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EX POST FACTO RELIABILITY CONSIDERATIONS

by

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ABSTRACT. This report describes the basic considerations of an effective and comparatively low-cost reliability program for an exemplary airborne missile. It covers cases where expediency precludes full reliability considerations prior to production go-ahead and where the manufacturer has accepted a contractual requirement to demonstrate reliability at the systems level. It apportions reliability requirements, delineates important procedures that will provide worthwhile reliability assurance at reasonable cost, and fits the program into the quality assurance provisions of a typical manufacturer oriented to military contracts. The program is intended for missiles that are produced in small quantities.

U.S. NAVAL ORDNANCE TEST STATION

China Lake, California

October 1965

U. S. NAVAL ORDNANCE TEST STATION

AN ACTIVITY OF THE BUREAU OF NAVAL WEAPONS

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FOREWORD

This report expands the highlights of a reliability indoctrination lecture delivered to members of the Philco Communications and Electronics Division technical staff in Philadelphia, Pa., on 30 June 1964. It is released for use with other reliability reference data. Expansion of the included procedures and concepts can provide higher reliability than is currently being achieved by some programs in which costs are greater by an order of magnitude.

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INTRODUCTION

The implementation of an effective reliability program is as much an art as it is a science. The existence of a formal program does not always provide assurance that the reliability of a system or unit will be satisfactory. There have been instances where implemented disciplines have resulted in serious production slowdowns, and still other instances where disruption of product flow caused an actual net decrease in reliability. A worthwhile ex post facto reliability program must provide short cuts to worthwhile reliability and also should include applicable value engineering of a self-disciplinary nature. Such a program should be used only when it is too late or too expensive to include full reliability considerations at or near the conceptual stage.

There is a wide variation in industry as to the degree of reliability implementation used on the various programs now in existence. As technical requirements become more and more complex, vendors with established reputations can suddenly drop far behind in the implementation of the minimal considerations necessary to maintain a required reliability. Some vendors are refusing to keep pace not only with the complexities of modern reliability but also with today's stringent quality control requirements, and in certain cases are forcing procurement agencies to accept components of poorer quality than desired. Still other vendors believe that they are producing reliable components, but lack the over-all technical capability to evaluate their products objectively. This paper calls attention to new, successful procedures such as Machining Reliability Control (MRC) currently in use at Parker Aircraft Co.

An effective ex post facto reliability program must consider practical requirements, vendor capabilities, costs, schedules, and reliability value. (The term "reliability value" indicates value engineering considerations with respect to reliability.) Should the design assurance program prove to be inadequate, additional design assurance must be conducted in areas that prove to be troublesome. This report presents an exemplary program as a basic reliability philosophy to be considered, expanded, and improved.

BASIC RELIABILITY CONSIDERATIONS

DEFINITION OF "RELIABILITY"

The term "reliability," when used herein, is based upon standard present-day techniques for computing the "probability of survival." It is mathematically expressed in the following simplified equation by the term "R":

$$R = e^{-\lambda t} \tag{1}$$

where e = the Naperian logarithm base
λ = failure rate in failures per hour
t = operating time in hours

Reliability, then, is the probability that a device or system, operating within discrete performance limits in a specified environment, will survive for a given time. The actual mission reliability of a missile is the number of successful missions divided by the total number of missions launched. Failure rates can vary with time, and readers are referred to papers on the Weibull Distribution for a deeper analysis.

RELIABILITY APPORTIONMENT

The reliability diagram of an exemplary missile is depicted in Fig. 1. Calculations for examples used in this publication will be based upon this standard configuration, and reliability considerations can be transferred to a specific missile by the application of simple adaptive techniques.

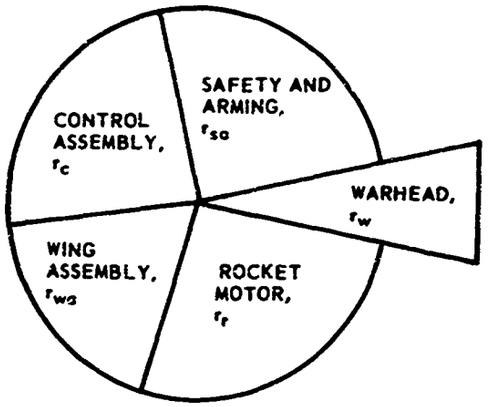

FIG. 1. Reliability Diagram, Standard Airborne Missile.

For a reliability apportionment, experience and judgment (as shown in MIL-STD-105) are used to obtain an estimate of the reliability requirements for various sections or subassemblies to provide the over-all net reliability on a feasible basis. Although reliability predictions are vulnerable to challenge, use of prediction data for comparisons of performance or achievement is invaluable.

For the block diagram of Fig. 1, the over-all mission reliability (the intercept reliability or probability of successful intercept) is determined by the following formula:

$$R_i = r_r \cdot r_{wa} \cdot r_c \cdot r_{sa} \cdot r_w \qquad (2)$$

where R_i = intercept reliability (reliability during intercept phase of mission)
r_r = reliability of the rocket motor
r_{wa} = reliability of the wing assembly
r_c = reliability of the control assembly
r_{sa} = reliability of safety and arming devices
r_w = reliability of the warhead

Each subassembly of the typical missile will have certain basic reliability capabilities. Thorough analysis of the parts in, and stresses of, each subassembly will yield a basic component reliability. The product of these component reliabilities will indicate a basic reliability capability for the entire assembly. Comparison of the basic reliability capability with the desired reliability will show that the subassembly must be designed and built to subnormal, normal, or rigid requirements. The originally indicated reliability can then be modified to reflect the expected reliability as a result of the new standard for design and construction. This process is known as reliability apportionment. For the typical airborne missile under consideration, reliability can be apportioned as follows:

Subassembly	*Reliability per flight*		*Probability of failure, Q, per flight*
Rocket motor	0.95		0.05
Wing assembly	0.97		0.03
Control assembly	0.90		0.10
Safety and arming	0.98		0.02
Warhead	0.99		0.01
Product	0.80	Sum	0.21

It should be noted that 1.00 - 0.80 is not equal to 0.21. Two significant figures are used in lieu of such terms as 0.7998736 to assure concentration on the philosophy.

APPORTIONED LABORATORY FAILURE RATES

MIL-STD-756A calls out an operational factor of 80 for missiles.[1] This means that a typical missile in flight will fail 80 times as frequently as it would under laboratory test conditions. For the rocket motor, then, the probability of failure during laboratory test conditions must be 1/80 times the probability of failure, Q, per flight, or 0.000625, during a time equal to the time of flight. Failure rates usually are expressed in multiples of an hour. A 1-minute flight is typical of an airborne missile, and the failure rate of the rocket motor per laboratory hour will be 60 times that for a laboratory minute, or 0.0375. Similar calculations for the control assembly yield an allowable failure rate of 0.075 per laboratory hour.

A typical control assembly will include an input section, an electronics section, a servo section, and an output section. The laboratory failure rate for the control assembly can be apportioned among its various sections as listed below:

Section	*R/hour (lab rate)*[2]		*Q/hour (lab rate)*[3]
Input	0.970		0.030
Electronics	0.970		0.030
Servo	0.990		0.010
Output	0.995		0.005
Product	0.925	Sum	0.075

The laboratory failure rate can be alternately expressed as follows:

Section	*Q/hour*	*Q', %/10³ hours*	*Q*, θ*/10⁶ hours*[4]	*MTBF, hours*[5]
Input	0.030	3,000	30,000	33
Electronics	0.030	3,000	30,000	33
Servo	0.010	1,000	10,000	100
Output	0.005	500	5,000	200

[1] The multiplier, 80, may not be in accord with other indices familiar to the reader. However, the use of MIL-STD-756A, as a reliability reference, is mandatory for BuWeps considerations.

[2] R/hour is the probability of survival for 1 hour.

[3] Q/hour is the probability of failure in 1 hour.

[4] $\theta^*/10^6$ hours is failures per million hours.

[5] MTBF is the mean time between failures (with replacement upon failure).

SUBASSEMBLY LABORATORY FAILURE RATE APPORTIONMENT

The term "%/10^3 hours" is the usual method of presentation of failure rates at or near the component level (MIL-217). Further apportionment can be made for each section. For instance, the laboratory failure rate for subassemblies of an exemplary electronics section can be apportioned as follows:

Input section subassembly	*Q', %/10^3 hours (lab rate)*
Sensing	300
Amplifier	400
Servo amplifier	500
Servo drive	500
Control	500
Cables and miscellaneous	800
Total	3,000%/10^3 hours

The sensing (or equivalent) subassembly also can be apportioned. A 100-part sensing unit would be allowed an average basic failure rate of 3% per 1,000 hours per part. The allowable basic failure rate includes mission and other operating and correction factors, which will be discussed later.

Typical failure rates for a few electromechanical components are listed below (failure rates are extracted from MIL-217):

Item	*Failure rate/10^3 hours*
Subminiature tube	1.33
Diode	0.04
Transistor	0.22
Microwave diode	7.00
Resistor	0.06
Capacitor	0.08
20-pin connector	0.32
Relay	0.2
Small motor	0.8
Solder joints (10 considered as one part)	0.03
Total	10.08
Average	1.008

The above rates will vary with mission, stress, application, and manufacturer (MIL-217). This example indicates that the design goal intercept reliability is achievable for the evaluated design concept, in the case of a 100-component design with 10 each of the listed components, wherein 10 each of a 10-component group totals 100 components. The allowable average for a 100-component design is 3% per 1,000 hours. The average of the typical components above is 1.008% per 1,000 hours. The design is feasible, since 1.008 is less than 3.

RELIABILITY IMPLEMENTATION

ACHIEVEMENT OF RELIABILITY

Reliability can be achieved only by specific attention to important details from the conception of to the use of the product. Perfection is not required, yet a good reliability program may

be described as one of "specific tolerance to imperfection." There are hundreds of articles and manuals describing methods of achieving reliability. Most of the accepted methods are either in use or are extremely expensive; most manufacturers use reliability programs they consider to be the most practical for the existing situation. It is important that one man, or one group, in a company serve as the assembler, interpreter, and referee of reliability data.

Several important areas of reliability control can be used by a conscientious manufacturer to exert sufficient leverage to assure achieving a reasonably high reliability without the usual staggering costs of such an accomplishment. These areas are as follows:

1. Individual responsibility
2. Receiving inspection
3. Special attention to qualification and performance at the module level
4. Failure reporting and analysis

The term "individual responsibility" is receiving considerable attention at Parker Aircraft Co., at the Martin Co. and its subcontractors, and elsewhere. This term includes and depends upon pride of accomplishment, team spirit, reasonably conscientious workmanship, and assumption of responsibility at the lowest practical levels. It is difficult to express individual responsibility in mathematical terms, but this difficulty is no excuse for leaving out one of the prime ingredients used by successful manufacturers of reliable equipment.

The term "receiving inspection" includes sampling of all incoming parts and in-house-produced parts, as well as vendor control and compilation of important quality statistics. Insofar as is practicable, parts of known or guaranteed reliability should be purchased. Some manufacturers are producing parts with known or certified reliabilities. For instance, Motorola manufactures semiconductors to various standards of reliability. For a small premium in cost, Motorola Inc. will supply certain basic types of MIL-Spec semiconductors subjected to additional processes such as burn-in, screening, and special inspections, and will furnish generic or lot data. The savings in subsequent testing, troubleshooting, and reworking seem to be well worth the additional cost premium. The purchase of parts from alert manufacturers will help to achieve high reliability at low cost.

It is to be noted that a failure rate of 3% per 1,000 hours is allowable for a typical part in the conceptual missile analyzed in this report. A rejection rate of 0.003% is then applicable to an individual part which is under test for 1 hour, and a rate of 0.03% for a part tested for 6 minutes. Most vendor quality control programs are based on an Acceptable Quality Level (AQL) of 1%, and are almost worthless insofar as assuring rejection rates of 0.003% per hour of test, or less.

A 1% AQL vendor control program can be of value when used as a screening mechanism, provided it is recognized exactly as such. Contractual means can and must be used to stop the purchase of parts from vendors whenever the AQL reaches or passes 1% defective. For parts with an AQL below 1% and yet above 0.1%, 100% sampling should be accomplished, preferably under overstressed conditions. Parts with AQL's of 0.1% and lower can be accepted, on the basis that subsequent tests will result in sufficient disclosures of unacceptable parts to preclude serious compromise of the reliability goals.

As stated at the beginning of this section, the module (or equivalent) level is the optimum level at which strict attention to operational and qualification details must be provided. Comprehensive tests at this level will provide early feedback on bad lots of parts, and at the same time will accommodate the above 1% AQL level for the testing of parts. Good modules make good systems, and the early rejection of marginal modules will preclude large amounts of rework at

later stages. Thus, concentration of effort at the module level will result in savings in the testing of individual parts, savings in troubleshooting and rework time, and achievement of the highest possible reliability within the available budget.

The term "failure reporting and analysis" includes the standard procedures for such action, and also a check on the reliability demonstrated during assembly and tests versus the design goal reliability. Here again, the costs for a normal program of documentation and investigation are staggering. A deductive program can accomplish the same results at a fraction of the cost of an inductive program, and is explained below.

Consider the case of the manufacturer of 1,000 units of the electronics section described earlier. The required reliability under laboratory conditions is 0.970. For a production lot of 1,000 units the manufacturer should expect 30 failures for each hour of test. By determining the average test time for a unit, the total number of allowable failures for the contract can easily be determined. Comparison of the total failures during the contract with the allowable number will provide a ball-park go/no-go indication as to whether or not the reliability requirements have been met. The normal method of logging operational hours will provide a more accurate figure, but at many times the cost of the deductive method.

Similarly, the servo section is allowed a laboratory failure rate of 0.010 per hour. For 1,000 units, 10 failures are allowable for each hour of test. If average system and subsystem test time is 5 hours, then 50 failures are allowable under the contract. Should the actual number of failures be, for instance, 100 when the contract is 50% complete, then a serious problem is indicated. Under such circumstances ordinary methods of failure analysis are inadequate, and improved degrees of corrective action are in order. It is imperative that any and all data, which indicate a possibility of unsatisfactory reliability, be analyzed and processed on an expedited basis. Such action will determine the success or failure of an ex post facto reliability program.

Questions have been asked concerning the reliability of MIL-Spec parts. In general, MIL-Spec parts are not guaranteed to meet the above high reliability requirements, and the three basic areas of reliability control must also be implemented for MIL-Spec parts. The required corrective action for a part would be notification of the appropriate procuring agency concerning excessive failure rates. Follow-up corrective action for unsatisfactory parts would consist of informal notification of the nature of unsatisfactory operation to the parts manufacturer, and/or to the appropriate procurement agency. MIL-Spec parts should be subjected to the same receiving inspections and screening inspections as are ordinary parts whenever there is a question as to the degree of reliability of the parts. The corrective action for the subassembly would be derating, redesign, change of material or material specifications, eventual removal of an unsatisfactory vendor from the Qualified Products List (QPL), or the incorporation of Specification Control Drawings to assure parts of better quality. The minimum derating for any redesigned stage or assembly should be 50% if practicable.

RELIABILITY PREDICTION

Reliability predictions are becoming a normal requirement for military weapon systems. MIL-STD-756A is the current standard for reliability predictions.

The reliability of a subassembly is the product of the reliability of the individual parts. Thus, for parts installed in a series configuration:

$$R_s = R_1 \cdot R_2 \cdot R_3 \cdot R_4 \cdot R_5 \cdot \ldots \cdot R_n \qquad (3)$$

where R_s = the over-all reliability of a subassembly from the logistics through the firing phases

R_n = the over-all reliability of part n

Under today's usage, the reliability of a part depends upon stress ratio, environment, storage, application, manufacturing skill, and a host of other functions. In accordance with MIL-STD-756A, R_n can be calculated by:

$$R_n = r_{st} \cdot r_{PF} \cdot r_F \cdot r_I \tag{4}$$

where r_{st} - reliability during storage

r_{PF} - reliability during preflight test

r_F = reliability during airborne flight

r_I = reliability during intercept mission

The value of r_{st} can be calculated from the basic reliability formula:

$$R = e^{-\lambda t} \tag{1}$$

Specifically:

$$R_{st} = e^{-\lambda_{st} t_{st}} \tag{5}$$

where λ_{st} = storage failure rate in failures per 1,000 hours

t_{st} = storage time in thousands of hours

There is a scarcity of available data on storage failure rates. When specific data are unavailable, the storage failure rate under controlled environment may be postulated by multiplying the basic rate for 50% stress conditions by 0.001. Thus

$$\lambda_{st} = 0.001\lambda_L \tag{6}$$

where λ_L = basic laboratory failure rate under conditions of 50% stress.

The above calculation could be off 10% or more, but a reliability estimate that is within 10% is of much greater value than the case where funding limitations or excessive research time results in an incomplete or untimely evaluation. Another important cost savings can be made by use of the approximation wherein, for the small value of λt,

$$e^{-\lambda t} \sim 1 - \lambda t \tag{7}$$

For example, $e^{-0.0050} = 0.9950125 \sim 0.9950$. Considerable calculation expenses can be saved by making use of this mathematical approximation when feasible. The basic reliability of a complex missile system can be computed to acceptable accuracy by adding up the failure rates of all parts, and multiplying the total by a mission factor. Thus

$$R_m = R_{st} \cdot R_{PF} \cdot R_F \cdot R_I \tag{8}$$

where R_m is the probability that the entire missile will survive storage, preflight test, airborne flight, and intercept mission, and R_{st}, R_{PF}, R_F, and R_I are the missile equivalents to the individual reliabilities defined in Eq. 4. Note that Eq. 8 is similar to Eq. 4.

A typical missile can undergo the following sequence of events subsequent to acceptance:

1. Storage for 5 years
2. 2-hour test and preflight test
3. 10 hours of captive flight prior to firing
4. 60-second flight after firing

Equations 1 and 8 can be combined into

$$R_m = e^{-\lambda_{st} t_{st}} \cdot e^{-\lambda_{PF} t_{PF}} \cdot e^{-\lambda_F t_F} \cdot e^{-\lambda_I t_I} \tag{9}$$

Using $\lambda_s = 0.001\lambda_L$, $\lambda_{PF} = \lambda_L$, $\lambda_F = 6.5\lambda_L$, and $\lambda_I = 80\lambda_L$, adding exponents and replacing individual failure rates by equivalence in terms of λ'_L

$$R_m = e^{-\lambda'_L(43.80 + 2 + 65 + 80/60)\text{ hours}}$$

$$R_m = e^{-112.13\lambda'_L\text{ hours}}$$

using $$\lambda' = \lambda_1 + \lambda_2 + \ldots\ldots + \lambda_n \qquad (10)$$

where λ_n = basic laboratory failure rate per hour for an individual part. A simplification of Eq. 7 cannot be used here since the exponent is greater than 0.2. Equation 7 should not be used when analysis or tabulation is performed by a computer.

The input section was apportioned a failure rate of 3.000% per 1,000 hours. This can be converted to terms of over-all probability of failure:

$$Q = 1 - R \qquad (11)$$

substituting, $Q_{IS(b)} = 1 - e^{-0.03 \times 112.13}$

$$Q_{IS(b)} = 1 - e^{-3.36}$$

$$Q_{IS(b)} = 1 - 0.035 = 0.965$$

where $Q_{IS(b)}$ is the probability of failure of the input section during the complex logistics- through-firing phases. The total of the basic failure rates of all parts in the input section, then, should be maintained at a fraction of the originally apportioned values. These basic rates should be obtained from MIL-217 or other acceptable documents. The important situation demonstrated here is that this hypothetical missile could meet the reliability requirements from firing to intercept but could barely survive to the time of pickle (firing operation). The percentage of failures during environmental testing can be expected to greatly exceed the percentage of failures that occur during acceptance testing. The percentage of failures during the interval from production to firing also will exceed the percentage that occurs during firing. A well-planned environmental program will bring about equivalence of these ratios.

RELIABILITY DEMONSTRATION

The demonstration of required reliability for each and every part is impractical in a low-cost reliability program. For instance, a failure rate of 0.06% per 1,000 hours would allow six failures in 10,000 resistors tested for 1,000 hours each. The testing of only 100 resistors for the same period would require an increase of test time to 100,000 hours. There are certain fallacies in this product relationship, but generally these may be neglected for confidence levels below 90%. A smaller sample or fewer test hours without corresponding increase in the alternate variable would not provide data at any worthwhile level of confidence. In individual cases of new design, to correct a high failure rate, a reliability demonstration can be the only solution that will preclude high producer's risk. Under such circumstances, accelerated testing is reluctantly acceptable. Typical rules of thumb presently in use are (1) the failure rate of mica condensers increases in proportion to the eighth power of applied voltage; and (2) a twentyfold increase in the failure rate of small transformers occurs at 10 g vibration at 60 cps, compared to the rate that exists at 1 g. Such rules of thumb are empirical and subject to challenge, yet they are used for reliability analysis by a large capacitor manufacturer and by a leading manufacturer of equipment for space

vehicles. Kemet Department, Linde Company, uses Weibull graphs and other considerations to provide time accelerations of 10,000 to 1, and even higher. Although the final system test cannot be considered to be a demonstration of reliability, failure rates in excess of the basic laboratory rate can be considered as indicative of unsatisfactory reliability. When a better equivalence cannot be obtained, the allowable failure rate at prefinal level can be five times that of the basic laboratory rate; the failure rate at complex module or subassembly level can be 25 times the basic laboratory rate. For this missile, the percentage of failures during realistic environmental testing should be not more than 112.13 hours divided by the quotient of the time duration of final testing and the percentage of failures during final system test.

A reliability demonstration of the complete system is almost mandatory for a high-performance missile. The reliability requirement for a flight period of the control assembly of the typical missile described in this report is 0.925 under laboratory conditions. Unless a specific confidence level is indicated, parts failure rates, MTBF predictions, and similar reliability data are computed from general formulae at a 50% confidence level.

There are several acceptable methods of conducting a reliability demonstration:

1. Operate × missiles until all fail
2. Operate × missiles until y failures occur
3. Operate × missiles for z hours

Method 3 is the most practical. There is always a possibility that no failure will occur, and so the following formula must be used for computations to a single confidence limit:

$$T > \frac{2T\ln(1/p)}{\chi^2_{\alpha}(2r+2)} \qquad (12)$$

where T = service life at reliability p

T = total test time, with replacement upon failure

ln = Naperian logarithm symbol

χ^2 = distribution factor

α = 1 minus the confidence level (ratio)

r = number of failures

System reliability tests also can be accelerated. Such an acceleration would include a determination of critical, major, and minor defects and testing to environmental excursions for a specified number of hours.

Given a requirement for 95% reliability for 10 hours at 90% confidence level under accelerated test, and substituting in Eq. 12,

$$10 > \frac{2 \cdot T \cdot \ln 1/0.95}{\chi^2_{0.1}(0+2)} \qquad \text{(0 failures)}$$

$$454.72 > T$$

Rounding off the figures for required test time, one missile must be tested for 450 hours without a failure, or three missiles must be tested for 150 hours each, etc. The sample must, of course, be identical to all other units if data are to be considered applicable to a particular model of missile.

Table 1 provides data as to demonstrated life with 95% reliability at 90% confidence level for various numbers of test missiles tested for 150 hours.

TABLE 1. SYSTEM DEMONSTRATED LIFE

No. missiles tested	Total test hours	Demonstrated life, hours			
		0 failures	1 failure	2 failures	3 failures
1	150	3.30	1.96	1.44	1.14
2	300	6.60	3.91	2.87	2.27
3	450	9.90	5.86	4.30	3.41
4	600	13.20	7.82	5.74	4.54
5	750	16.50	9.77	7.17	5.67

For the information given in Table 1 it is assumed that all missiles are made of identical components and with identical standards of workmanship. Calculations are based upon repair of failed items and continuation—not restart—of test. For an accelerated testing factor of 10:1, two missiles tested for 150 hours each with two failures permissible during the test, have demonstrated a service life of 28.7 hours.

In Table 2 are two-place χ^2 (chi squared) values for 90% confidence level. The term "degrees of freedom" refers to the quantity $(2r + 2)$. (The 90% confidence level for a single requirement is the lower limit for an 80% confidence level which calls out both upper and lower limits.)

TABLE 2. VALUES OF χ^2 FOR 90% CONFIDENCE LEVEL ($\alpha = 0.1$)[a]

Degrees of freedom	χ^2
2	4.61
4	7.78
6	10.6
8	13.4
10	16.0
12	18.5
14	21.1
16	23.5
18	26.0
20	28.4
22	30.8
24	33.2
26	35.6
28	37.9
30	40.3

[a] These values provide χ^2 to only three significant figures. Other tables may be used to achieve higher accuracy. These values are delineated in Table 2 only to allow the reader to arrive at answers identical to those in Table 1.

SUMMARY

This report extracts practical methods from the great quantity of reliability data and procedures which have resulted in effective reliability achievements at some of the largest electromechanical manufacturers in the United States. Use of the procedures and concepts described

herein can provide higher actual reliability than currently is being achieved by programs in which costs are greater by an order of magnitude. This program uses computers where they should be used. It is to be noted that the cognizant reliability engineer is to use ingenuity and judgment to direct the activities of the computer,[6] and is not to become lost in the maze of data and indicated directions offered at the computer output.

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[6] Under no circumstances is this to be interpreted as a license to experiment with data programmed to a computer to obtain a desired or expected result. During the 1952 election tabulations, a computer was programmed with past election histories and it predicted a landslide for President Eisenhower almost at the start of the processing of returns. The computer "experts" became frantic and set in "corrections" to show a closer end result. As recorded by history, President Eisenbower won by a landslide and a major computer manufacturer lost a chance to lead the computer industry by a wide margin.

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13. ABSTRACT

This report describes the basic considerations of an effective and comparatively low-cost reliability program for an exemplary airborne missile. It covers cases where expediency precludes full reliability considerations prior to production go-ahead and where the manufacturer has accepted a contractual requirement to demonstrate reliability at the systems level. It apportions reliability requirements, delineates important procedures that will provide worthwhile reliability assurance at reasonable cost, and fits the program into the quality assurance provisions of a typical manufacturer oriented to military contracts. The program is intended for missiles that are produced in small quantities.

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14 KEY WORDS	LINK A		LINK B		LINK C	
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