SAVED DATA FROM FILE
 - 20 - STOP
- 15

TO GET NEW PAGE, TAKE PRINTER OFF LINE, ADVANCE PAPER TO TOP OF PAGE.
TO PROCEED, RETURN PRINTER ON LINE AND HIT RETURN.

EXAMPLE 3 - NUMBER 2
SPARES - CHANGE IN LENGTH OF WARRANTY

PART 1: ANALYSIS OF WARRANTY PRICE (BASED ON WARRANTED FAILURES ONLY)

THE MODIFIED MTBF IS 85.0
(THE MODIFIED MTBF IS THE MTBF
OF ALL FAILURES INHERENT AND INDUCED
WHICH ARE REPAIRED AT GS OR ABOVE.)

EXPECTED NUMBER OF WARRANTED FAILURES IS 62

BREAKOUT OF COST OF 62.70 WARRANTED FAILURES:

COST ELEMENT	PAID TO CONTRACTOR	IN-HOUSE	TOTAL
FIXED & VARIAB	1277	0	1277
TOTALS:	1277	0	1277
WARRANTY PRICE=	1277		

TO GET NEW PAGE, TAKE PRINTER OFF LINE, ADVANCE PAPER TO TOP OF PAGE.
TO PROCEED, RETURN PRINTER ON LINE AND HIT RETURN.

ENTER APPROPRIATE NUMBER TO STOP OR TO REENTER DATA, OR TO RERUN ANALYSIS

- 1 - REENTER EVERYTHING
- 2 - HEADER INFORMATION
- 3 - ECONOMIC LIFE
- 4 - DELIVERY SCHEDULES (FOR SYSTEMS AND SPARES)
- 5 - USAGE HOURS PER SYSTEM PER TIME PERIOD
- 6 - DISCOUNT RATE
- 7 - ESCALATION INDICES
- 8 - MTBF VALUES AND PERCENT OF FAILURES COVERED BY WARRANTY
- 9 - LENGTH OF WARRANTY
- 10 - COSTS FOR WARRANTED REPAIRS
- 11 - EXCLUSIONS TO WARRANTY PRICE FOR COMPARISON PURPOSES
- 12 - COSTS FOR NONWARRANTED REPAIRS
- 13 - COSTS OF REPAIRS AFTER WARRANTY EXPIRES
- 14 - COSTS UNDER NO WARRANTY ALTERNATIVE
- 15 - RERUN ANALYSIS
- 16 - PRINT THIS MENU
- 17 - PRINT CURRENT VALUES OF INPUT DATA
- 18 - TO SAVE INPUT DATA ON FILE
- 19 - TO RETRIEVE SAVED DATA FROM FILE
- 20 - STOP
- 19

ENTER THE NAME OF THE INPUT FILE
2EXMPL3.DAT

ENTER APPROPRIATE NUMBER TO STOP OR TO REENTER DATA, OR TO RERUN ANALYSIS

- 1 - REENTER EVERYTHING
- 2 - HEADER INFORMATION
- 3 - ECONOMIC LIFE
- 4 - DELIVERY SCHEDULES (FOR SYSTEMS AND SPARES)
- 5 - USAGE HOURS PER SYSTEM PER TIME PERIOD
- 6 - DISCOUNT RATE
- 7 - ESCALATION INDICES
- 8 - MTBF VALUES AND PERCENT OF FAILURES COVERED BY WARRANTY
- 9 - LENGTH OF WARRANTY
- 10 - COSTS FOR WARRANTED REPAIRS
- 11 - EXCLUSIONS TO WARRANTY PRICE FOR COMPARISON PURPOSES
- 12 - COSTS FOR NONWARRANTED REPAIRS
- 13 - COSTS OF REPAIRS AFTER WARRANTY EXPIRES
- 14 - COSTS UNDER NO WARRANTY ALTERNATIVE
- 15 - RERUN ANALYSIS
- 16 - PRINT THIS MENU
- 17 - PRINT CURRENT VALUES OF INPUT DATA
- 18 - TO SAVE INPUT DATA ON FILE
- 19 - TO RETRIEVE SAVED DATA FROM FILE
- 20 - STOP
- 2

ENTER TWO LINES OF HEADER INFORMATION

EXAMPLE 3 - NUMBER 3
SPARES - CHANGE TO LENGTH OF WARRANTY

ENTER APPROPRIATE NUMBER TO STOP OR TO REENTER DATA, OR TO RERUN ANALYSIS

- 1 - REENTER EVERYTHING
 - 2 - HEADER INFORMATION
 - 3 - ECONOMIC LIFE
 - 4 - DELIVERY SCHEDULES (FOR SYSTEMS AND SPARES)
 - 5 - USAGE HOURS PER SYSTEM PER TIME PERIOD
 - 6 - DISCOUNT RATE
 - 7 - ESCALATION INDICES
 - 8 - MTBF VALUES AND PERCENT OF FAILURES COVERED BY WARRANTY
 - 9 - LENGTH OF WARRANTY
 - 10 - COSTS FOR WARRANTED REPAIRS
 - 11 - EXCLUSIONS TO WARRANTY PRICE FOR COMPARISON PURPOSES
 - 12 - COSTS FOR NONWARRANTED REPAIRS
 - 13 - COSTS OF REPAIRS AFTER WARRANTY EXPIRES
 - 14 - COSTS UNDER NO WARRANTY ALTERNATIVE
 - 15 - RERUN ANALYSIS
 - 16 - PRINT THIS MENU
 - 17 - PRINT CURRENT VALUES OF INPUT DATA
 - 18 - TO SAVE INPUT DATA ON FILE
 - 19 - TO RETRIEVE SAVED DATA FROM FILE
 - 20 - STOP
- 9

ENTER LENGTH OF WARRANTY IN TIME PERIODS (MUST BE A WHOLE NUMBER) AND IN
USAGE HOURS
2 40

ENTER APPROPRIATE NUMBER TO STOP OR TO REENTER DATA, OR TO RERUN ANALYSIS

- 1 - REENTER EVERYTHING
 - 2 - HEADER INFORMATION
 - 3 - ECONOMIC LIFE
 - 4 - DELIVERY SCHEDULES (FOR SYSTEMS AND SPARES)
 - 5 - USAGE HOURS PER SYSTEM PER TIME PERIOD
 - 6 - DISCOUNT RATE
 - 7 - ESCALATION INDICES
 - 8 - MTBF VALUES AND PERCENT OF FAILURES COVERED BY WARRANTY
 - 9 - LENGTH OF WARRANTY
 - 10 - COSTS FOR WARRANTED REPAIRS
 - 11 - EXCLUSIONS TO WARRANTY PRICE FOR COMPARISON PURPOSES
 - 12 - COSTS FOR NONWARRANTED REPAIRS
 - 13 - COSTS OF REPAIRS AFTER WARRANTY EXPIRES
 - 14 - COSTS UNDER NO WARRANTY ALTERNATIVE
 - 15 - RERUN ANALYSIS
 - 16 - PRINT THIS MENU
 - 17 - PRINT CURRENT VALUES OF INPUT DATA
 - 18 - TO SAVE INPUT DATA ON FILE
 - 19 - TO RETRIEVE SAVED DATA FROM FILE
 - 20 - STOP
- 15

TO GET NEW PAGE, TAKE PRINTER OFF LINE, ADVANCE PAPER TO TOP OF PAGE.
TO PROCEED, RETURN PRINTER ON LINE AND HIT RETURN.

EXAMPLE 3 - NUMBER 3
SPARES - CHANGE TO LENGTH OF WARRANTY

PART 1: ANALYSIS OF WARRANTY PRICE (BASED ON WARRANTED FAILURES ONLY)

THE MODIFIED MTBF IS 85.0
(THE MODIFIED MTBF IS THE MTBF
OF ALL FAILURES INHERENT AND INDUCED
WHICH ARE REPAIRED AT GS OR ABOVE.)

EXPECTED NUMBER OF WARRANTED FAILURES IS 43

BREAKOUT OF COST OF 43.70 WARRANTED FAILURES:

COST ELEMENT	PAID TO CONTRACTOR	IN-HOUSE	TOTAL
FIXED & VARIAB	1087	0	1087
TOTALS:	1087	0	1087
WARRANTY PRICE=	1087		

TO GET NEW PAGE, TAKE PRINTER OFF LINE, ADVANCE PAPER TO TOP OF PAGE.
TO PROCEED, RETURN PRINTER ON LINE AND HIT RETURN.

D. Example 4: Firings per Round

Suppose that the government is going to purchase a lot of 2000 rounds of ammunition and that the ammunition is to be used at a rate of 1000 rounds a year for 2 years. Further suppose that the government expects 20 rounds of the lot to be defective, is willing to accept that number of defectives but expects the contractor to reimburse the government for the cost of all defectives above 20. By correctly interpreting the variables in WARM, it is possible to analyze such a warranty with the WARM model.

In previous examples, usage referred to equipment usage per time period (flying hours per year) or miles per time period. In this example, usage is assigned the meaning of firings per round per time period, more specifically the usage is .5 firing per year for each of two years. (Each round is fired one time in a two year period.) Time periods have the same meaning as before and specifically are years in this example. MTBF is measured in terms of usage amount per failure (or between failures). Examples are flying hours per failure or miles per failure. In this example, MTBF will be measured in terms of firings per failure (or between failures). Since it is expected that there will be 20 failures when expending the 2000 rounds, the MTBF will be

$$\text{MTBF} = 2000 \text{ firings} / 20 \text{ failures} = 100 \text{ firings per failure}$$

Take 100 firings per failure to be the inherent MTBF, and take the inherent failure rate to be 100% (i.e., assume there are no induced failures), the valid claim rate to be 100% and the percent repaired at GS or above to be 100%. Actually none of the failures is repaired at GS or above or anywhere for that

matter. Note that the percent repaired at GS or above is a means of designating what percent of the failures the model is to analyze. In this case, it is desired to analyze all of them even though the failures are not repaired. For the above choice of percentages, the inherent MTBF equals the modified MTBF.

Since it is desired to warranty the entire lot of 2000, take the warranty duration to be 2 years or 1 firing, whichever comes first. The time period, 2 years, and the usage rate 1 firing per round are equivalent and represent the period over which the 2000 items are used.

Since the warranty lasts for 2 years, there is no need to have an economic life longer than 2 years. Take the economic life to be 2 years. Also there will be deliveries only during the first year, 2000 items and no spares.

Assume that each round costs \$100. Since the items are not repaired, take the repair cost to be the replacement cost of \$100. That will be a variable cost and assume there are no fixed costs. Again, we are using only one cost element, fixed and variable. The cost of warranted repairs would be 0 100 0 0 (This is a threshold case; all costs are assigned to the government). The cost of unwarranted repairs during the warranty period would be 0 100. However, any numbers could be entered because there are no unwarranted repairs for the data in this example. Post-warranty costs would also be 0 100, but there is no post warranty period in this example. However, some cost must be entered whether it is used or not. Finally the costs for the no warranty case would be 0 100.

Assume that the administrative cost of record keeping for the warranty is 50. Also assume that there is no discounting and no escalation. As a range of MTBF, use 90 110 5 100.

When the model is run, it is seen that the threshold number of failures is 20, as it should have been.

It is also seen that while such an example can be analyzed by WARM, it may be preferable to analyze it without using WARM.

pcwarm3

WARRANTY PROGRAM UPDATED SEPTEMBER 1987

TYPE T TO INPUT DATA AT TERMINAL; TYPE F TO RETRIEVE DATA STORED ON FILE
t

ENTER TWO LINES OF HEADER INFORMATION

EXAMPLE 4

FIRINGS PER ROUND

ENTER ECONOMIC LIFE IN TIME PERIODS (WHOLE NUMBER BETWEEN 1 AND 240)

2

ENTER NUMBER OF TIME PERIODS DELIVERIES ARE MADE (MUST BE A
WHOLE NUMBER FROM 1 TO 240)

1

ENTER NUMBER OF SYSTEMS DELIVERED EACH PERIOD FOR 1 TIME PERIODS

2000

ENTER NUMBER OF SPARES DELIVERED EACH PERIOD FOR 1 TIME PERIODS

0

ENTER USAGE HOURS PER SYSTEM PER TIME PERIOD, FOR 2 PERIODS

.5 .5

ENTER DISCOUNT RATE AS PERCENT PER TIME PERIOD, E.G., 10. FOR 10%

0

ENTER ESCALATION INDICES PER TIME PERIOD, FOR 2 PERIODS

1 1

ENTER INHERENT FAILURE RATE, VALID CLAIM RATE
AND PERCENT WHICH REQUIRES GS OR ABOVE LEVEL REPAIR

100 100 100

ENTER INHERENT MTBF

100

ENTER RANGE OF MTBF VALUES AS BEGINNING MTBF, ENDING MTBF, STEP SIZE
AND THE MODE(=MOST LIKELY MTBF)

90 110 5 100

ENTER MTBF FACTORS FOR WARRANTY ALTERNATIVE; ONE FOR EACH PERIOD, FOR
2 TIME PERIODS. TO INPUT A VALUE N TIMES USE N*VALUE; FOR EXAMPLE,

3*1.2 BECOMES 1.2,1.2,1.2

1 1

ENTER MTBF FACTORS FOR NO WARRANTY ALTERNATIVE; ONE FOR EACH PERIOD, FOR
2 TIME PERIODS. TO INPUT A VALUE N TIMES USE N*VALUE; FOR EXAMPLE,

3*.99 BECOMES .99,.99,.99

2*1.0

ENTER LENGTH OF WARRANTY IN TIME PERIODS (MUST BE A WHOLE NUMBER) AND IN
USAGE HOURS

COSTS FOR WARRANTED REPAIRS BY COST ELEMENT:

1. THESE COSTS ARE INITIALIZED TO ZERO.
2. A FIXED COST, A VARIABLE COST, AND PERCENTAGES OF THESE COSTS PAID TO THE CONTRACTOR ARE REQUIRED FOR EACH COST ELEMENT TO BE ENTERED.
3. USE SUBMENU TO SELECT COST ELEMENTS TO BE INPUT.
4. VARIABLE COSTS FOR COST ELEMENTS OTHER THAN 2.02 (RECURRING PRODUCTION) MAY BE ENTERED AS A PERCENT OF THE VARIABLE COST FOR 2.02. BY ENTERING THE PERCENTAGE AS A NEGATIVE NUMBER, E.G., -10.0 FOR 10%.

AFTER MESSAGE IS NOTED HIT RETURN.

SUBMENU FOR COSTS OF WARRANTED REPAIRS:

ENTER ON 1 LINE NUMBERS FOR ALL COST ELEMENTS YOU WISH TO INPUT, OR ENTER 0 (ZERO) TO SKIP INPUTTING ANY COSTS

- 1 - TO ENTER COSTS FOR 2.01/3.02, NONRECURRING PRODUCTION
- 2 - TO ENTER COSTS FOR 2.02, RECURRING PRODUCTION
- 3 - TO ENTER COSTS FOR 2.03, ENGINEERING CHANGES
- 4 - TO ENTER COSTS FOR 2.04, DATA
- 5 - TO ENTER COSTS FOR 2.05/4.01, SYSTEMS TEST AND EVALUATION
- 6 - TO ENTER COSTS FOR 2.06/4.02 ILS TRAINING, SERVICE AND EQUIPMENT
- 7 - TO ENTER COSTS FOR 2.07/4.04, INITIAL SPARES/REPAIR PARTS
- 8 - TO ENTER COSTS FOR 2.08/3.03/3.04, OPERATIONAL/SITE ACTIVATION
- 9 - TO ENTER COSTS FOR 2.09/4.06, OTHER
- 10 - TO ENTER COSTS FOR 4.03, TRANSPORTATION

YOU MAY CHOOSE DIFFERENT COST ELEMENTS SUCH AS:

- 12 - TO SELECT 4 COST ELEMENTS, MATERIAL, LABOR, OVERHEAD, OTHER
- 13 - OR TO SELECT JUST FIXED COSTS AND VARIABLE COSTS

13

ENTER FIXED COSTS AND VARIABLE COSTS,
PERCENT OF FIXED COSTS PAID TO CONTRACTOR
AND PERCENT OF VARIABLE COSTS PAID TO CONTRACTOR
0 100 0 0

ENTER EXCLUSIONS TO WARRANTY PRICE TO BE USED WHEN COMPARING WARRANTY AND NO WARRANTY ALTERNATIVES
0

COSTS FOR NONWARRANTED REPAIRS DURING WARRANTY PERIOD:

1. THESE COSTS ARE INITIALIZED TO ZERO.
2. USE SUBMENU TO SELECT COST ELEMENTS TO BE INPUT.
3. A FIXED COST AND A VARIABLE COST ARE REQUIRED FOR ANY COST ELEMENT ENTERED.
4. VARIABLE COSTS FOR COST ELEMENTS OTHER THAN 2.02 (RECURRING PRODUCTION) MAY BE ENTER AS A PERCENT OF THE VARIABLE COST FOR 2.02, BY ENTERING THE PERCENTAGE AS A NEGATIVE NUMBER, E.G., -10.0 FOR 10%.

AFTER MESSAGE IS NOTED HIT RETURN.

SUBMENU FOR COSTS OF NONWARRANTED REPAIRS DURING WARRANTY PERIOD:

ENTER ON 1 LINE NUMBERS OF ALL COSTS ELEMENTS TO BE INPUT, OR
ENTER 0 (ZERO) TO SKIP INPUTTING COSTS

- 1 - TO ENTER COSTS FOR 2.01/3.02, NONRECURRING PRODUCTION
- 2 - TO ENTER COSTS FOR 2.02, RECURRING PRODUCTION
- 3 - TO ENTER COSTS FOR 2.03, ENGINEERING CHANGES
- 4 - TO ENTER COSTS FOR 2.04, DATA
- 5 - TO ENTER COSTS FOR 2.05/4.01, SYSTEMS TEST AND EVALUATION
- 6 - TO ENTER COSTS FOR 2.06/4.02, ILS TRAINING, SERVICE AND EQUIPMENT
- 7 - TO ENTER COSTS FOR 2.07/4.04, INITIAL SPARES/REPAIR PARTS
- 8 - TO ENTER COSTS FOR 2.08/3.03/3.04, OPERATIONAL/SITE ACTIVATION
- 9 - TO ENTER COSTS FOR 2.09/4.06, OTHER
- 10 - TO ENTER COSTS FOR 4.03, TRANSPORTATION

YOU MAY CHOOSE DIFFERENT COST ELEMENTS SUCH AS:

- 12 - TO SELECT 4 COST ELEMENTS, MATERIAL, LABOR, OVERHEAD, OTHER
- 13 - OR TO SELECT JUST FIXED COSTS AND VARIABLE COSTS

13

ENTER FIXED COSTS AND VARIABLE COSTS
0 100

COSTS FOR NONWARRANTED REPAIRS AFTER WARRANTY EXPIRES:

- 1. THESE COSTS ARE INITIALIZED TO ZERO.
- 2. A FIXED AND A VARIABLE COST ARE REQUIRED FOR A COST ELEMENT.
- 3. USE SUBMENU TO SELECT COST ELEMENTS TO BE INPUT.
- 4. VARIABLE COSTS FOR COST ELEMENTS OTHER THAN 2.02 (RECURRING PRODUCTION) MAY BE ENTERED AS A PERCENT OF THE VARIABLE COST FOR 2.02, BY ENTERING THE PERCENTAGE AS A NEGATIVE NUMBER, E.G., -10.0 FOR 10%.

AFTER MESSAGE IS NOTED HIT RETURN.

SUBMENU FOR COSTS OF REPAIRS AFTER THE WARRANTY EXPIRES:

ENTER ON 1 LINE NUMBERS OF COSTS ELEMENTS TO BE INPUT, OR
ENTER 0 (ZERO) TO SKIP INPUTTING DATA

- 1 - TO ENTER COSTS FOR 2.01/3.02, NONRECURRING PRODUCTION
- 2 - TO ENTER COSTS FOR 2.02, RECURRING PRODUCTION
- 3 - TO ENTER COSTS FOR 2.03, ENGINEERING CHANGES
- 4 - TO ENTER COSTS FOR 2.04, DATA
- 5 - TO ENTER COSTS FOR 2.05/4.01, SYSTEMS TEST AND EVALUATION
- 6 - TO ENTER COSTS FOR 2.06/4.02, ILS TRAINING, SERVICE AND EQUIPMENT
- 7 - TO ENTER COSTS FOR 2.07/4.04 INITIAL SPARES/REPAIR PARTS
- 8 - TO ENTER COSTS FOR 2.08/3.03/3.04, OPERATIONAL/SITE ACTIVATION
- 9 - TO ENTER COSTS FOR 2.09/4.06, OTHER
- 10 - TO ENTER COSTS FOR 4.03, TRANSPORTATION

YOU MAY CHOOSE DIFFERENT COST ELEMENTS SUCH AS:

- 12 - TO SELECT 4 COST ELEMENTS, MATERIAL, LABOR, OVERHEAD, OTHER
- 13 - OR TO SELECT JUST FIXED COSTS AND VARIABLE COSTS

ENTER FIXED COSTS AND VARIABLE COSTS
0 100

COSTS FOR REPAIRS FOR NO WARRANTY ALTERNATIVE:

1. THESE COSTS ARE INITIALIZED TO ZERO.
2. A FIXED AND A VARIABLE COST ARE REQUIRED FOR A COST ELEMENT.
3. USE SUBMENU TO SELECT COST ELEMENTS TO BE INPUT.
4. VARIABLE COSTS FOR COST ELEMENTS OTHER THAN 2.02
MAY BE ENTERED AS A PERCENT OF THE VARIABLE COST FOR 2.02 BY
ENTERING THE PERCENTAGE AS A NEGATIVE NUMBER, E.G., -10.0 FOR 10%.

AFTER MESSAGE IS NOTED HIT RETURN.

SUBMENU FOR COSTS OF REPAIRS FOR NO WARRANTY CASE:

ENTER ON 1 LINE NUMBERS FOR ALL COST ELEMENTS TO BE INPUT
ENTER 0 (ZERO) TO SKIP INPUTTING ANY VALUES

- 1 - TO ENTER COSTS FOR 2.01/3.02, NONRECURRING PRODUCTION
- 2 - TO ENTER COSTS FOR 2.02, RECURRING PRODUCTION
- 3 - TO ENTER COSTS FOR 2.03, ENGINEERING CHANGES
- 4 - TO ENTER COSTS FOR 2.04, DATA
- 5 - TO ENTER COSTS FOR 2.05/4.01, SYSTEMS TEST AND EVALUATION
- 6 - TO ENTER COSTS FOR 2.06/4.02 ILS TRAINING, SERVICE AND EQUIPMENT
- 7 - TO ENTER COSTS FOR 2.07/4.04 INITIAL SPARES/REPAIR PARTS
- 8 - TO ENTER COSTS FOR 2.08/3.03/3.04, OPERATIONAL/SITE ACTIVATION
- 9 - TO ENTER COSTS FOR 2.09/4.06, OTHER
- 10 - TO ENTER COSTS FOR 4.03, TRANSPORTATION

YOU MAY CHOOSE DIFFERENT COST ELEMENTS SUCH AS:

- 12 - TO SELECT 4 COST ELEMENTS, MATERIAL, LABOR, OVERHEAD, OTHER
- 13 - OR TO SELECT JUST FIXED COSTS AND VARIABLE COSTS

13

ENTER FIXED COSTS AND VARIABLE COSTS

0 100

TO GET NEW PAGE, TAKE PRINTER OFF LINE, ADVANCE PAPER TO TOP OF PAGE.
TO PROCEED, RETURN PRINTER ON LINE AND HIT RETURN.

EXAMPLE 4
FIRINGS PER ROUND

PART 1: ANALYSIS OF WARRANTY PRICE (BASED ON WARRANTED FAILURES ONLY)

THE MODIFIED MTBF IS 100.0
(THE MODIFIED MTBF IS THE MTBF
OF ALL FAILURES INHERENT AND INDUCED
WHICH ARE REPAIRED AT GS OR ABOVE.)

EXPECTED NUMBER OF WARRANTED FAILURES IS 20

BREAKOUT OF COST OF 20.00 WARRANTED FAILURES:

COST ELEMENT	PAID TO CONTRACTOR	IN-HOUSE	TOTAL
FIXED & VARIAB	0	2000	2000
TOTALS:	0	2000	2000
WARRANTY PRICE=	0		

TO GET NEW PAGE, TAKE PRINTER OFF LINE, ADVANCE PAPER TO TOP OF PAGE.
TO PROCEED, RETURN PRINTER ON LINE AND HIT RETURN.

EXAMPLE 4
 FIRINGS PER ROUND

DISTRIBUTION OF WARRANTED FAILURES
 (GIVEN WARRANTED MTBF)

COSTS OF WARRANTED FAILURES

NUMBER OF FAILURES	CUMULATIVE PROBABILITY	WARRANTY VALUE	IN-HOUSE	TOTAL
13	.07	0	1300	1300
14	.10	0	1400	1400
15	.16	0	1500	1500
16	.22	0	1600	1600
17	.30	0	1700	1700
18	.38	0	1800	1800
18	.38	0	1800	1800
19	.47	0	1900	1900
19	.47	0	1900	1900
20	.56	0	2000	2000
20	.56	0	2000	2000
21	.64	0	2100	2100
22	.72	0	2200	2200
22	.72	0	2200	2200
23	.79	0	2300	2300
24	.84	0	2400	2400
25	.89	0	2500	2500
26	.92	0	2600	2600
28	.97	0	2800	2800

DO YOU WANT A COST BREAKOUT FOR ANOTHER NUMBER OF
 WARRANTED FAILURES (THAT YOU ENTER)? (ANSWER Y OR N)

N

TO GET NEW PAGE, TAKE PRINTER OFF LINE, ADVANCE PAPER TO TOP OF PAGE.
 TO PROCEED, RETURN PRINTER ON LINE AND HIT RETURN.

EXAMPLE 4
 FIRINGS PER ROUND

IS THIS A FAILURE-FREE OR THRESHOLD WARRANTY ?
 TYPE "F-FREE" FOR FAILURE-FREE OR "THRESH"
 FOR THRESHOLD WARRANTY
 IF THRESHOLD, ENTER THE ADMIN COST
 PAID TO THE CONTRACTOR
 THRESH

ENTER ADMINISTRATIVE COST
 50

PART 2: COMPARISON OF ALTERNATIVES (BASED ON ALL FAILURES)-THRESHOLD CASE

REMEMBER THAT IN THE THRESHOLD CASE THE FAILURES
 BELOW THE THRESHOLD ARE IDENTIFIED AS WARRANTED
 FAILURES AND THEIR COSTS SHOULD HAVE BEEN ASSIGNED
 TO THE GOVERNMENT

AMOUNT OF ADMINISTRATIVE COST
 GOVERNMENT PAID TO CONTR = 50

MODIFIED MTBF	EXP NO. OF WARRANTY	OF FAIL	WARRANTY ?	ADMIN COST	OTHER	POST WARRANTY	TOTAL
90.0	20		YES	50	2000	0	2050
90.0	12		NO		2222	0	2222
95.0	20		YES	50	2000	0	2050
95.0	21		NO		2105	0	2105
100.0	20		YES	50	2000	0	2050
100.0	20		NO		2000	0	2000
105.0	17		YES	50	1905	0	1955
105.0	19		NO		1905	0	1905
110.0	18		YES	50	1818	0	1868
110.0	18		NO		1818	0	1818
115.0	17		YES	50	1739	0	1789
115.0	17		NO		1739	0	1739

DO YOU WISH TO ASSUME YOUR DISTRIBUTION
 OF MTBFS IS TRIANGULAR OR WEIBUL ?

TYPE "TRIANG" FOR TRIANGULAR OR "WEIBUL"
 FOR WEIBULL DISTRIBUTION
 NOTE: IN SOME CASES, WEIBULL DISTRIBUTION MIGHT NOT BE
 SUITABLE AND MUELLER ITERATION MIGHT NOT CONVERGE.
 IN GENERAL TRIANGULAR DISTRIBUTION WILL GIVE YOU
 A GOOD APPROXIMATION
 TRIANG

PART 3: PROBABILITY DISTRIBUTION

PROBABILITY DISTRIBUTION OF MODIFIED MTBF

THE EXPECTED MODIFIED MTBF = 101.7

MODIFIED MTBF	PROB.	CUM. PROB.
90	.000	.000
95	.200	.200
100	.400	.600
105	.267	.867
110	.133	1.000
115	.000	1.000

TO GET NEW PAGE, TAKE PRINTER OFF LINE, ADVANCE PAPER TO TOP OF PAGE
TO PROCEED, RETURN PRINTER ON LINE AND HIT RETURN.

DISTRIBUTION OF TOTAL COSTS

TOTAL COSTS	CUM. PROB. WARRANTY	CUM. PROB. NO WARRANTY
1739	.000	.000
1789	.000	.084
1818	.049	.133
1868	.133	.287
1905	.246	.400
1955	.400	.610
2000	.590	.800
2050	.800	.895
2050	1.000	.895
2050	1.000	.895
2105	1.000	1.000
2222	1.000	1.000

E. Example 5: Comprehensive Example

The earlier examples were simplified to make it easier to see how the model works. Example 5 is a more complex example which contains a greater variety of information than the previous examples.

The warranty clauses, as written for Widget X, requires the government to pay up front for the cost of expected failures given that the warranted MTBF is met. The clause then requires the Contractor to repair/replace all warranted claims at no additional cost to the Government.

Widget X is an essential item of weapon system Y and therefore requires a warranty. The current contract is for the second year of full-scale production. To this point in time, 90 installed and 12 spare widgets have been produced from a total program of 1000 installed and 150 spares. The current buy calls for 100 installed and 15 spares, at an average unit price of \$18,500. None of these items is intended for war reserve.

The warranty clause covers all repairs to GS level and above for a period of 2 calendar years or 1 year's usage (400 hours), whichever comes first. The inherent MTBF (per contract) is 867 hours.

The following Reliability and Maintainability (RAM) data have been provided by project engineers:

1. It is anticipated that we will actually experience an inherent MTBF somewhere between 600 and 1050 hours, with a most likely value of 950 hours; a triangular probability distribution of MTBF is assumed. Thus a range of 600 to 1050 is entered with an increment of 25.

2. Of the failures experienced, historically, 85% were inherent while 15% were induced (mechanical error, improper usage, etc.). It is estimated

that of the inherent failures, 5% will have their warranty claims invalidated because of improper processing.

3. Of the failures experienced historically, only 10% are field repairable (Org and DS). The remaining 90% require action at GS or above; their breakout by nature of repair is:

- 10% scrap
- 55% minor repair
- 35% major repair

4. Previous experience and the contractor's insistence that all warranty repairs be done at his plant have led to the following estimates of price per repair:

	<u>Minor</u>	<u>Major</u>
Warranted Repair	\$1850.	\$6500.
Non-warranted repair	\$1760.	\$6500.

5. A 5% false failure rate has been experienced.

a. It is anticipated that the Contractor will perform \$12K worth of ECOs (at no cost to the Government) if the warranty is implemented. If a warranty is not purchased, the Government would fund these ECOs.

b. The conditions of the warranty require that the Contractor submit a quarterly report for each item type (such as Widget X). The price for each report is \$600 plus 1% of the repair cost for each failure (for collecting and formulating pertinent data).

c. A one-time expense of \$15K is required for tooling to reestablish a GS-level repair line at the Contractor's site. Additional sustaining tooling costs required by the warranty will be \$1000 per 100 failures.

d. Additional spare parts (3% of the item production price) will be required, up front, if the warranty is bought (due to reduced turn-around time). However, these additional items can be used after the warranty period to augment supply requirements.

e. It costs \$100 per warranted item to manufacture and apply a warranty label.

f. Contractor will require the following additional personnel for warranty management:

	<u>Burdened Salary Per Year</u>
1 manager	\$140 K
2 first line supervisors	\$100 K
2 quality supervisors	\$135 K

Each of the above can manage 10 item types (the widget being one such) on a regular basis.

g. The following processing costs are incurred for each failure processed:

In- house, inventory control	\$ 50.
In-house, claim determination	\$ 80.
Contractor, claim determination	\$100.
In-house, claim processing	\$ 30.
Contractor, claim processing	\$ 80.

h. Transportation costs (one way) to the Contractor are \$225; normal transportation costs (no warranty case) average \$206.

To prepare the input data, consider the following analysis:

1. Non-Recurring - The \$15,000 one-time tooling charge should be entered as warranty fixed cost. However, its impact for costs comparison purposes

should be prorated over the last $1150 - 102 = 1048$ items to be produced. Thus, only $115/1048 (15,000) = \$1646$. should be used in the cost comparison; hence, \$13,354, goes under "Exclusion". Recurring tooling costs would be $\$1000/100 = \10 .

2. Recurring Production

a. The contractual inherent MTBF 867 hours is used as input. Since inherent failures are historically only 85% of the total failures, 85 is entered as the inherent failure rate and 95% and 90% are used for the valid claim rate and the repairable rate, respectively. The program will make adjustments to all the input MTBFs according to the given input rates.

b. In computing the average cost per repair, we utilize the "failure type" breakout in E.3. and the "cost per repair" data in E.4. to obtain a weighted average cost per repair:

warranted repair: $(.10)(18,500) + (.55)(1850) + (.35)(6500) = \5143 .

non-warranted repair: $(.10)(18,500) + (.55)(1760) + (.35)(6500) = \5093 .

c. A fixed cost of $115 \times \$100 = \$11,500$ should be added for application of warranty labels.

3. Engineering Change Orders - The base case production contract is assumed to be non-warranty case and hence would already contain the \$12K for the ECOs in question. Thus, a fixed cost of $-\$12,000$ should be entered in the warranty case; 0 should be used in the non-warranty case.

4. Data - A fixed cost of $8 \times \$600 = \4800 (2 years at \$600 per quarter) plus a recurring 1% factor (enter as -1) should be entered as warranty costs.

5. Initial Spares/Repair Parts - A fixed cost of $(0.03) (115) (18,500) = \$63,825$ should be added to the warranty cost because it will be required

up-front. However, since it will result in a like cost avoidance later in the program, it should also be put under "Exclusions" and not considered in the cost comparison between warranty and non-warranty.

6. Other - A fixed cost of $((140K + 2x100K + 2x135K)/10) \times 2 = \$122,000$ should be charged against the warranty for Contractor management personnel. A two-year period is costed since the warranty is for a two-year calendar period and hence the funds must be committed. However, if a warranty is purchased with the next contract, no additional people would be required. Thus, the cost of these people for one of the two years, \$61,000, should be put under "Exclusions" for comparison purposes. A recurring cost of $(50 + 80 + 100 + 30 = 80)/95 = \358 . is charged against the warranty for processing costs. The division by .95 is to allow for the 5% false failure rate. Of these costs, 47% are in-house and 53% are contractor.

7. Transportation - A recurring cost of $2x\$225 \times (1/.95) = \474 . is charged against the warranty. The 2 represents round trip and the 1/.95 is, again, to account for the 5% false failure rate. Similarly, a recurring cost of $2x\$206 \times (1/.95) = \434 . is charged against the no warranty alternative. \$138,179 is entered for the exclusion, where

$$\begin{aligned} \$138,179 &= \$13,354 \text{ (exclusion under non-recurring)} \\ &+ \$63,825 \text{ (fixed cost exclusion for IS/RP)} \\ &+ \$61,000 \text{ (fixed cost exclusion for other)} \end{aligned}$$

For the expected MTBF, the warranty should cost the government \$328,832.06 above the cost of the production contract. (See Part 1, Analysis of Warranty Price.)

Making the exclusion for comparison purposes, the warranty is basically

cost effective (see Part 2, Comparison of Alternatives) if we anticipate an actual MTBF (total failures at GS level and above) of 750 or less (note that a 750 MTBF shows "yes" costs less than "no" costs; at 775 MTBF, "yes" costs more than "no").

If we allow say 5% variation for estimating uncertainty, we could even say the warranty is cost effective if our anticipated actual MTBF is 850 or less.

Note that in our analysis of data, we expected an actual MTBF of about 866. This would seem to say that, on the surface, the warranty is not cost effective.

If, however, the contractor offers the warranty for \$300,000 (91.2% of our "should cost" figure), we could then use a comparative warranty cost of $\$240,428.06 \times (.912) = \$219,270.39$. This yields cost effectiveness for an MTBF of 825 or less (straight comparison) or for an MTBF of 925-950 or less (allowing 5% for estimating uncertainty). This might tend to sway the decision maker to buy the warranty.

On the other hand, if the contractor comes in with a proposal of \$500,000 because he claims he is taking a risk of many more failures than the 37.44 used to price the warranty, we could use Part 1, Distribution of Warranted Failures, to argue that he has only a 4% chance of exceeding \$385,770.00 and hence his price is probably excessive. Making subsequent runs and varying such things as warranted MTBF, cost per repair, etc., we can get sensitivity analysis data for evaluating risk (to both contractor and government) in other areas.

C:\PCWARM>PCWARM3

WARRANTY PROGRAM UPDATED SEPTEMBER 1987

TYPE T TO INPUT DATA AT TERMINAL; TYPE F TO RETRIEVE DATA STORED ON FILE
T

ENTER TWO LINES OF HEADER INFORMATION

EXAMPLE 5

COMPREHENSIVE EXAMPLE

ENTER ECONOMIC LIFE IN TIME PERIODS (WHOLE NUMBER BETWEEN 1 AND 240)

2

ENTER NUMBER OF TIME PERIODS DELIVERIES ARE MADE (MUST BE A
WHOLE NUMBER FROM 1 TO 240)

1

ENTER NUMBER OF SYSTEMS DELIVERED EACH PERIOD FOR 1 TIME PERIODS

100

ENTER NUMBER OF SPARES DELIVERED EACH PERIOD FOR 1 TIME PERIODS

15

ENTER USAGE HOURS PER SYSTEM PER TIME PERIOD, FOR 2 PERIODS

400 400

ENTER DISCOUNT RATE AS PERCENT PER TIME PERIOD, E.G., 10. FOR 10%

0

ENTER ESCALATION INDICES PER TIME PERIOD, FOR 2 PERIODS

1 1

ENTER INHERENT FAILURE RATE, VALID CLAIM RATE
AND PERCENT WHICH REQUIRES GS OR ABOVE LEVEL REPAIR

85 95 90

ENTER INHERENT MTBF

867

ENTER RANGE OF MTBF VALUES AS BEGINNING MTBF, ENDING MTBF, STEP SIZE
AND THE MODE(=MOST LIKELY MTBF)

600 1050 25 950

ENTER MTBF FACTORS FOR WARRANTY ALTERNATIVE; ONE FOR EACH PERIOD, FOR
2 TIME PERIODS. TO INPUT A VALUE N TIMES USE N*VALUE; FOR EXAMPLE,

3*1.2 BECOMES 1.2,1.2,1.2

2*1.0

ENTER MTBF FACTORS FOR NO WARRANTY ALTERNATIVE; ONE FOR EACH PERIOD, FOR
2 TIME PERIODS. TO INPUT A VALUE N TIMES USE N*VALUE; FOR EXAMPLE,

3*.99 BECOMES .99,.99,.99

1 1

ENTER LENGTH OF WARRANTY IN TIME PERIODS (MUST BE A WHOLE NUMBER) AND IN
USAGE HOURS

COSTS FOR WARRANTED REPAIRS BY COST ELEMENT:

1. THESE COSTS ARE INITIALIZED TO ZERO.
2. A FIXED COST, A VARIABLE COST, AND PERCENTAGES OF THESE COSTS PAID TO THE CONTRACTOR ARE REQUIRED FOR EACH COST ELEMENT TO BE ENTERED.
3. USE SUBMENU TO SELECT COST ELEMENTS TO BE INPUT.
4. VARIABLE COSTS FOR COST ELEMENTS OTHER THAN 2.02 (RECURRING PRODUCTION) MAY BE ENTERED AS A PERCENT OF THE VARIABLE COST FOR 2.02, BY ENTERING THE PERCENTAGE AS A NEGATIVE NUMBER, E.G., -10.0 FOR 10%.

AFTER MESSAGE IS NEXT RETURN.

SUBMENU FOR COSTS OF WARRANTED REPAIRS:

ENTER ON 1 LINE NUMBERS FOR ALL COST ELEMENTS YOU WISH TO INPUT, OR ENTER 0 (ZERO) TO SKIP INPUTTING ANY COSTS

- 1 - TO ENTER COSTS FOR 2.01/3.02, NONRECURRING PRODUCTION
- 2 - TO ENTER COSTS FOR 2.02, RECURRING PRODUCTION
- 3 - TO ENTER COSTS FOR 2.03, ENGINEERING CHANGES
- 4 - TO ENTER COSTS FOR 2.04, DATA
- 5 - TO ENTER COSTS FOR 2.05/4.01, SYSTEMS TEST AND EVALUATION
- 6 - TO ENTER COSTS FOR 2.06/4.02 ILS TRAINING, SERVICE AND EQUIPMENT
- 7 - TO ENTER COSTS FOR 2.07/4.04, INITIAL SPARES/REPAIR PARTS
- 8 - TO ENTER COSTS FOR 2.08/3.03/3.04, OPERATIONAL/SITE ACTIVATION
- 9 - TO ENTER COSTS FOR 2.09/4.06, OTHER
- 10 - TO ENTER COSTS FOR 4.03, TRANSPORTATION

YOU MAY CHOOSE DIFFERENT COST ELEMENTS SUCH AS:

- 12 - TO SELECT 4 COST ELEMENTS, MATERIAL, LABOR, OVERHEAD, OTHER
- 13 - OR TO SELECT JUST FIXED COSTS AND VARIABLE COSTS

1 2 3 4 7 9 10

ENTER FIXED AND VARIABLE COSTS AND THEN PERCENTAGES FOR 2.01/3.02, NONRECURRING
15000 10 100 100

ENTER FIXED AND VARIABLE COSTS AND PERCENTAGES FOR 2.02, RECURRING PRODUCTION
11500 5143 100 100

ENTER FIXED AND VARIABLE COSTS AND PERCENTAGES FOR 2.03, ENGINEERING CHANGES
-12000 0 100 0

ENTER FIXED AND VARIABLE COSTS AND PERCENTAGES FOR 2.04, DATA
4800 -1 100 100

ENTER FIXED AND VARIABLE COSTS AND PERCENTAGES FOR 2.07/4.04, INITIAL SPARES/REPAIR PARTS
42550 0 100 0

ENTER FIXED AND VARIABLE COSTS AND PERCENTAGES FOR 2.09/4.06, OTHER
65000 358 100 53

ENTER FIXED AND VARIABLE COSTS AND PERCENTAGES FOR 4.03, TRANSPORTATION

0 474 0 0

WARNING: FIXED COST FOR COST ELEMENT 3 IS NEGATIVE.
ENTER EXCLUSIONS TO WARRANTY PRICE TO BE USED WHEN COMPARING WARRANTY AND
NO WARRANTY ALTERNATIVES
138179

COSTS FOR NONWARRANTED REPAIRS DURING WARRANTY PERIOD:

1. THESE COSTS ARE INITIALIZED TO ZERO.
2. USE SUBMENU TO SELECT COST ELEMENTS TO BE INPUT.
3. A FIXED COST AND A VARIABLE COST ARE REQUIRED FOR ANY COST ELEMENT ENTERED.
4. VARIABLE COSTS FOR COST ELEMENTS OTHER THAN 2.02 (RECURRING PRODUCTION) MAY BE ENTER AS A PERCENT OF THE VARIABLE COST FOR 2.02, BY ENTERING THE PERCENTAGE AS A NEGATIVE NUMBER, E.G., -10.0 FOR 10%.

AFTER MESSAGE IS NOTED HIT RETURN.

SUBMENU FOR COSTS OF NONWARRANTED REPAIRS DURING WARRANTY PERIOD:

ENTER ON 1 LINE NUMBERS OF ALL COSTS ELEMENTS TO BE INPUT, OR
ENTER 0 (ZERO) TO SKIP INPUTTING COSTS

- 1 - TO ENTER COSTS FOR 2.01/3.02, NONRECURRING PRODUCTION
- 2 - TO ENTER COSTS FOR 2.02, RECURRING PRODUCTION
- 3 - TO ENTER COSTS FOR 2.03, ENGINEERING CHANGES
- 4 - TO ENTER COSTS FOR 2.04, DATA
- 5 - TO ENTER COSTS FOR 2.05/4.01, SYSTEMS TEST AND EVALUATION
- 6 - TO ENTER COSTS FOR 2.06/4.02, ILS TRAINING, SERVICE AND EQUIPMENT
- 7 - TO ENTER COSTS FOR 2.07/4.04, INITIAL SPARES/REPAIR PARTS
- 8 - TO ENTER COSTS FOR 2.08/3.03/3.04, OPERATIONAL/SITE ACTIVATION
- 9 - TO ENTER COSTS FOR 2.09/4.06, OTHER
- 10 - TO ENTER COSTS FOR 4.03, TRANSPORTATION

YOU MAY CHOOSE DIFFERENT COST ELEMENTS SUCH AS:

- 12 - TO SELECT 4 COST ELEMENTS, MATERIAL, LABOR, OVERHEAD, OTHER
- 13 - OR TO SELECT JUST FIXED COSTS AND VARIABLE COSTS

2 10

ENTER FIXED AND VARIABLE COSTS FOR 2.02, RECURRING PRODUCTION
0 5093

ENTER FIXED AND VARIABLE COSTS FOR 4.03, TRANSPORTATION
0 434

COSTS FOR NONWARRANTED REPAIRS AFTER WARRANTY EXPIRES:

1. THESE COSTS ARE INITIALIZED TO ZERO.
2. A FIXED AND A VARIABLE COST ARE REQUIRED FOR A COST ELEMENT.
3. USE SUBMENU TO SELECT COST ELEMENTS TO BE INPUT.
4. VARIABLE COSTS FOR COST ELEMENTS OTHER THAN 2.02 (RECURRING PRODUCTION) MAY BE ENTERED AS A PERCENT OF THE VARIABLE COST FOR 2.02, BY ENTERING THE PERCENTAGE AS A NEGATIVE NUMBER, E.G., -10.0 FOR 10%.

AFTER MESSAGE IS NOTED HIT RETURN.

SUBMENU FOR COSTS OF REPAIRS AFTER THE WARRANTY EXPIRES:

ENTER ON 1 LINE NUMBERS OF COSTS ELEMENTS TO BE INPUT, OR
ENTER 0 (ZERO) TO SKIP INPUTTING DATA

- 1 - TO ENTER COSTS FOR 2.01/3.02, NONRECURRING PRODUCTION
- 2 - TO ENTER COSTS FOR 2.02, RECURRING PRODUCTION
- 3 - TO ENTER COSTS FOR 2.03, ENGINEERING CHANGES
- 4 - TO ENTER COSTS FOR 2.04, DATA
- 5 - TO ENTER COSTS FOR 2.05/4.01, SYSTEMS TEST AND EVALUATION
- 6 - TO ENTER COSTS FOR 2.06/4.02, ILS TRAINING, SERVICE AND EQUIPMENT
- 7 - TO ENTER COSTS FOR 2.07/4.04 INITIAL SPARES/REPAIR PARTS
- 8 - TO ENTER COSTS FOR 2.08/3.03/3.04, OPERATIONAL/SITE ACTIVATION
- 9 - TO ENTER COSTS FOR 2.09/4.06, OTHER
- 10 - TO ENTER COSTS FOR 4.07, TRANSPORTATION

YOU MAY CHOOSE DIFFERENT COST ELEMENTS SUCH AS:

- 12 - TO SELECT 4 COST ELEMENTS, MATERIAL, LABOR, OVERHEAD, OTHER
- 13 - OR TO SELECT JUST FIXED COSTS AND VARIABLE COSTS

0

COSTS FOR REPAIRS FOR NO WARRANTY ALTERNATIVE:

- 1. THESE COSTS ARE INITIALIZED TO ZERO.
- 2. A FIXED AND A VARIABLE COST ARE REQUIRED FOR A COST ELEMENT.
- 3. USE SUBMENU TO SELECT COST ELEMENTS TO BE INPUT.
- 4. VARIABLE COSTS FOR COST ELEMENTS OTHER THAN 2.02
MAY BE ENTERED AS A PERCENT OF THE VARIABLE COST FOR 2.02 BY
ENTERING THE PERCENTAGE AS A NEGATIVE NUMBER, E.G., -10.0 FOR 10%.

AFTER MESSAGE IS NOTED HIT RETURN.

SUBMENU FOR COSTS OF REPAIRS FOR NO WARRANTY CASE:

ENTER ON 1 LINE NUMBERS FOR ALL COST ELEMENTS TO BE INPUT
ENTER 0 (ZERO) TO SKIP INPUTTING ANY VALUES

- 1 - TO ENTER COSTS FOR 2.01/3.02, NONRECURRING PRODUCTION
- 2 - TO ENTER COSTS FOR 2.02, RECURRING PRODUCTION
- 3 - TO ENTER COSTS FOR 2.03, ENGINEERING CHANGES
- 4 - TO ENTER COSTS FOR 2.04, DATA
- 5 - TO ENTER COSTS FOR 2.05/4.01, SYSTEMS TEST AND EVALUATION
- 6 - TO ENTER COSTS FOR 2.06/4.02 ILS TRAINING, SERVICE AND EQUIPMENT
- 7 - TO ENTER COSTS FOR 2.07/4.04 INITIAL SPARES/REPAIR PARTS
- 8 - TO ENTER COSTS FOR 2.08/3.03/3.04, OPERATIONAL/SITE ACTIVATION
- 9 - TO ENTER COSTS FOR 2.09/4.06, OTHER
- 10 - TO ENTER COSTS FOR 4.03, TRANSPORTATION

YOU MAY CHOOSE DIFFERENT COST ELEMENTS SUCH AS:

- 12 - TO SELECT 4 COST ELEMENTS, MATERIAL, LABOR, OVERHEAD, OTHER
- 13 - OR TO SELECT JUST FIXED COSTS AND VARIABLE COSTS

2 10

ENTER FIXED AND VARIABLE COSTS FOR 2.02, RECURRING PRODUCTION
0 5043

ENTER FIXED AND VARIABLE COSTS FOR 4.03, TRANSPORTATION
0 434

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EXAMPLE 5
COMPREHENSIVE EXAMPLE

PART 1: ANALYSIS OF WARRANTY PRICE (BASED ON WARRANTED FAILURES ONLY)

THE MODIFIED MTBF IS 818.8
(THE MODIFIED MTBF IS THE MTBF
OF ALL FAILURES INHERENT AND INDUCED
WHICH ARE REPAIRED AT GS OR ABOVE.)

EXPECTED NUMBER OF WARRANTED FAILURES IS 45

BREAKOUT OF COST OF 45.36 WARRANTED FAILURES:

COST ELEMENT	PAID TO CONTRACTOR	IN-HOUSE	TOTAL
NONRECURR PROD	15454	0	15454
RECURRING PROD	244804	0	244804
ENG CHANGES	-11999	0	-11999
DATA	7133	0	7133
SYS TEST & EVL	0	0	0
ILS TR,SER,EQU	0	0	0
INIT S.R. PART	42550	0	42550
OPERT SITE ACT	0	0	0
OTHER	73607	7633	81240
TRANSPORTATION	0	21502	21502
TOTALS:	371548	29135	400683
WARRANTY PRICE=	371547		

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EXAMPLE 5
COMPREHENSIVE EXAMPLE

DISTRIBUTION OF WARRANTED FAILURES
(GIVEN WARRANTED MTBF)

COSTS OF WARRANTED FAILURES

NUMBER OF FAILURES	CUMULATIVE PROBABILITY	WARRANTY VALUE	IN-HOUSE	TOTAL
35	.07	315646	21479	338125
37	.12	326434	23764	350198
38	.15	331828	24406	356234
40	.24	342617	25690	368307
41	.29	348011	26333	374344
42	.34	353405	26975	380380
43	.40	358799	27617	386416
44	.46	364194	28259	392453
44	.46	364194	28259	392453
45	.52	369588	28902	398489
46	.58	374982	29544	404526
47	.63	380376	30186	410562
48	.69	385770	30828	416599
49	.74	391164	31471	422635
50	.78	396559	32113	428672
51	.82	401953	32755	434708
52	.85	407347	33398	440744
54	.91	418135	34682	452817
57	.96	434318	36609	470927

DO YOU WANT A COST BREAKOUT FOR ANOTHER NUMBER OF
WARRANTED FAILURES (THAT YOU ENTER)? (ANSWER Y OR N)
N

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EXAMPLE 5
 COMPREHENSIVE EXAMPLE

IS THIS A FAILURE-FREE OR THRESHOLD WARRANTY ?
 TYPE "F-FREE" FOR FAILURE-FREE OR "THRESH"
 FOR THRESHOLD WARRANTY
 IF THRESHOLD, ENTER THE ADMIN COST
 PAID TO THE CONTRACTOR
 F-FREE

PART 2: COMPARISON OF ALTERNATIVES (BASED ON ALL FAILURES)--FAILURE FREE

WARRANTY PRICE = 371548
 EXCLUSIONS FOR COMPARISON PURPOSES = 138179
 AMOUNT EXCLUDED DUE TO DISCOUNTING = 0
 VALUE USED FOR COMPARISON PURPOSES = 233369

MODIFIED MTBF	EXP NO. OF WARRANTD FAIL	WARRANTY ?	WARRANTY COST	OTHER	POST WARRANTY	TOTAL
566.7	66	YES	233369	460088	0	693456
566.7	66	NO		773224	0	773224
591.7	63	YES	233369	440647	0	674016
591.7	63	NO		740552	0	740552
616.7	60	YES	233369	422783	0	656152
616.7	60	NO		710530	0	710530
641.7	58	YES	233369	406311	0	639680
641.7	58	NO		662847	0	662847
666.7	56	YES	233369	391070	0	624439
666.7	56	NO		657240	0	657240
691.7	54	YES	233369	374431	0	607800
691.7	54	NO		633454	0	633454
716.7	52	YES	233369	357792	0	591161
716.7	52	NO		611381	0	611381
741.7	50	YES	233369	341153	0	574528
741.7	50	NO		595147	0	595147
766.7	48	YES	233369	324514	0	558883
766.7	48	NO		572140	0	572140
791.7	47	YES	233369	307875	0	541244
791.7	47	NO		559764	0	559764
816.7	45	YES	233369	291236	0	524605
816.7	45	NO		546650	0	546650
841.7	44	YES	233369	274597	0	508966
841.7	44	NO		533064	0	533064
866.7	42	YES	233369	257958	0	493327
866.7	42	NO		519530	0	519530
891.7	41	YES	233369	241319	0	477688
891.7	41	NO		505100	0	505100
916.7	40	YES	233369	224680	0	462049
916.7	40	NO		490880	0	490880

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WARRANTY MODEL (WARM) USER'S GUIDE REVISION(U) ARMY
AVIATION SYSTEMS COMMAND ST LOUIS MO R CROSIER ET AL.
SEP 87 USARUSCOM-TR-87-F-3

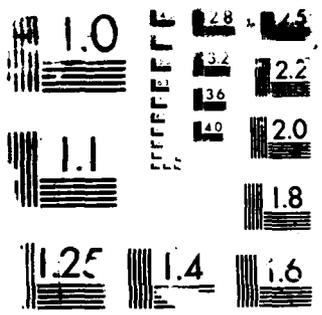
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8



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916.7	41	YES	233369	284418	0	517786
916.7	41	NO		477993	0	477993
941.7	39	YES	233369	276867	0	510235
941.7	39	NO		465303	0	465303
966.7	38	YES	233369	269707	0	503075
966.7	38	NO		453269	0	453269
991.7	37	YES	233369	262907	0	496276
991.7	37	NO		441842	0	441842
1016.7	37	YES	233369	256442	0	489811
1016.7	37	NO		430977	0	430977

DO YOU WISH TO ASSUME YOUR DISTRIBUTION
OF MTBFS IS TRIANGULAR OR WEIBUL ?

TYPE "TRIANG" FOR TRIANGULAR OR "WEIBUL"
FOR WEIBULL DISTRIBUTION

NOTE: IN SOME CASES, WEIBULL DISTRIBUTION MIGHT NOT BE
SUITABLE AND MUELLER ITERATION MIGHT NOT CONVERGE.
IN GENERAL TRIANGULAR DISTRIBUTION WILL GIVE YOU
A GOOD APPROXIMATION
TRIANG

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PART 3: PROBABILITY DISTRIBUTION

PROBABILITY DISTRIBUTION OF MODIFIED MTBF

THE EXPECTED MODIFIED MTBF = 826.9

MODIFIED MTBF	PROB.	CUM. PROB.
566	.000	.000
591	.008	.008
616	.017	.025
641	.025	.050
666	.034	.084
691	.042	.126
716	.050	.176
741	.059	.235
766	.067	.303
791	.076	.378
816	.084	.462
841	.092	.555
866	.101	.655
891	.109	.765
916	.093	.858
941	.070	.927
966	.047	.974
991	.023	.997
1016	.000	.997

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DISTRIBUTION OF TOTAL COSTS

TOTAL COSTS	CUM. PROB. WARRANTY	CUM. PROB. NO WARRANTY
430977	.000	.000
441842	.000	.023
453269	.000	.070
465303	.000	.140
477993	.000	.233
489811	.000	.329
491394	.006	.342
496276	.023	.377
503075	.070	.425
505569	.094	.443
510235	.140	.471
517786	.233	.518
520586	.271	.535
525761	.342	.562
534195	.443	.607
536522	.467	.619
543130	.535	.649
552613	.619	.691
553465	.626	.695
562694	.695	.729
571513	.750	.762
573433	.762	.768
584896	.821	.803
590778	.845	.821
597159	.871	.836
610308	.913	.869
611386	.916	.871
624443	.947	.896
633484	.962	.913
639680	.972	.922
656152	.989	.945
657240	.989	.947
674016	.997	.963
682847	.997	.972
693456	.997	.978
710530	1.000	.989
740552	1.000	.997
773224	1.000	.997

VI. Additional Model Usage Notes

A. In all the examples, MTBF was measured in usage hours between failures. Another common measure of MTBF is in miles between failures, and that could also be used in WARM. If MTBF is measured in miles between failures, then the measure of usage is miles rather than hours; and the usage per time period and the usage portion of the warranty duration should be entered in miles.

B. The type of warranty analyzed by WARM is length of time or usage, whichever occurs first. If it is desired to analyze a warranty which is length of time only, or usage hours only, that can be done by making the length of time of the warranty equate to usage duration of the warranty. For example, if the usage under the warranty were 90 hours and 120 hours, respectively, for the first two years, and it was desired to have a warranty of length of time only, for a duration of 2 years, then the duration of the warranty should be entered in WARM as 2 years or 210 hours, whichever comes first. If with the same usage for the first two years, 90 and 120 respectively, it were desired to have a warranty of length of usage only, for a duration of 150 hours, then time periods would have to be in months and 150 hours of usage would occur at the end of 18 months (90 hours the first year and 10 hours a month for six months the second year). Then the warranty duration would be for 18 months or 150 hours, whichever comes first.

C. In analyzing a threshold warranty, the threshold is computed from the input inherent MTBF as well as some other factors. It may be the case that the contractor will not agree to a warranty with the threshold set as the expected number of warranted failures computed from the inherent MTBF. The contractor may propose a higher threshold. That proposal can be evaluated in WARM by

converting the proposed threshold to a corresponding inherent MTBF and inputting that inherent MTBF into the model. For example, in example 2, the inherent MTBF was 50 and the resulting threshold was 95 failures. Suppose the contractor proposes a threshold of 105 failures. First use the formula for the expected number of failures to compute the modified MTBF.

$$\text{modified MTBF} = \frac{\text{items} \times \text{usage} \times \text{inherent failure rate} \times \text{valid claim rate}}{\text{number of failures}}$$

Using the input data from example 2 gives

$$\text{modified MTBF} = \frac{100 \times 100 \times .85 \times .95}{105} = 77$$

The formula relating the modified and inherent MTBF is

$$\text{modified MTBF} = \frac{\text{inherent MTBF} \times \text{inherent failure rate}}{\text{percent repaired at GS or above}}$$

Therefore for the data in example 2,

$$\text{inherent MTBF} = 77 \times \frac{50}{85} = 45$$

The contractor is proposing that the threshold be set corresponding to an inherent MTBF of 45 rather than 50. If the value of 45 is input for the inherent MTBF along with the same data used before in example 2, then the contractor's threshold will be computed and analyzed by WARM.

D. This section describes the discounting and escalation features of the model. AMC has advised that escalation is inappropriate in an economic analysis. However, since WARM already had the capability of escalation, it was decided to leave that capability in WARM in case it was desired to use escalation for some purpose other than a formal economic analysis. If it is desired to have no escalation in WARM, then enter 1 as the escalation factor for each time period. In Part 1, the section where the warranty price is computed, all the

costs can be escalated but not discounted. In Part 2, the warranty cost which is used for comparison purposes of the warranty/no warranty alternatives has been reduced by an amount to allow for discounting. In other words, the warranty price can be escalated but not discounted, and the warranty cost can be both escalated and discounted. All the costs in Part 2 can be both escalated and discounted. Fixed costs which occur in the first time period can be escalated but are not discounted. Variable costs which occur in the first time period can be both escalated and discounted. Fixed costs for warranted repairs, unwarranted repairs during the warranty period, and the no warranty case are assumed to occur in the first time period. Fixed costs for post-warranty repairs are assumed to occur in the first time period after the length (in time periods) of the warranty has expired. Because of possible different uses of the amount to be excluded for comparison purposes in the failure-free case and the administration costs in the threshold case, those values are not escalated or discounted in the model. If it is desired to have them escalated or discounted, that must be done outside the model.

E. Mainframe Version

A mainframe version of WARM also exists. However, the PC version is more commonly used because it is more transportable and more convenient to use. The PC version has all the features of the mainframe version except for the graphics capability which is dependent on the type of PC hardware and software and therefore was not practicable to be included in the PC version.

A description and illustration of the graphics capability for the output of example 5 is shown in Appendix C.

The mainframe version has been written in the 1977 Standard FORTRAN

language, and was compiled on the IBM 4341 using the VS FORTRAN compiler. The graphical subroutines are written in PLOT 10 Advanced Graphing II. To utilize the graphs, the user must have a computer equipped with a PLOT-10 compiler and a graphical terminal such as TEKTRONIX 4010, 4014, 4010, 4114 series. For users who do not have access to the PLOT-10 software or the required hardware, the program has an option to print the graph data in tabular form.

The program is designed to be used interactively on a computer terminal with a video display screen. It will work on a hardcopy terminal such as a DECWRITER, or in batch mode, but will produce unneeded output. The prompts and menus are those normally used in an interactive program. The program is designed to allow for a sensitivity analysis. It does this by means of a menu that allows the user to selectively change some of the input data, and rerun the analysis. Initially, the menu is ignored and the program prompts the user for all input data. After the analysis is done, the program prints the menu and waits for the user's directions. All input is free-format; this means that blanks or commas separate numbers, decimal points are optional on all whole numbers. Percentages are entered as percentages and not as decimal fractions, e.g., 80. for 80% not .8.

APPENDIX A - MAIN PROGRAM VARIABLES

APPENDIX A

MAIN PROGRAM VARIABLES

AMOUNT - AMOUNT warranty Price is reduced by discounting

BMTBF - Beginning MTBF

COMPAR - Warranty Price less all exclusions for COMPARison purposes

COSTNW - COST for No Warranty alternative; dimensioned (3,11)

COSTS - Temporary array used to input costs; dimensioned (3,11)

COST4 - Temporary array used to input costs; dimensioned (4,11)

DEPWF - Discounted Expected Post Warranty Failures

DEUF - Discounted Expected Unwarranted Failures

DEWF - Discounted Expected Warranted Failures

DISFAC - DIScount FACTor for a time period

DISTOT - DIScounted TOTal number of systems delivered

DLVRS - DeLiVeRy Schedule; an array of length NDYRS

DSCNT - DiSCouNT rate

ELIFE - Economic LIFE

EMTBF - Ending MTBF

EPWF - Expected Post Warranty Failures (escalated but not discounted)

ESCLAT - An array of ESCaLATION Indices

EUUF - Expected Unwarranted Failures (escalated but not discounted)

EWWF - Expected Warranted Failures (escalated but not discounted)

EXCLU - EXCLUsions to warranty price (entered by user)

FACNW - MTBF FACTors for No Warranty Alternative

FCNTRC - sum of Fixed costs paid to CoNTRaCtor

FCSUMN - Fixed Cost SUM for No warranty alternative

FCSUMP - Fixed Cost SUM for Post warranty period failures
FCSUMU - Fixed Cost SUM for Unwarranted failures
FCSUMW - Fixed Cost SUM for Warranted failures
FPRCNT - PerCeNT of Fixed costs paid to contractor
IGO - Integer variable for computed GO TO for menu
IN - unit to retrieve saved data from
IOUT - unit to save data on
ITP - Index over Time Periods
J - Used as index over cost elements
JCOST - labels of cost elements
JHEAD - user's header lines
LENGTH - LENGTH of warranty in time periods
LMENU - Logical variable to indicate MENU use
LTERM - Logical variable to indicate input from TERMinal
MAXYR - MAXimum number of YeaRs allowed (INTEGER VARIABLE)
MAXYRS - MAXimum number of YeaRS allowed (PARAMETER)
MLIFE - Multi-year economic LIFE
MTBF - Mean Time Between Failures - for DO loop that varies MTBFs.
MYRWP - Multi-YeaR Warranty Period
NDYRS - Number of Delivery YeaRS
NLIFE - Economic LIFE
NSTEPS - Number of STEPS or iterations of MTBF loop.
NULL - Input variable used to halt execution while user clears screen
PCOSTS - Post warranty COSTS

PERCNT - PERCeNT of failures that are inherent & validly claimed

RMTBF - a Real variable MTBF; varied in MTBF loop

SAVFAC - SAVed escalation and discounting FACTOR for post warranty fixed costs

SPARES - a vector containing SPARES delivered each year

STEP - increment used in MTBF loop

TOTAL - TOTAL number of systems delivered

UCOSTS - Unwarranted failure COSTS

USAGE - a vector of USAGE hours per system per time period.

UWF - a vector containing UnWarranted Failures each time period

VCNTRC - Variable Costs (sum paid to CoNTRaCtor)

VCSUMN - Variable Costs SUM for No warranty alternative

VCSUMP - Variable Cost SUM for Post warranty failures

VCSUMU - Variable Costs SUM for Unwarranted failures

VCSUMW - Variable Cost SUM for Warranted failures

VEC - temporary vector; dimensioned (2)

VEC3 - temporary vector; dimensioned (3)

VEC4 - temporary vector; dimensioned (4)

VPRCNT - PeRCeNT of Variable costs paid to contractor

WCOSTS - COSTS for Warranted failures

WF - vector of Warranted Failures by time period

WFAC - MTBF FACTORs for Warranty alternative

WHRS - Warranty length in usage HouRS

WMTBF - Modified MTBF

APPENDIX B - METHODOLOGY DETAILED

This section contains a detailed explanation of the calculations performed by the program. This will help subsequent computer programmers understand and maintain the program, as well as answer user's questions about how various quantities are actually calculated. Variable names are included here to aid maintenance programmers.

There is an important difference between single "year" (or other time period) contracts and multiyear (multi-time-period) contracts. A single "year" contract has all the systems delivered the first time period; a multiyear contract has systems delivered over 2 or more time periods. This has an interaction with economic life, which is specified in time periods. The program must compare the warranty and no warranty alternatives over a sufficient period of time to include the economic life of the last delivered systems. Hence, economic life as specified by the user (i.e., for one system) is the variable NLIFE, but the evaluation is over the period of time specified by MLIFE (for Multiyear economic LIFE). The relationship between NLIFE and MLIFE is $MLIFE = NLIFE + NDYRS - 1$, where NDYRS is the number of periods deliveries are made (i.e., the time period the last system is delivered).

Because some input data (MTBF factors, escalation indices and usage hours) are entered for MLIFE periods, and the menu allows the user to change NLIFE and NDYRS, the first step in the analysis is a check to make sure that there is sufficient data (MTBF factors, escalation indices and usage hours) to do the analysis.

In a similar manner, the warranty length in time periods (LENGTH) is extended by the use of multiyear contracts to $MYRWP = LENGTH + NDYRS - 1$. (MYRWP is an acronym for MultiYeaR Warranty Period.).

The next step of the analysis is to sum the fixed costs and variable costs over the cost elements. Because there are fixed costs and variable costs for warranted repairs, nonwarranted repairs during the warranty period, nonwarranted repairs after the warranty expires, and repairs under the no warranty alternative, there are 4 fixed cost sums, and 4 variable cost sums:

FCSUMW - sum of fixed costs for warranted repairs

VCSUMW - sum of variable costs for warranted repairs

FCSUMU - sum of fixed costs for unwarranted repairs during the warranty period

VCSUMU - sum of variable costs for unwarranted repairs during the warranty period

FCSUMP - sum of fixed costs for post-warranty repairs

VCSUMP - sum of variable costs for post-warranty repairs

FCSUMN - sum of fixed costs for no warranty case

VCSUMN - sum of variable costs for no warranty case

In addition, it is helpful to have the summed fixed and variable costs paid to the contractor (FCNTRC and VCNTRC). These are found by summing only the percentages of the fixed and variable costs for warranted repairs that are paid to the contractor.

The price of the warranty is just fixed cost (FCNTRC) plus variable cost (VCNTRC) times the expected number of warranted failures; hence, the next step is to calculate the expected number of warranted failures. This is done by two subroutines, EXPO and SUMF.

EXPO calculates the expected number of warranted and unwarranted failures per time period, for MLIFE time periods (Arrays WF and UWF, respectively). While the expected number of failures is, generally, just the hours the

systems are used divided by the MTBF, there are several complications that EXPO must consider. These are (1) the delivery schedule, (2) the need to classify the failures as warranted or unwarranted, and (3) the use of spares which are still under warranty after the warranty on the original equipment has expired. EXPO takes the delivery schedule into account by treating the deliveries in each time period, along with their spares, separately. Failures due to the systems and spares delivered in the first time period are calculated and stored in the arrays WF and UWF; then the failures due to the systems and spares delivered in the second time period are calculated and added into the arrays WF and UWF; this procedure continues until the last delivered systems and spares are processed. This "DO LOOP" over all deliveries is the "outer loop" of the algorithm in EXPO. The "inner loop" is over the economic life of the systems being considered, i.e., those delivered in a specific time period. The warranty on both systems and spares is in effect for a specified period of time (LENGTH), or until the clock on the system or spare reaches the warranted hours (WHRS) limit, whichever occurs first. To classify failures as warranted or unwarranted, two IF statements are required, one to compare the AGE of the systems to the warranty LENGTH, another to compare the CLOCK to the warranted hours (WHRS).

The third complication (use of spares after warranty on original systems expires) occurs only when the clock on the original systems exceeds the warranted hours before the end of the *i*th time period (ITP), but the *i*th time period is within the warranty period LENGTH. In this case it is possible to put the spares to use and their usage would be warranted. Two situations arise:

(1) The clocks on the original systems pass the warranty limit (WHRS) during the i th time period, and

(2) The clocks on the original systems have already passed the warranty limit before the i th time period began.

In the first case, the original systems would be under warranty for a fraction of the i th time period, and the spares for the remainder of the i th time period (provided the usage time in the remaining part of the i th period doesn't exceed the warranted hours limit WHRS). In the second case, only the spares will be warranted, either for their entire usage during the time period, or until their clocks exceed the warranty hours limit (note that the warranty hours limit is essentially doubled by putting on the spares when the clocks on the original equipment reach the warranty hours limit).

After the arrays containing warranted failures (WF) and unwarranted failures (UWF) have been filled by summing the failures for all systems and spares in the delivery schedule, the final step in EXPO is to reduce the number of warranted failures to the percent of potential warranted failures that are inherent, validly claimed failures. This simply transfers a certain percentage of the failures in the array WF to the array UWF.

Subroutine SUMF has the arrays WF and UWF as input, and sums the failures over the time periods. The unwarranted failures are summed separately for the warranty period and the post-warranty period. The summations are done both with discounting and without discounting. Normally discounting and escalation are performed on costs, not failures. In this warranty application, the costs in a time period are just the variable costs times the number of failures in the time period. Because the variable costs are the same for all time

periods, variable costs can be pulled out of the summation (leaving failures, discount factor, and escalation factor within the summation). Then total costs can be calculated later by $\text{Fixed Costs} + (\text{Variable Costs} \times \text{Discounted Failures})$. Note that fixed costs are not discounted by this method. They are however escalated by the first period escalation factor. The only fixed costs that are discounted are the fixed costs for repairs during the post-warranty period. Hence, a combined factor for discounting and escalation for the first year of the post warranty period is returned by SUMF for future use.

The discounting factor for a time period is the midperiod factor obtained by averaging the factor for the end of the period and the factor for the end of the previous period. To sum up SUMF, it calculates these quantities

EWF - expected warranted failures (escalated but not discounted)

EUW - expected unwarranted failures (during the warranty period)

EPWF - expected post-warranty failures (necessarily unwarranted)

DEWF - discounted expected warranted failures (escalated & discounted)

DEUW - discounted expected unwarranted failures

DEPWF - discounted expected post-warranty failures.

WNUM - expected number of warranted failures (no discounting or escalation)

Now that the expected number of warranted failures has been calculated (using, of course, the warranted MTBF and the MTBF factors for the warranty case), the program is ready to analyze the warranty "should cost" price. This analysis is part one of the output for the user and consist of two subparts: (1) a breakout of the warranty price by cost element, (2) and determination of risk due to random fluctuations in the number of warranted failures. Subroutine PART1 prints the expected number of warranted failures, and calls

subroutines BRKOUT (breakout) and DIST (distribution) to get these two subparts. BRKOUT calculates, by cost element, the amount paid to the contractor and the government's in-house costs for a specific number of failures (the expected number of warranted failures is used to calculate the warranty price). In doing these calculations, no discounting is applied either to the amount paid to the contractor, or to the government's in-house costs. The total amount paid to the contractor is returned by BRKOUT as the PRICE of the warranty. Subroutine PART1 prints this price as the warranty price, and returns it to the main program.

Subroutine DIST calculates the distribution of warranted failures, and both the contractor cost and government in-house cost, from about the 5th percentile to about the 95th percentile. If the expected number of failures is greater than 50, the Gaussian or normal distribution, is used to approximate the distribution of the number of failures; in this case the percentiles will appear as exactly 5, 10, 15, 20, ..., 95 but the number of failures has been rounded to the nearest integer. For a smaller number of expected failures, the actual distribution of failures (which is Poisson) is used; in this case the percentiles will not be exactly 5, 10, 15, 20, etc. The algorithm searches for the smallest integer (i.e., number of failures) such that the percentile is at least 5, then at least 10, etc. As in the breakout by cost element (BRKOUT), no discounting is applied. At this point, the program (subroutine PART1) allows the user to obtain a cost-breakout for a specific number of failures. However, the warranty price (used in part 2 of the analysis) remains fixed at the contractor charge to fix the expected number of warranted failures.

Part 2 of the analysis compares the warranty and no warranty alternatives.

This is done over a range of MTBF values requested by the user. The analysis is done by the main program, rather than a separate subroutine. The first step is merely to print out the user's header, the part 2 header, and the warranty price, both with and without any exclusions used when comparing the warranty and no warranty alternatives. The warranty price, without any exclusions, is the amount actually paid to the contractor to fix all warranted failures. The user's exclusions represent, for example, pro-rating of one-time costs in acquiring a warranty for the first time. This assumes that a warranty will also be acquired on future years' production contracts, so that the spreading of those one-time costs is appropriate. The exclusion due to discounting is based on the following: the cost of the warranty (for comparison purposes) is the warranty price less the user's exclusions. However it is not paid up front (at beginning of first time period). Rather it is paid as the systems are delivered. Hence the warranty price (less exclusions) is discounted as if the delivery schedule is the payment schedule. The second step is to set up the DO Loop for the MTBF values. Within this DO Loop, the costs for the warranty alternative are calculated and printed, and then the costs for the no warranty alternative are calculated and printed. And that, in short, is part two of the program's output. Detail on the calculation of these costs follows.

To calculate costs for the warranty alternative, subroutine EXPO is called (with MTBF factors for the warranty case) to obtain the number of warranted and nonwarranted failures for each time period; then subroutine SUMF sums the failures over time periods. The calculation of costs is done by subroutine WLINE as follows. The warranty price minus the exclusions is used for comparison purposes as the amount the government pays the contractor to get

all warranted failures fixed. The government must also pay its in-house costs to get the warranted failures fixed. This amount is calculated as the fixed costs for warranted repairs minus the part of these fixed costs paid to the contractor (which is already included in the warranty price) plus the number of warranted failures times the variable costs for these failures (calculated as the variable costs for warranted failures minus the part of these variable costs paid to the contractor). The discounted figures are used for the variable costs, because the government bears these in-house costs over time, i.e., as they occur. No discounting is applied to the in-house fixed costs, as the fixed costs are assumed to be paid at time zero. In addition to these in-house costs for warranted repairs, the government must also repair the nonwarranted failures during the warranty period. The cost for this is the fixed cost for nonwarranted repairs during the warranty period plus the variable costs for nonwarranted repairs during the warranty period times the (discounted) number of unwarranted failures during the warranty period. These two costs (in-house for warranted failures and total for nonwarranted failures during the warranty period) added together give the "other" column of the output for the warranty case.

Costs for the post-warranty period (the next column of the line output for the warranty case) are calculated as the (discounted) fixed costs for the post-warranty period repairs plus the (discounted) variable costs for post-warranty period repairs. Finally, all three costs (warranty price less exclusions, "other," and post-warranty costs) added yield the total for the warranty alternative. (All costs have been escalated by the factor for the time period in which they occur.)

To calculate costs for the no warranty alternative, subroutine EXPO is

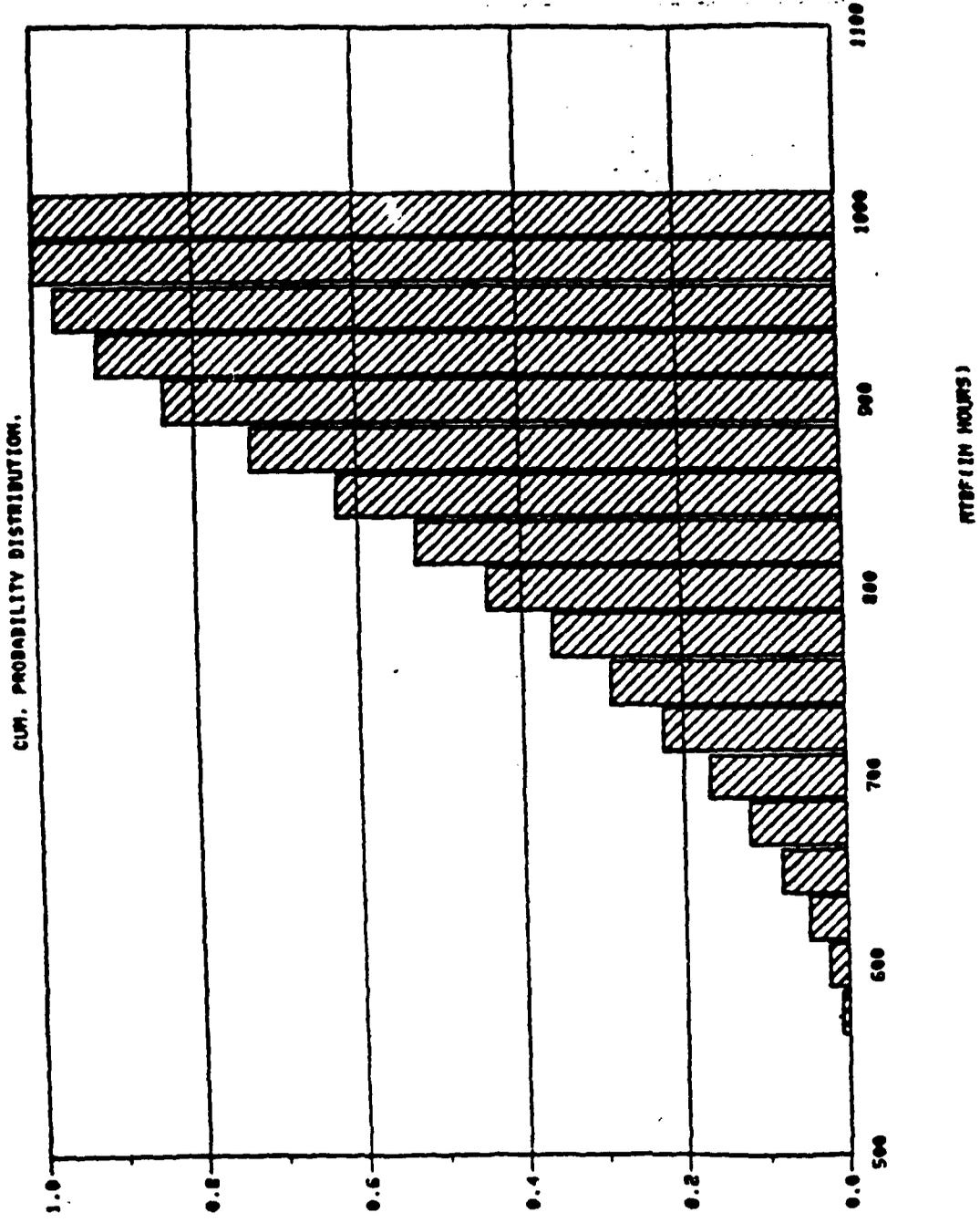
called again, but this time with the MTBF factors for the no warranty alternative. The subroutine SUMF adds up the failures over time periods, and subroutine NWLINE calculates the costs for the no warranty line of output. The amount paid to the contractor is of course, nonexistent so that the "other" column has all costs for the "warranty period". This cost is calculated as the fixed costs for the no warranty alternative (assumed to be paid up front and hence not discounted) plus the variable costs for the no warranty alternative times the total number of failures during the warranty period (discounted).

The costs for the "post-warranty" period under the no warranty alternative is just the variable costs for the no warranty alternative times the number of failures (discounted) during the post warranty period. Adding the costs for the "other" column and the post warranty column gives the total for the no warranty alternative. Again, all costs (fixed and variable) have been escalated.

APPENDIX C - MAINFRAME GRAPHICS



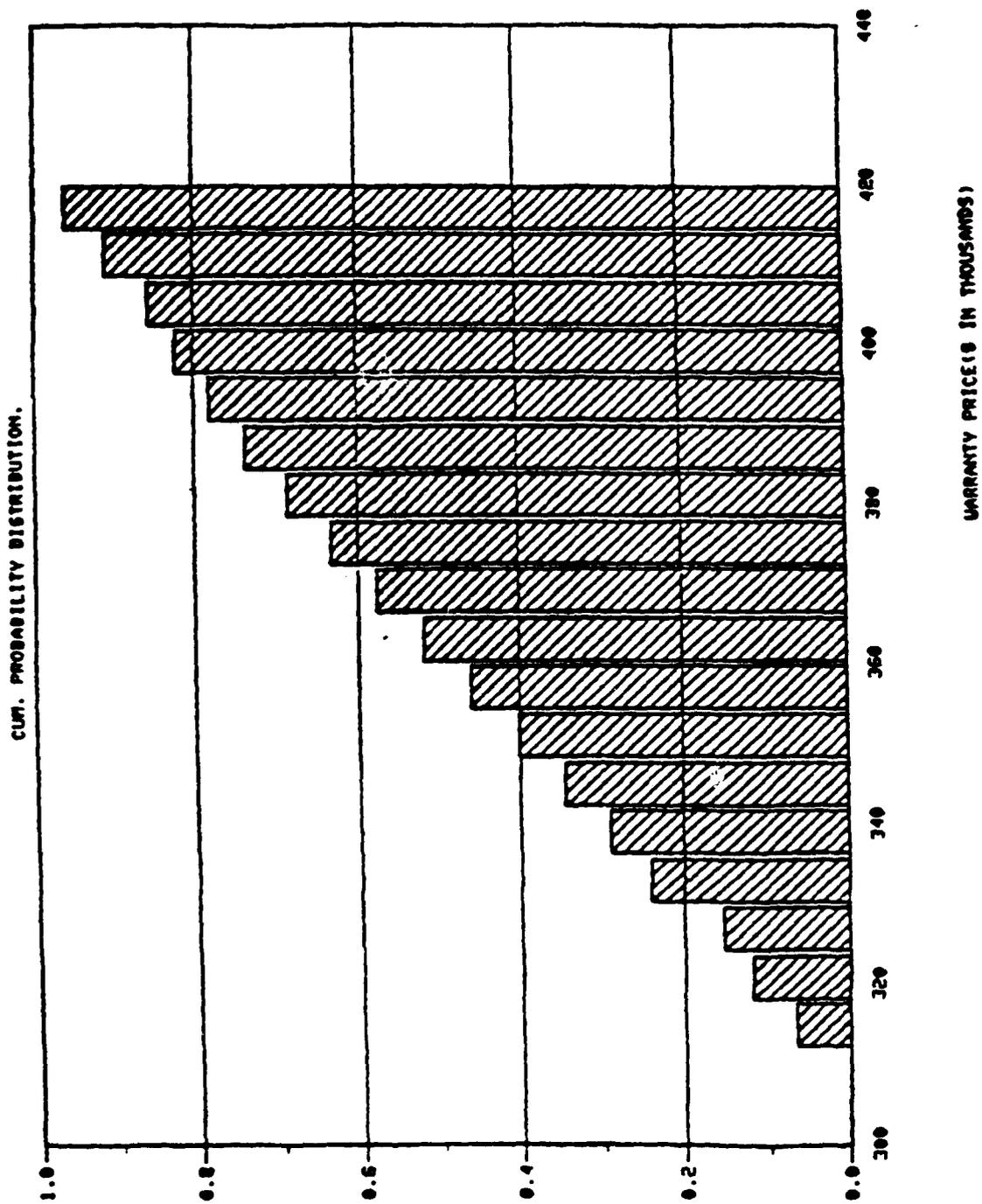
CHART #1



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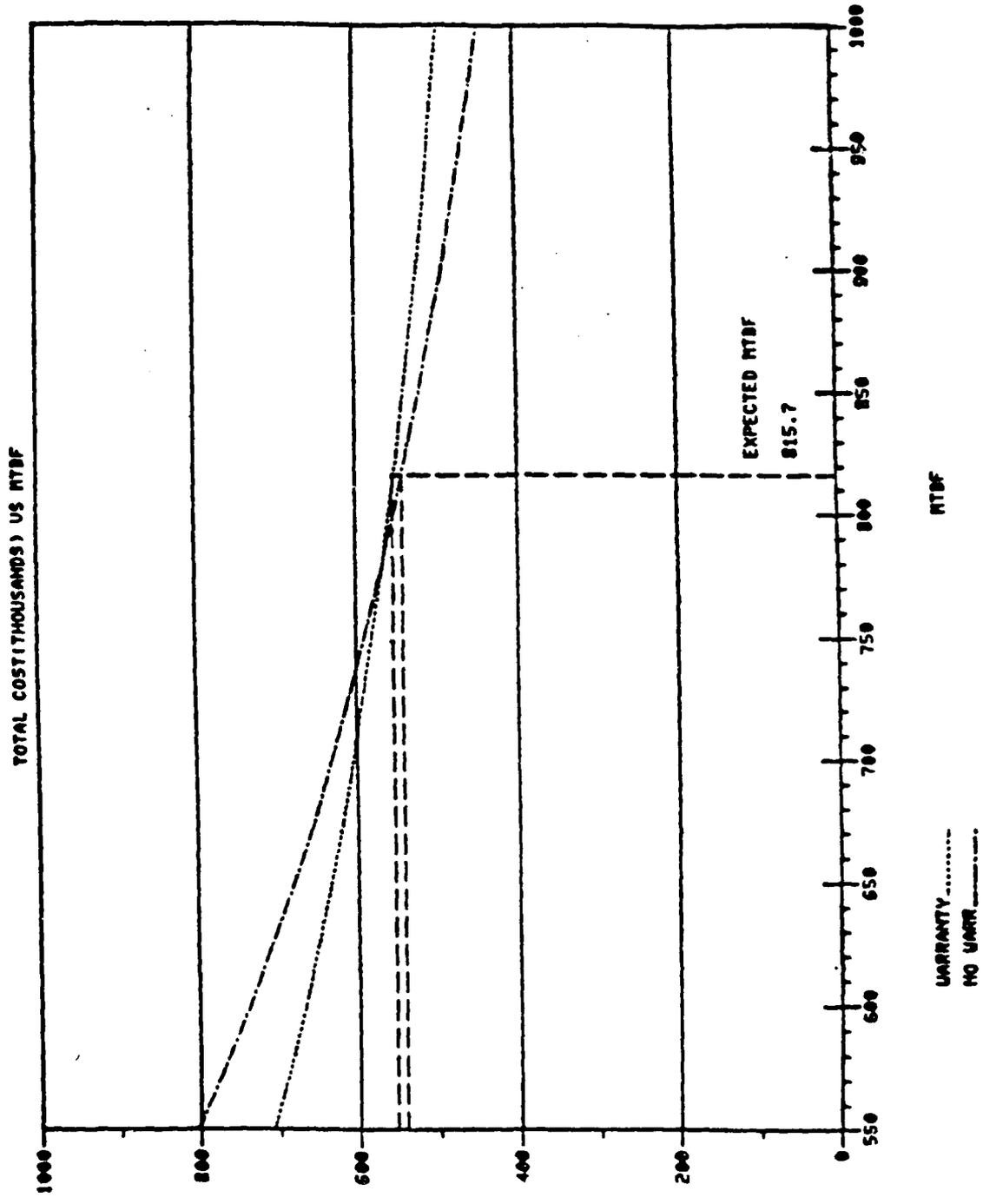
USE AREA

CHART #
C-3



002 2208

CHART #3



4509

CHART #4
C-5

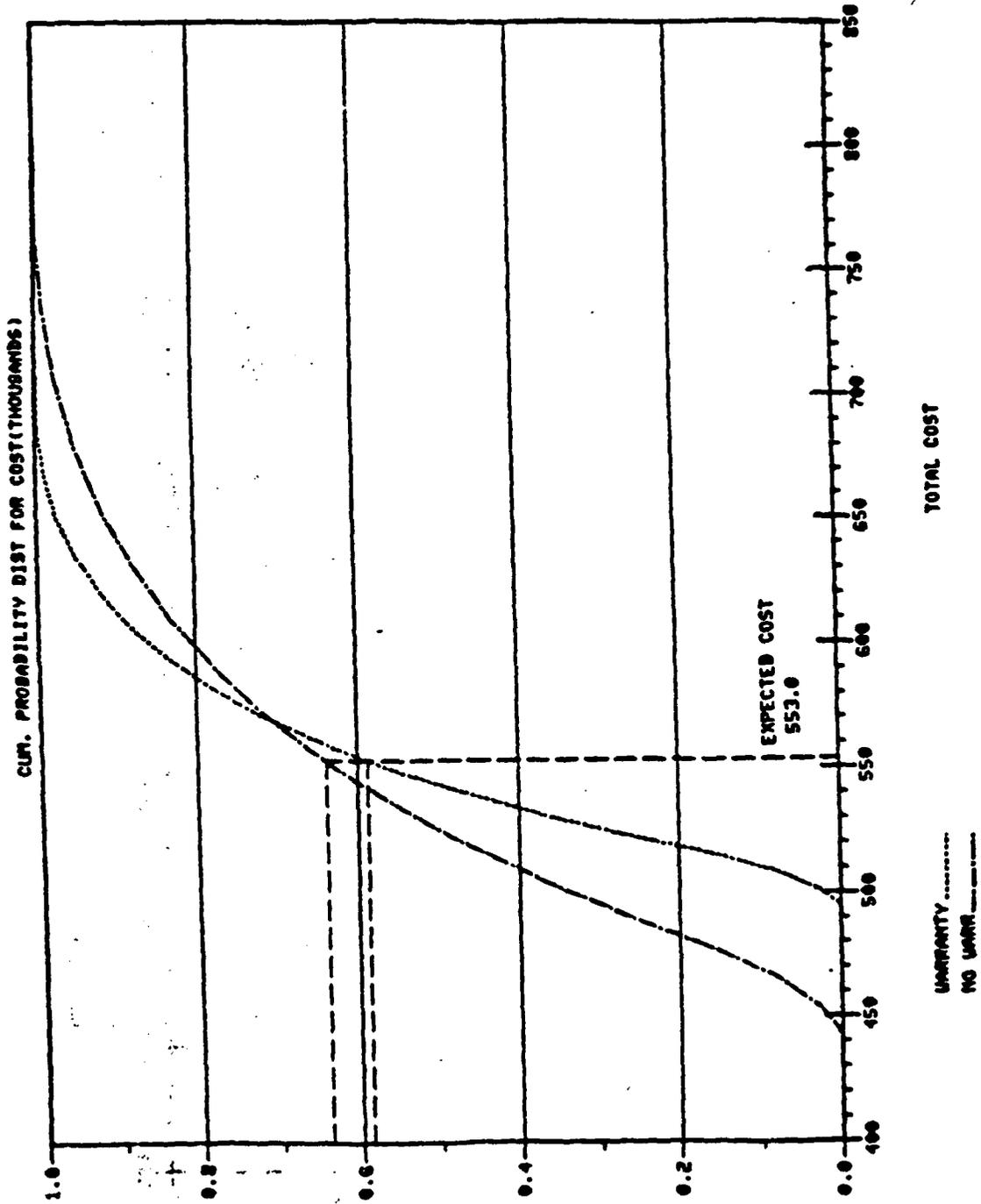


CHART #5

C-6

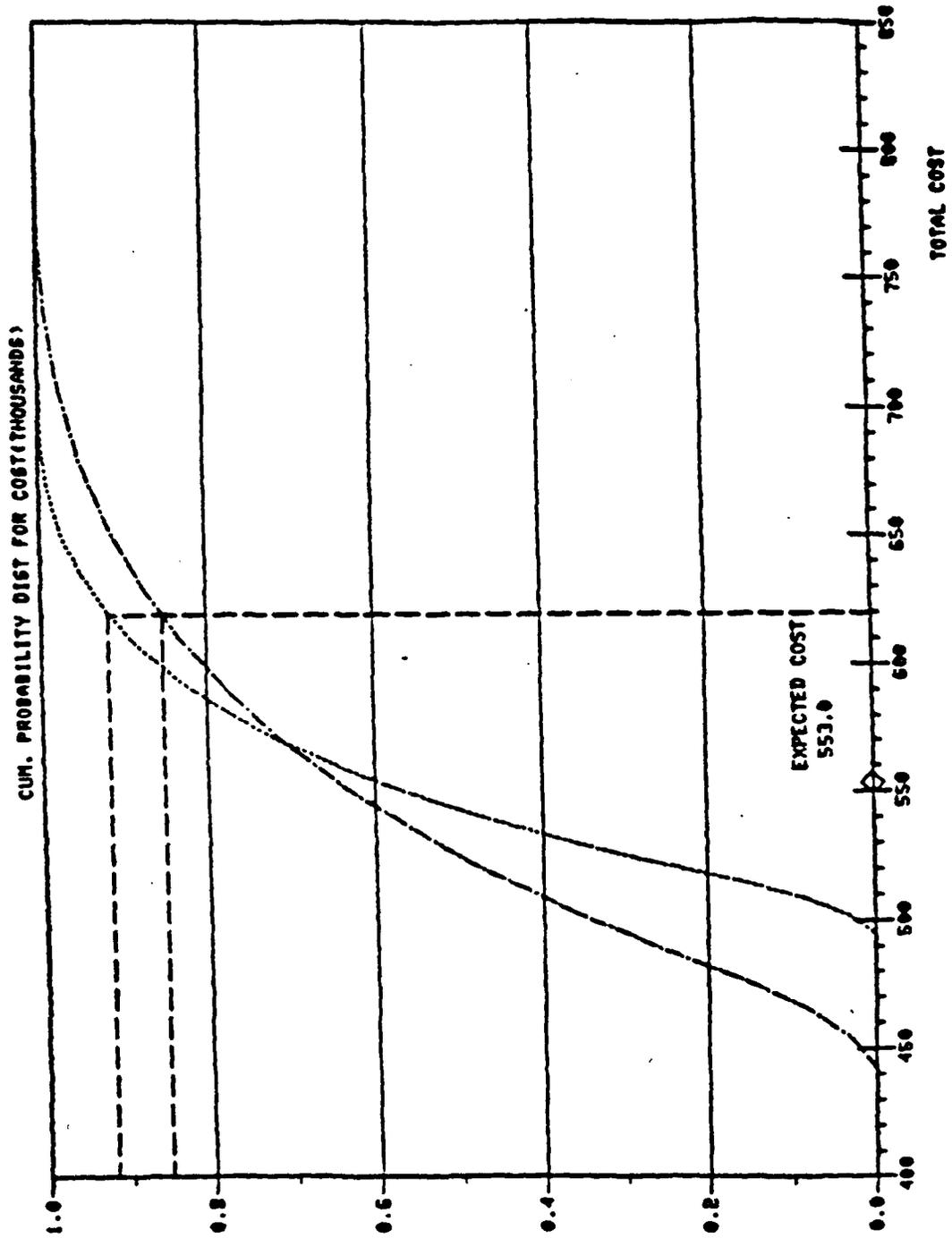


CHART #6
C-7

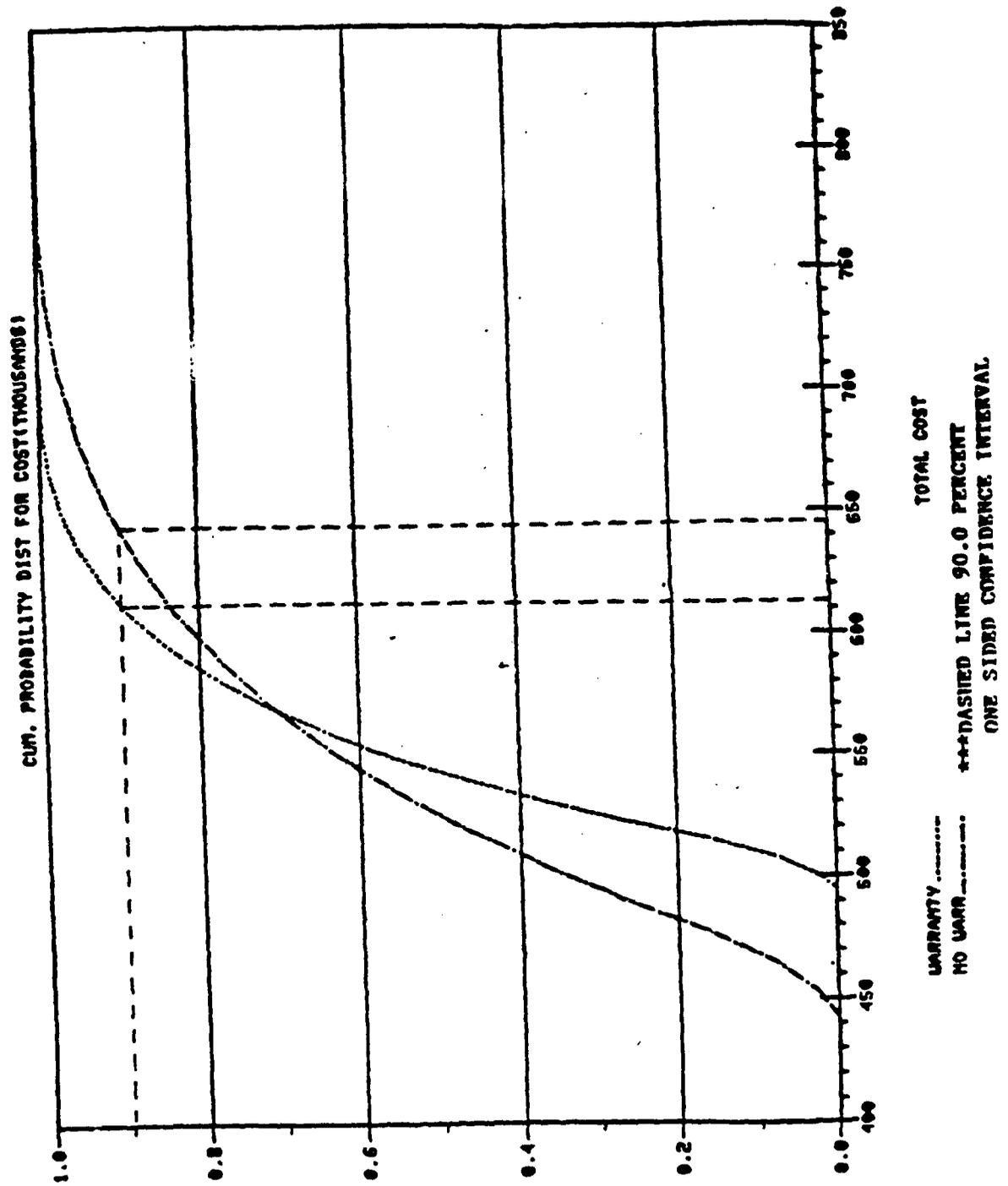


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C-8

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88