DEVELOPMENT OF KSC PROGRAM FOR INVESTIGATING AND GENERATING FIELD FAILURE RATES

RELIABILITY HANDBOOK FOR GROUND SUPPORT EQUIPMENT

FINAL REPORT
PRC R-1459

24 MAY 1972

PREPARED FOR
KENNEDY SPACE CENTER

PLANNING RESEARCH CORPORATION

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Under Contract No. NAS10-7621

Prepared by

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FOREWORD

This volume of the final report presenting results of the study to develop a program for investigating reliability aspects of the Ground Support Equipment of the Kennedy Space Center is in the form of the recommended reliability handbook for ground support equipment. The work of this volume was performed by the following study team members: E. E. Bean, C. E. Bloomquist, R. Hall, K. Hein, R. Kallmeyer, F. Kontrovich, W. Mull, D. O'Lear, J. Sorenson, J. R. Robles, and E. Rumble. Ms. E. E. Bean was the PRC Project Manager for the entire study. Mr. Bloomquist was primarily responsible for the supervision of the work reported in this volume.

JOHN F. KENNEDY SPACE CENTER

GP 975

RELIABILITY HANDBOOK FOR GROUND SUPPORT EQUIPMENT

24 May 1972

National Aeronautics and Space Administration
John F. Kennedy Space Center
Kennedy Space Center, Florida 32899

FOREWORD

This handbook presents a collection of reliability data for various components of the ground support equipment at the John F. Kennedy Space Center (KSC). These data have been obtained primarily by an analysis of the computerized data bank generated in conjunction with the Unsatisfactory Condition Report (UCR) system in effect at KSC.

Reliability data are presented for many different components and at varying levels of detail. The bulk of the handbook, including 20 individual reliability assessments of components (RACs), is intended primarily for reliability and design engineers. There are, however, numerous summary presentations that may be of interest to managers as well.

The data contained herein was generated by PRC Systems Sciences Company, an operating unit of Planning Research Corporation, under contract to the Technical Management Systems Office, Design Engineering. Methods for updating and extending the reliability data of this report are also included herein.

Comments or questions should be directed to Mr. Robert E. Cato, Code DD-SED-21, National Aeronautics and Space Administration, John F. Kennedy Space Center, Kennedy Space Center, Florida, 32899.

ABSTRACT

Field failure rates and confidence factors are presented for 88 identifiable components of the ground support equipment at the John F. Kennedy Space Center. For most of these, supplementary information regarding failure mode and cause is tabulated. Complete reliability assessments are included for three systems, eight subsystems, and nine generic piece-part classifications. Procedures for updating or augmenting the reliability results presented in this handbook are also included.

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II. INDIVIDUAL RELIABILITY ASSESSMENTS OF COMPONENTS

Each of the 20 subsections of this section of the report is devoted to one reliability assessment of a component (RAC) of the John F. Kennedy Space Center (KSC) ground support equipment (GSE). Each has been generated in accordance with the methodology of Section VI and each is completely self-contained. The tabs identify each RAC and mark the division between subsections.

Before turning to the RACs themselves reconsider, for a moment, what it is that is generally being presented. Each RAC is based on recorded data from field usage at the Kennedy Space Center. The basis of a RAC is actual experience, not a theoretical construct. This fact carries with it some implications for effective utilization of the results.

Each RAC is a summarization of actual experience of actual components in the environment of interest. There is no requirement to convert "standard" failure rate values to those applicable to the KSC GSE, for the rates presented are derived from component experience in the KSC environment. Furthermore, these data are not static but are continually changing reflecting changing conditions of utilization at KSC.

Each RAC presents not only failure rates but also failure modes, failure causes, repair times, and other information unique to the component under discussion. Supporting curves and tabulations for each of these elements are included in each RAC. Except for the failure rate itself there is no reason to suspect that the information given is not totally representative of the population at large.

The field failure rates are open to question on two grounds. First, only failing members of a component population are included in the assessment. Therefore, in large populations of relatively reliable components some members of the population are systematically excluded from the UCR sample, never having failed. This fact gives a higher field failure rate than would obtain if the nonfailing members of the population were included at the same rate as the failing members.

That is, the assumption is made that the true field failure rate (FFR) is given by

$$FFR = \frac{f}{\sum_{i=1}^{f} t_i + \sum_{j=f+1}^{n} t_j}$$

where f = number of failures,

t_i = time at failure for each of the f failing components,

t_j = time without failure for each of the $n - f$ nonfailing components.

The analysis of some components necessarily must exclude

$$\sum_{j=f+1}^{n} t_j$$

thereby increasing the field failure rate for those components.

The second question is the veracity of the Unsatisfactory Condition Report itself. That is, it is assumed that those completing the UCR forms for whatever reason, do not convey accurate information.

This second question can be easily answered. In the course of the component assessments a large number of related UCRs were studied quite carefully, including the narrative portions. No internal evidence of deliberately inaccurate data has ever been found. This implies that either the UCR generators are well coordinated, or that deliberate attempts to transmit inaccurate data are rare. The latter alternative is assumed to be true in the analyses. If, however, one assumes that the first alternative is true, it is still of interest to know what is being blamed or reported as being the problem by the UCR generators. That is, whether the goal of analyzing field experience data is to improve the hardware and/or to improve the reporting it is necessary to proceed from a base of actual information rather than subjective judgments.

The first and more important problem is basically one of visibility. The UCR system provides only a very imperfect record of the reliability of components. It reports only on failed items. And it reports only on some of these. Moreover, each UCR is fragmentary at best. It is generally accepted that analysis of incomplete data does aid in the understanding of a given phenomena, whether it be reliability of equipment, astronomical observations, government intelligence activities, etc. In fact, incomplete data in these areas serves to intensify rather than to diminish analysis activities. The results in the RACs are derived in the same spirit.

The information upon which the RAC is based is included therein and can be modified to reflect the reader's greater understanding of the problem or to reflect data not available to the assessment analyst. The data presented should, in fact, be used precisely in this creative fashion and not as though it were some update of other failure rate tabulations, such as MIL-HDBK-217A. What is presented is the observed (through the UCR system) experience of certain components at a particular point in time. This experience is reflected in the entire RAC but is summarized as a Field Failure Rate, Repair Time Statistics, and various apportionments of the Field Failure Rate.

There are, for components of KSC GSE, at least six different types of failure rates of interest as shown in Exhibit 1. The first is, in one sense at least, the failure rate one would really like to know. The second and third are the failure rates provided by the RAC. Although there is reason to believe that the failure rates identified under the second bar are generally greater than or equal to those under the first bar, the size of the discrepancy varies with component and in no case is it known with precision. For Tail Service Masts and similar components the failure rates of Bar 1 and Bar 2 should be within experimental error. For components such as capacitors or pressure switches, the indicated bias certainly exists (that is, failure rates under Bar 2 are greater than those under Bar 1). For system level components, however, the true field failure rate may be higher than

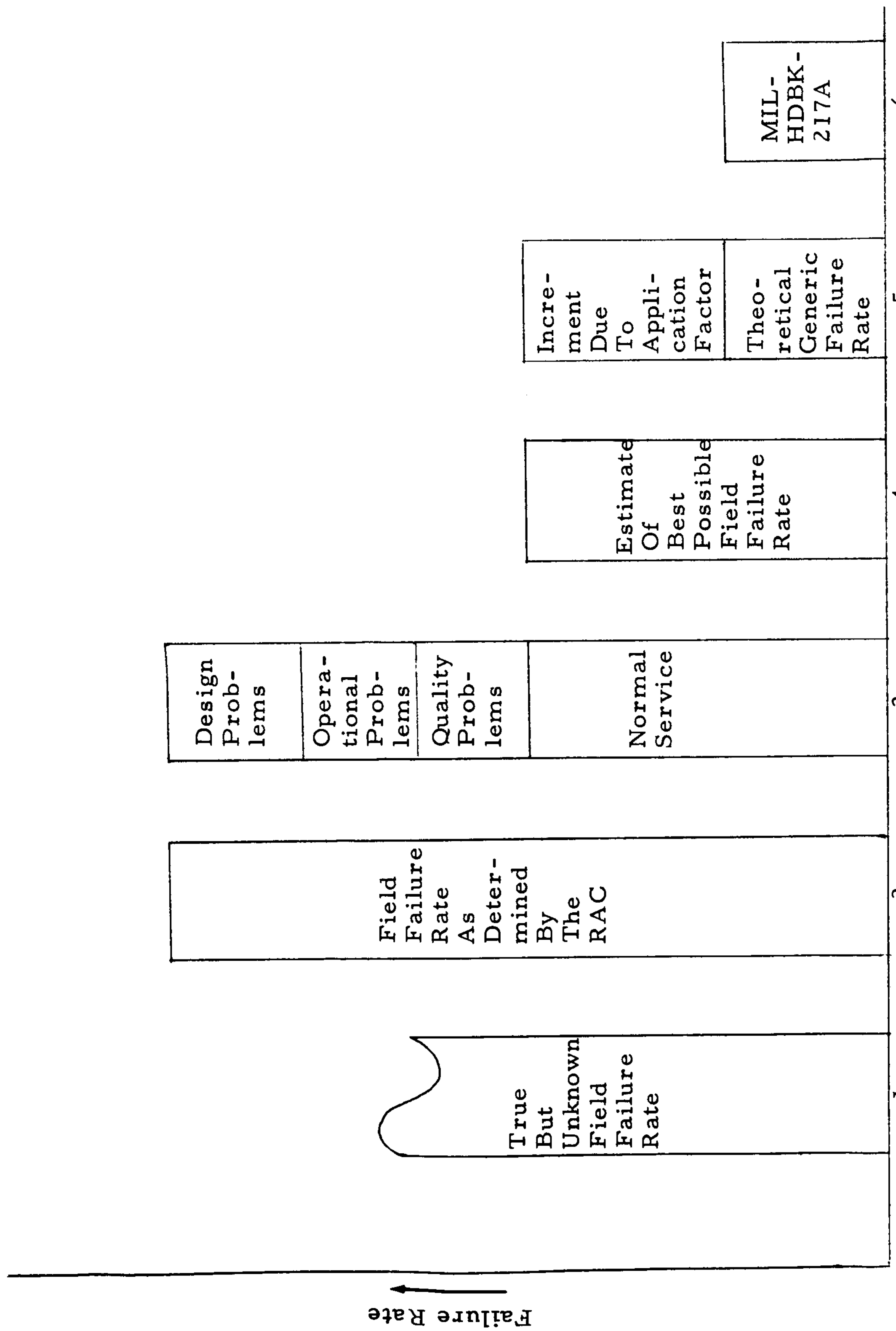


EXHIBIT 1 - VARIOUS KSC GSE COMPONENT FAILURE RATES

that given in the RAC simply because knowledge of failures as derived from the UCR system is more likely to be "lost" than is component installation time.

The third bar in the chart apportions the failures as to cause. By eliminating those failures with an obvious remedy or cause, a "best" failure rate for the given component can be estimated. If the world were simple, this value would equal the generic failure rate (as found for example in MIL-HDBK-217A) modified by the suitable application factor (also found in MIL-HDBK-217A). Since neither the failure rates nor the K-factors of MIL-HDBK-217A are particularly appropriate to KSC GSE, the failure rates of Bars 4 and 5 cannot be expected to be approximately equal as shown in Exhibit 1.

It is urged that consideration be given to the entire contents of each RAC before its results are used or rejected. Furthermore, since the handbook is primarily a design tool it should be used as a guideline of observed operational experience rather than as a theoretical model.

RELIABILITY ASSESSMENT
OF
AMPLIFIER/AMP BOX

Date: 24 May 1972

Observed Field Failure Rate In Failures Per Thousand Hours Of Installed Component Time		0.150
Observed Failure Times, In Hours		
Mean		6660
Minimum	0	
Maximum	43,200	
Number of Observations	215	
Observed Repair Times, In Hours		
Mean		2.58
Minimum	0.05	
Maximum	168	
Number of Observations	1896	

FAILURE MODES AND CAUSES CONTRIBUTING TO THE OBSERVED FIELD FAILURE RATE AS A PERCENT OF THE TOTAL

		Proximate Cause of Failure		
		Normal Service	Other	Total
Failure Mode	Function Unique	21.7	0.2	21.9
	No Output	19.5	0.3	19.8
	Noisy	14.6	0.3	14.9
	Incorrect Output	10.2	0.1	10.3
	Incorrect Gain	9.2	0.1	9.3
	Inoperative	5.8	0.4	6.2
	Unknown	4.4	0.3	4.7
	Intermittent	2.7	0.1	2.8
	Other	9.2	0.9	10.1
	Total	97.3	2.7	100.0

Problem Classification (Percent)

Number of Relevant UCRs: 2,134 Currency:[1] 15 September 1969

[1]Date of latest UCR run included in the assessment.

DESIGN BACKGROUND DATA

1. Component Description

This analysis deals with the UCR major item, "amplifier/amp box," or, in more generic terms, amplifiers. While a considerable number of amplifier types are included, they all function to provide an output that magnifies or increases (i. e., amplifies) some characteristic of the input. The wide range of amplifier types stems from the input characteristic that is amplified. For instance, a read amplifier in a tape recorder magnifies the weak signals read from the tape so that the signal information is usable in other circuitry in the recorder. A power amplifier converts the current-voltage characteristics of the input so that a higher current can be obtained from the output in power supply applications. All amplifier types included in the analysis are electrical/electronic and do not include mechanical amplifiers that would be found in, say, a fluidic control system.

2. Data Base

A total of 2219 UCR's are contained within the historical data file as of 15 September 1969, listed under the UCR major item code 348, amplifiers/amp box. In general each UCR represents a problem associated with one amplifier. In every case where an entry greater than one appears in the UCR data element, "quantity rejected," the entry refers to piece parts within the amplifier. In this analysis, therefore, the number of UCR's is also the number of amplifier problems.

Three of the 2219 UCR's were eliminated from further consideration, two because they are requests for design action on problems previously reported, and one because of unresolved data irregularities (attributed to an amplifier not located at KSC).

The remaining 2216 UCR's are distributed among 35 functional systems, with 96 percent concentrated in 8 of them. Exhibit 1 shows the number of UCR's in the data base for these 8 functional systems. About half of the total number of UCR's are written against amplifiers in the television and OIS-RF functional systems, each accounting for about one-fourth of the data. Another 20 percent of the UCR's are attributed to OIS-Audio. The 27 functional systems which are not

EXHIBIT 1 - AMPLIFIER DATA BASE: NUMBER OF UCR'S BY FUNCTIONAL SYSTEM

Functional System	No. of UCR's
Television	566
OIS-RF	564
OIS-Audio	452
Data Transmission	157
Measuring	158
Range Instrumentation	116
PA and Paging	81
Telemetry	40
Total:	2,134

represented in the exhibit account for only 82 widely scattered UCR's. Furthermore, these UCR's are written against amplifier types which are different from any of those appearing in the eight functional systems which are listed. Therefore, and for convenience of analysis, these UCR's are eliminated from the data base.

The data base, then, consists of the 2134 UCR's, distributed among the eight functional systems as shown in Exhibit 1.

3. <u>Engineering Analysis</u>

Numerous tabulations, contrasts and preliminary classifications were made in the course of the initial analysis of the 2134 amplifier UCR's. Only the more significant findings are summarized here.

First, the UCR's span a 5-year period from early 1964 to early 1969 and are distributed as shown in Exhibit 2. In all cases save two, the majority of the UCR's each month are from the three major functional systems in the sample (Television, OIS-Audio and OIS-RF). The UCR's from these systems comprise roughly three-fourths of the total number of UCR's and their monthly distribution generally reflects this. The two exceptions are: (1) no UCR's appear for these three systems before September 1965, and (2) in March 1967 the monthly distribution is altered slightly by a relatively large number of UCR's (31) against Range Instrumentation. The 31 Range Instrumentation UCR's, all Multiplexer Amplifiers, were generated during some kind of calibration-maintenance procedure.

The "peak" in September 1967 is due to 116 amplifier UCR's written against the television system. These 116 UCR's comprise roughly 75 percent of all UCR's for that month. All are from LC 39 and occurred approximately 6 weeks prior to the first launch from that complex. Of the 116 UCR's, slightly over half concern AGC/DA amplifiers, and slightly under a fourth, switching output amplifiers.

Ninety percent of the AGC/DA amplifier UCR's (57 of them) involve replacement of a "defective" photocell. It appears that this is related to an AVO modification (dated August 30, 1967) for "no AGC action," but the exact relationship is not clear. It is not obvious whether the photocell was actually defective, whether it would have become so had the

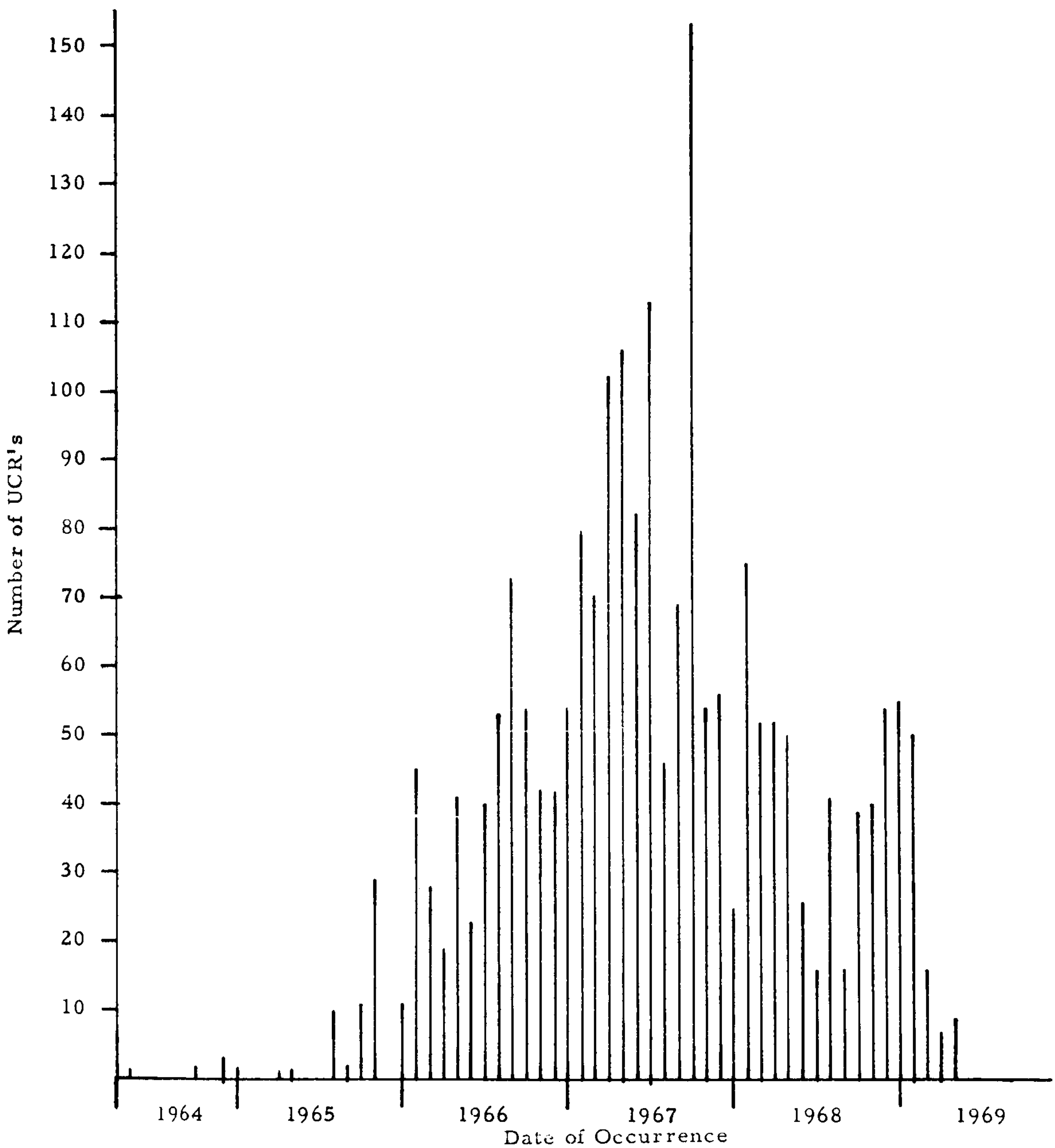


EXHIBIT 2 - FREQUENCY OF AMPLIFIER UCR'S BY DATE OF OCCURRENCE

modification not been made or whether the two are related only by time (i. e., perhaps the unit was to be repaired because of the defective photocell and the modification was also made at this time).

Exhibit 3 tabulates the distribution of UCR's by location. Slightly over 40 percent are from Launch Complex 39, with LC 34 accounting for the next largest group (20 percent of the total). The UCR's from Launch Complex 37 comprise a minor percentage of the total, roughly 7 percent. No UCR's within OIS-RF are attributed to Launch Complex 34 or 37. About 80 percent of the OIS-RF problems occurred at Launch Complex 39; the remaining 20 percent of the OIS-RF UCR's are from the MSO. The column titled "Other" in the exhibit represents a variety of locations, such as the VAB, CIF, and CDC.

In the total data base there are only 91 UCR's with time or age entries. However, determination of time-between-failure for a particular amplifier type is possible via the time tracing technique using serial numbered components for 153 additional time observations. Of these 244 time entries, 215 are distributed among 15 specific amplifier types in five functional systems as shown in Exhibit 4. In four of the 15 types, data for two part numbers are combined based on the similarity evident in their function and utilization. No grouping could be made for the remaining 29 time entries. Assuming that each time observation represents one amplifier time-to-failure, the cumulative distributions of time-to-failure for these amplifier types are shown in Exhibits 5 through 19.

Amplifier failures are related to problems associated with the piece parts contained within the component. Piece part and module failures reported in the data base are tabulated by functional system in Exhibit 20. There are a total of 2454 piece parts. The "miscellaneous" category in the exhibit includes all low-population piece parts such as relays, fuses, switches, photocells, potentiometers, inductors of various sorts, etc. The "unknown" column reflects those UCR's where parts were replaced but the type of part was not indicated and those cases where an overall number of various replaced part types is given but the exact number of each part type can not be determined.

EXHIBIT 3 - DISTRIBUTION OF UCR'S BY LOCATION

Functional System	LC 39	LC 37	LC 34	MSO	Other
Television	308	81	118	35	24
OIS-RF	457			104	3
OIS-Audio	17	28	283	22	102
Data Transmission	21			6	130
Measuring	93	31	13		21
Range Instrumentation					116
PA and Paging	10	1		6	64
Telemetry	27	3	10		
Total:	933	144	424	173	460

EXHIBIT 4 - NUMBER OF TIME OR AGE ENTRIES BY AMPLIFIER TYPE

Functional System	Amplifier Description	No. of UCR's with Time Observations	Total No. in Data Base
Television	Switching Amp, P/N 3207, 3207 A1 thru A5	29	97
Television	Switching Output Amp, P/N BO 5390A	9	19
Television	Insert Amp, P/N 3207-A12	14	72
Television	Video Distribution Amp, P/N D5864A, DA61PA	8	66
Television	Pulse Distribution Amp, P/N 5841A, 3202	4	44
Television	AGC/DA, P/N AG7394A	9	73
OIS-RF	Audio IF Amp, P/N 758-0081-001	40	447
OIS-Audio	Headset PCB, P/N 24620496	11	115
OIS-Audio	AIA PC Card, P/N CO-0046	9	57
OIS-Audio	Mike PCB, P/N 24620492	6	65
Measuring	Blue or Red Amp, P/N 173930	14	70
Measuring	Amplifier P/N 723397-1	10	11
Measuring	Amplifier P/N 356358-1	7	12
Measuring	Amplifier P/N 356410-7	7	7
Range Instrumentation	Multiplexer Amp, P/N 20010 and 20011	38	60
	Total:	215	1215

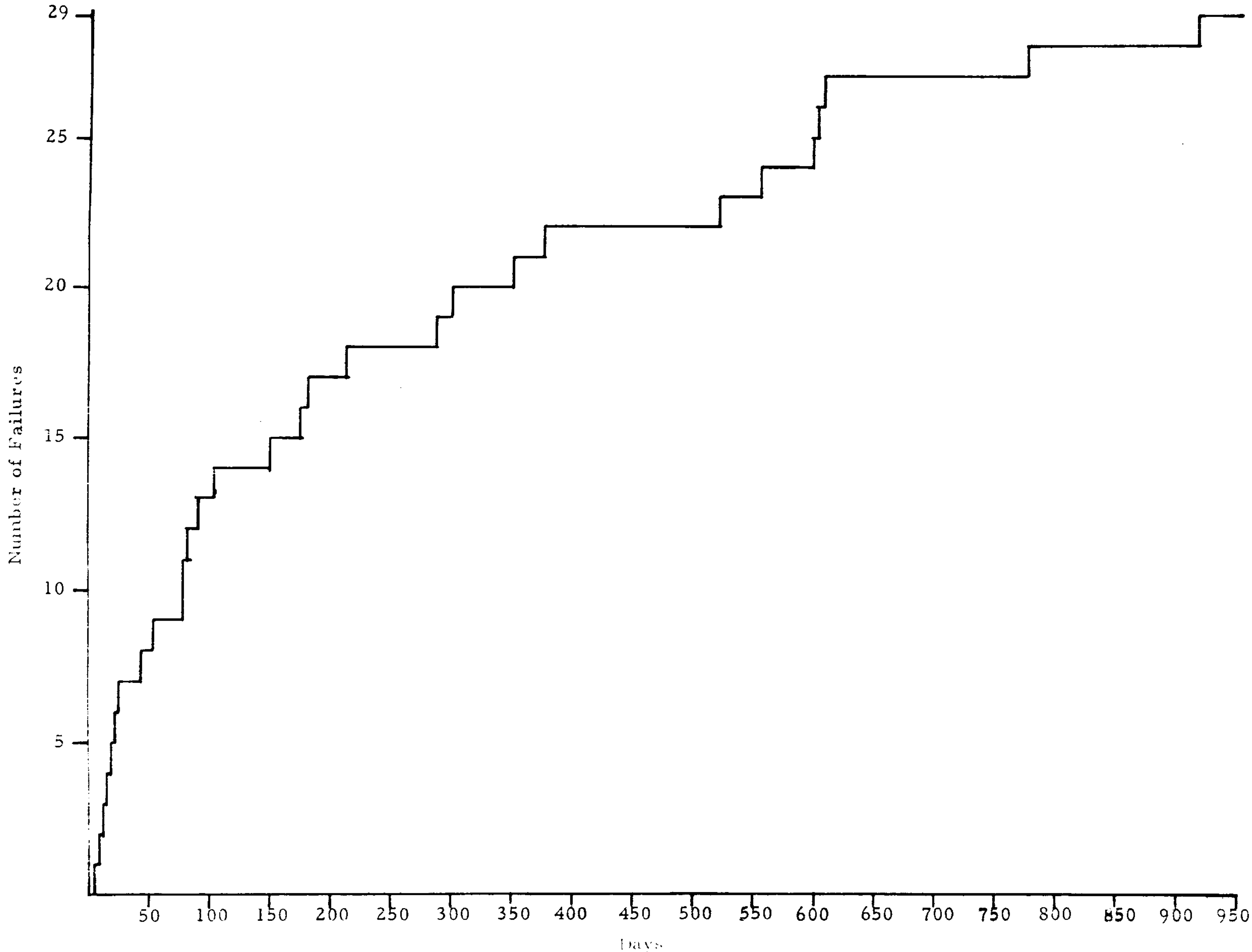


EXHIBIT 5 - CUMULATIVE DISTRIBUTION OF TIME-TO-FAILURE, SWITCHING AMPLIFIER P/N 3207, A1-5, TELEVISION FUNCTIONAL SYSTEM

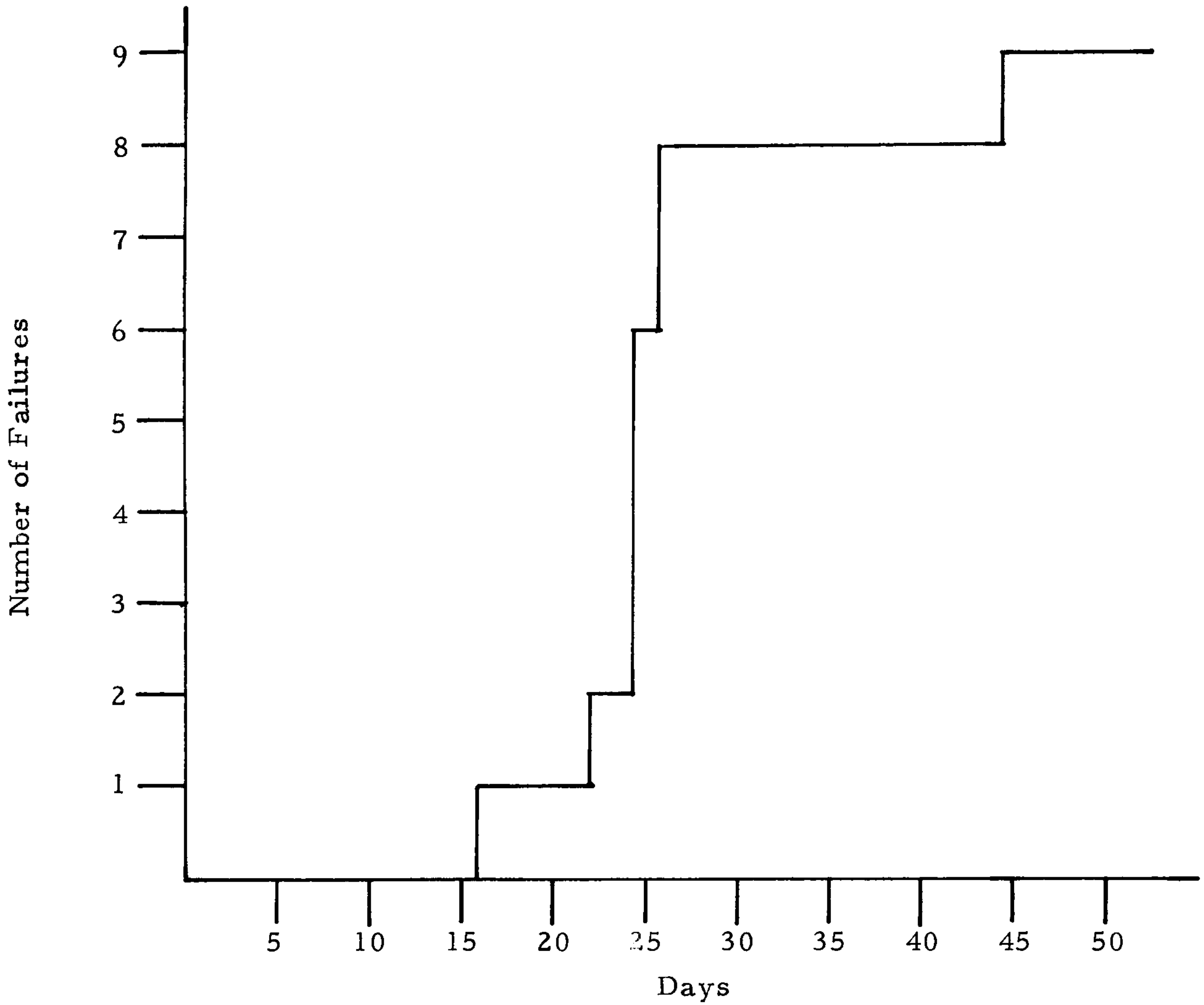


EXHIBIT 6 - CUMULATIVE DISTRIBUTION OF TIME-TO-FAILURE, SWITCHING OUTPUT AMPLIFIER P/NB05390A, TELEVISION FUNCTIONAL SYSTEM

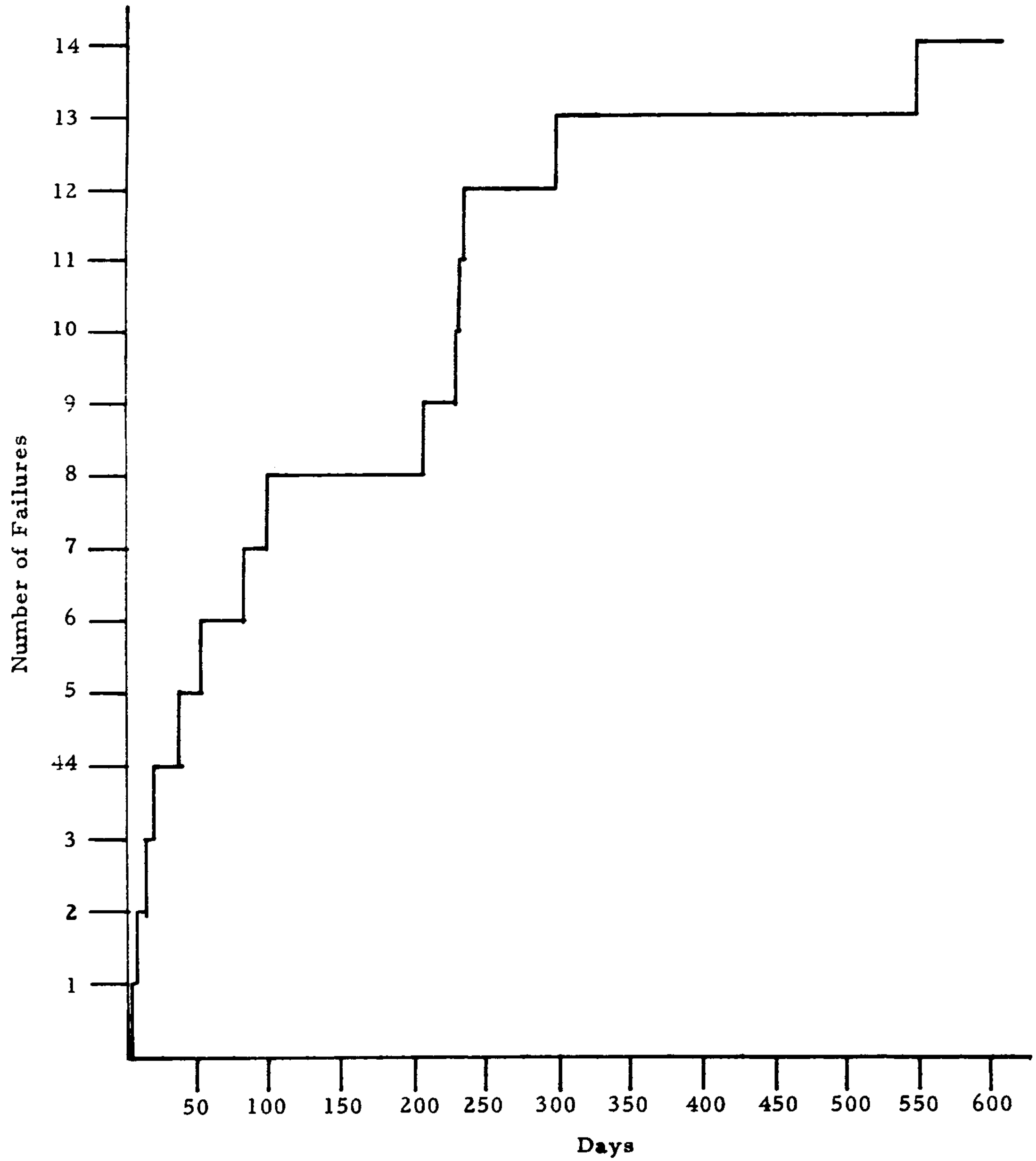


EXHIBIT 7 - CUMULATIVE DISTRIBUTION OF TIME-TO-FAILURE, INSERT AMPLIFIER P/N 3207, A12, TELEVISION FUNCTIONAL SYSTEM

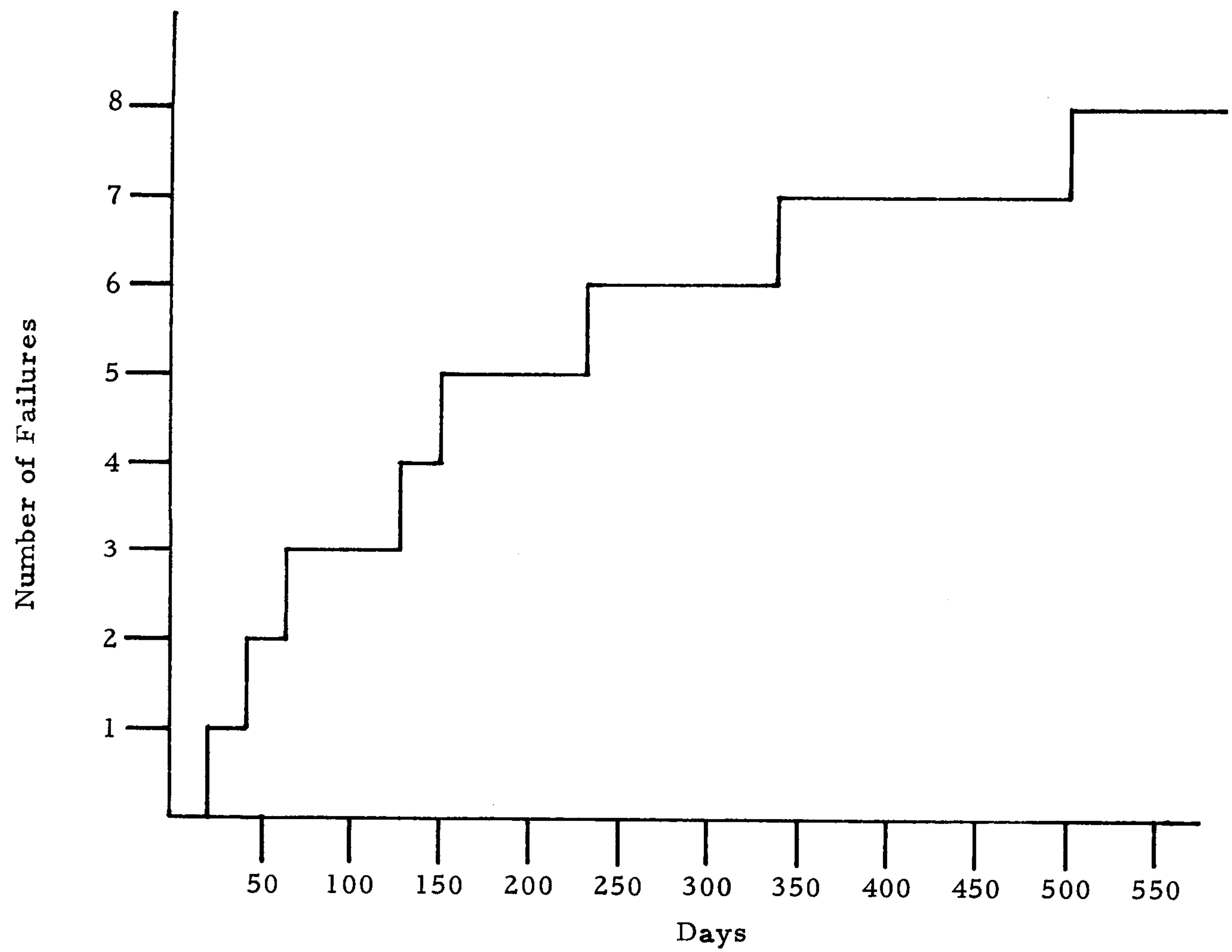


EXHIBIT 8 - CUMULATIVE DISTRIBUTION OF TIME-TO-FAILURE, VIDEO DISTRIBUTION AMPLIFIER P/N DA 5864A AND P/N 61PA, TELEVISION FUNCTIONAL SYSTEM

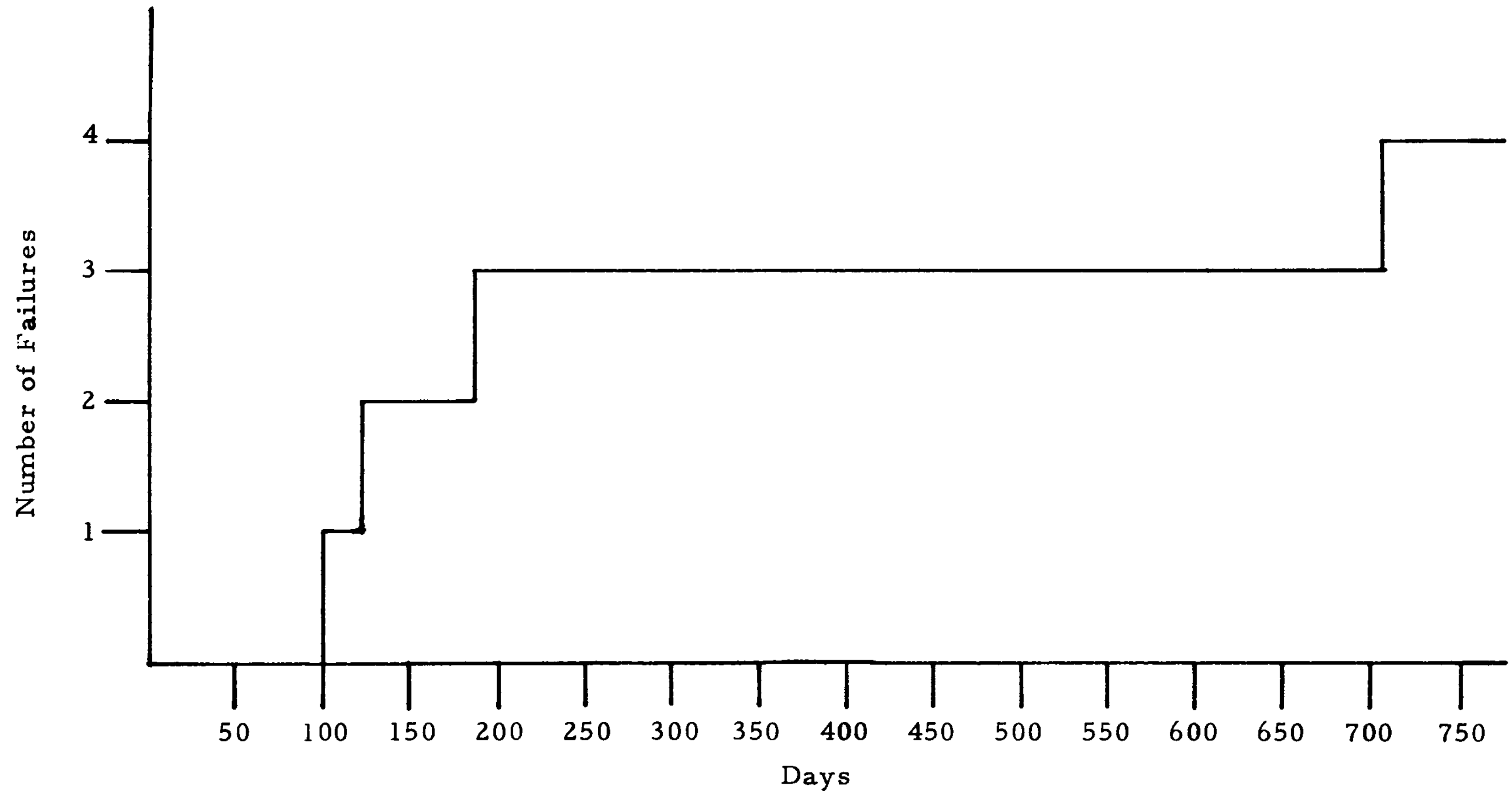


EXHIBIT 9 - CUMULATIVE DISTRIBUTION OF TIME-TO-FAILURE, PULSE DISTRIBUTION AMPLIFIER P/N PD 5841A AND P/N 3202, TELEVISION FUNCTIONAL SYSTEM

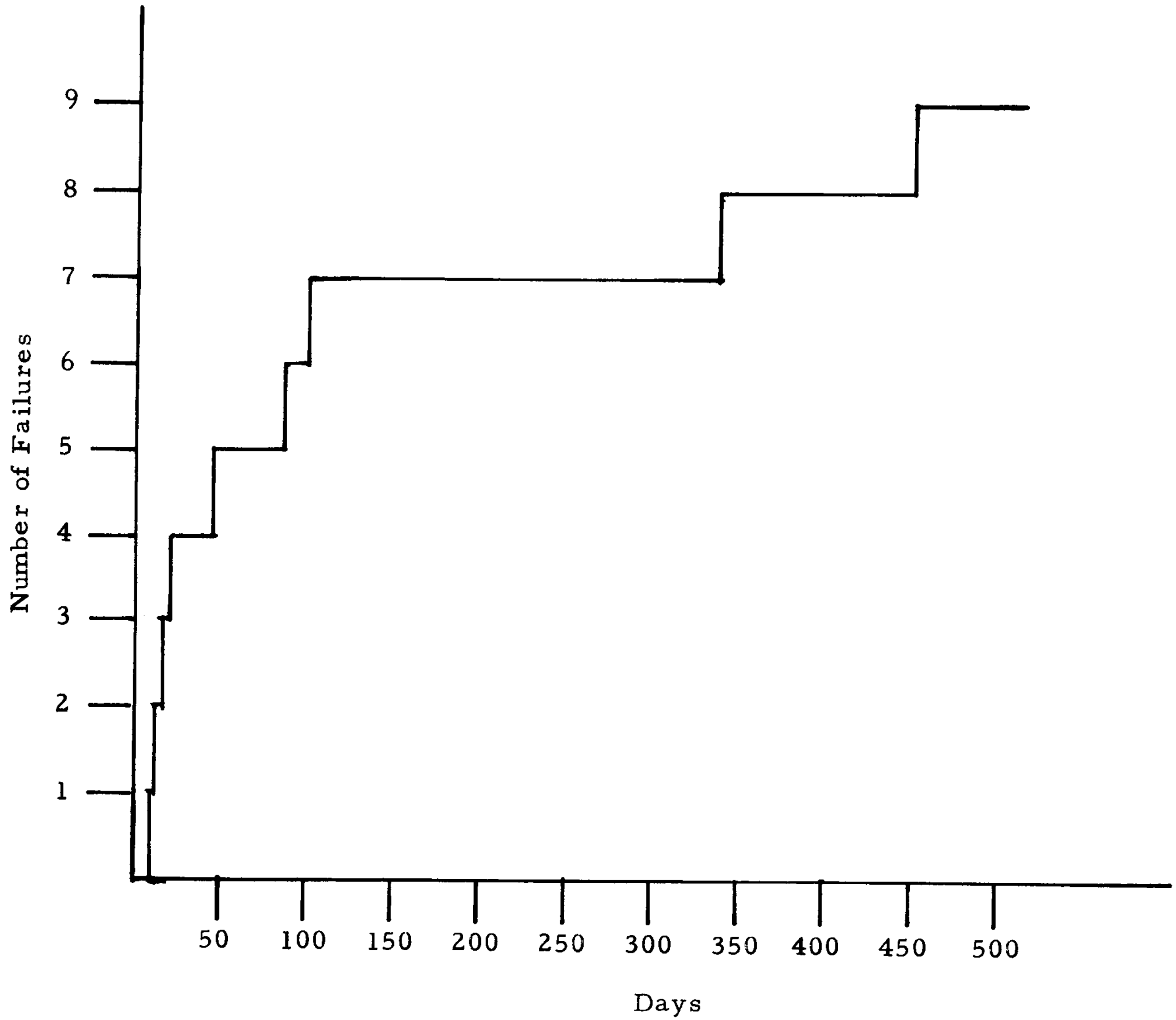


EXHIBIT 10 - CUMULATIVE DISTRIBUTION OF TIME-TO-FAILURE, AGC/DA AMPLIFIER P/N AG7394A, TELEVISION FUNCTIONAL SYSTEM

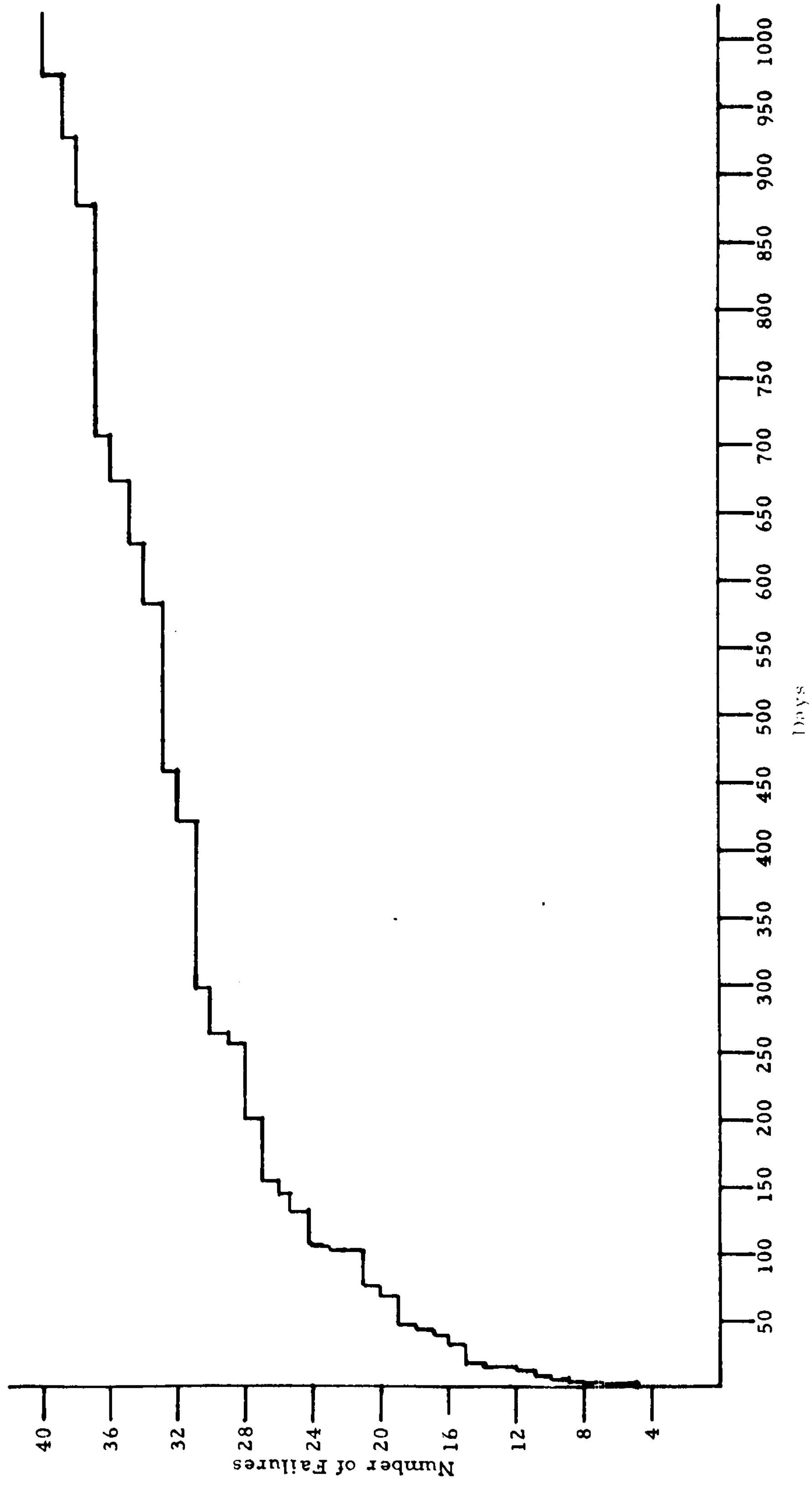


EXHIBIT 11 - CUMULATIVE DISTRIBUTION OF TIME-TO-FAILURE, AUDIO IF AMPLIFIER
P/N 758-0081-001, OIS-RF FUNCTIONAL SYSTEM

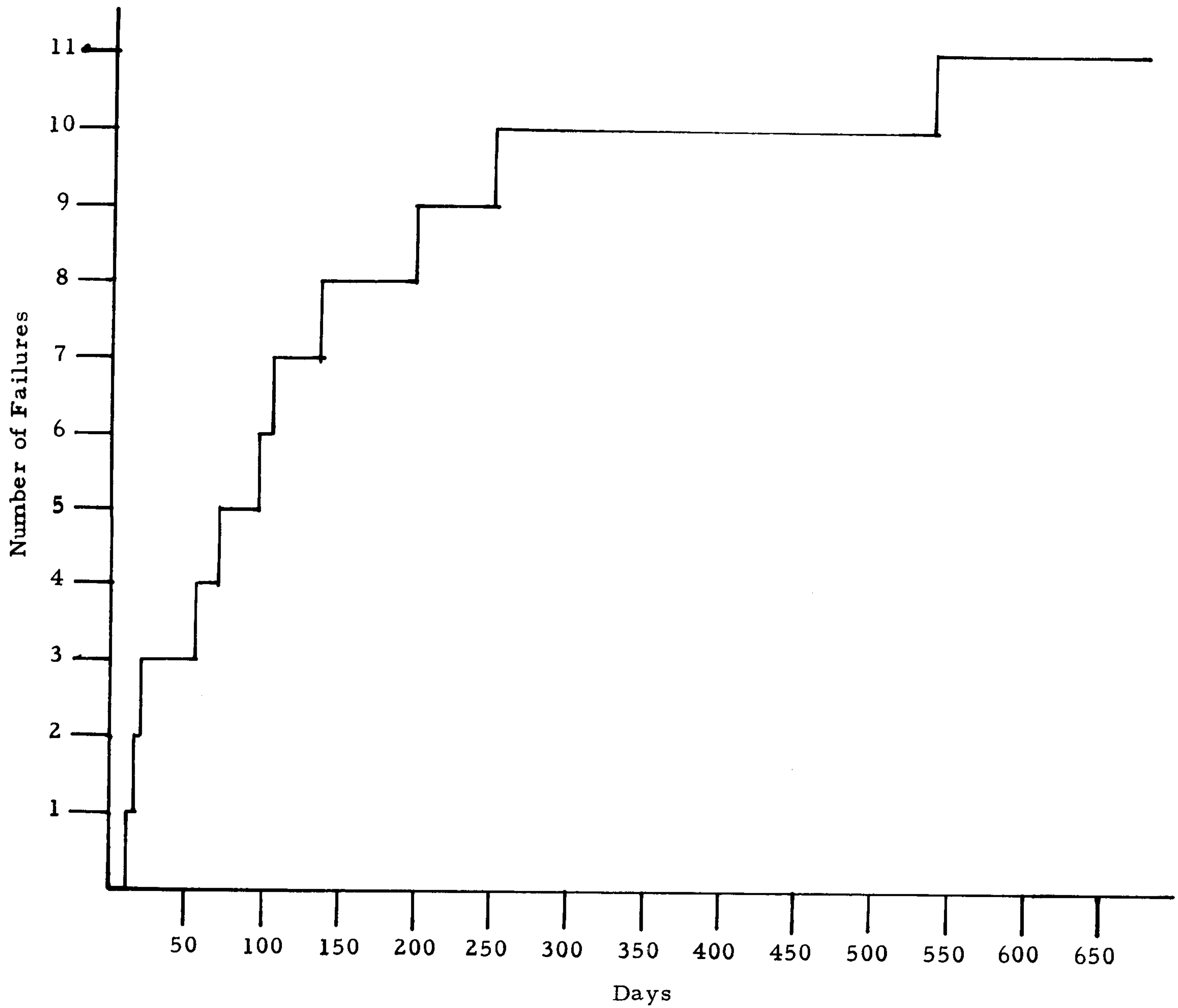


EXHIBIT 12 - CUMULATIVE DISTRIBUTION OF TIME-TO-FAILURE, HEADSET PCB P/N 24620496, OIS-AUDIO FUNCTIONAL SYSTEM

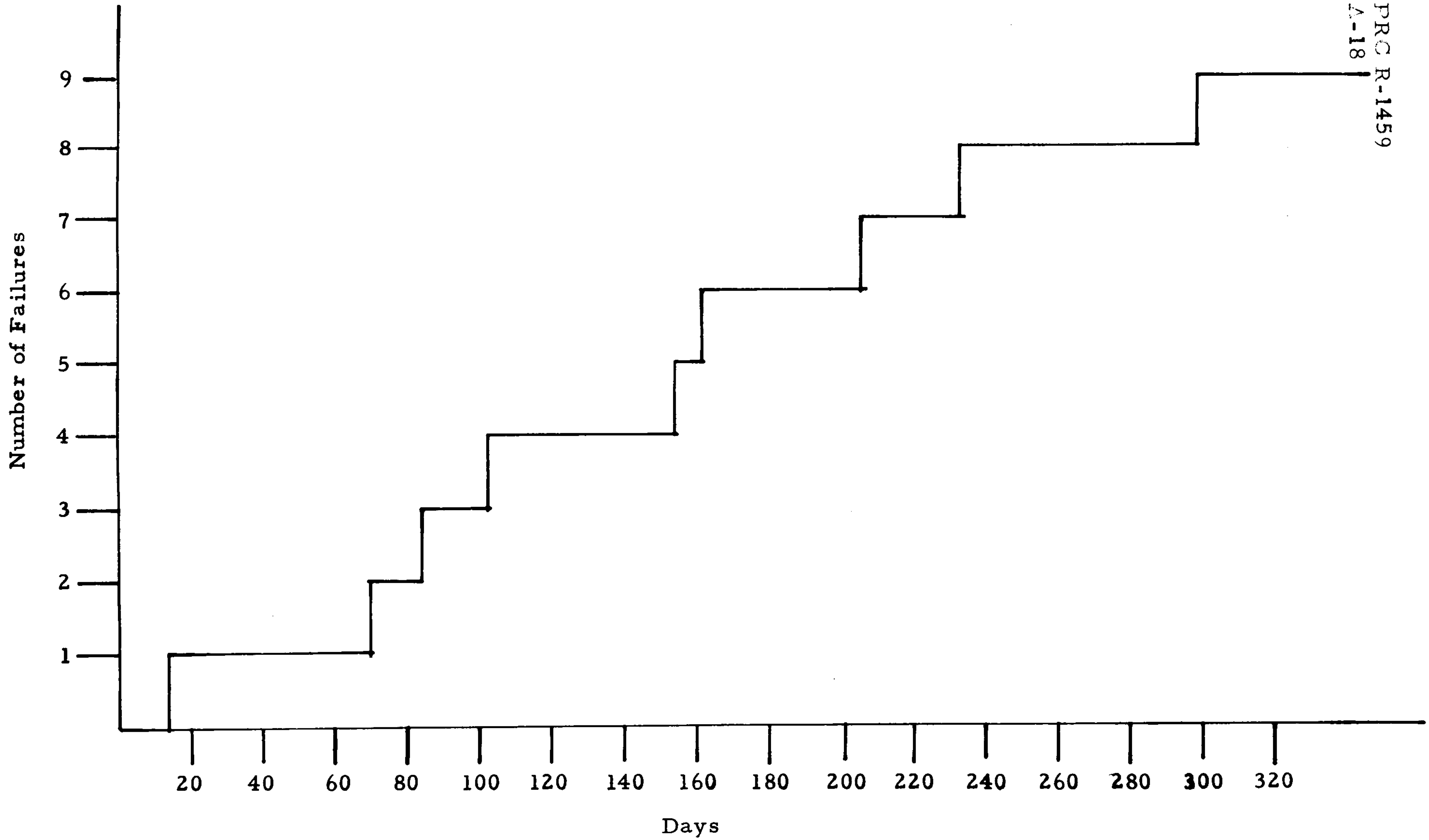


EXHIBIT 13 - CUMULATIVE DISTRIBUTION OF TIME-TO-FAILURE, AIA P.C. CARD P/N CO-0046, OIS-AUDIO FUNCTIONAL SYSTEM

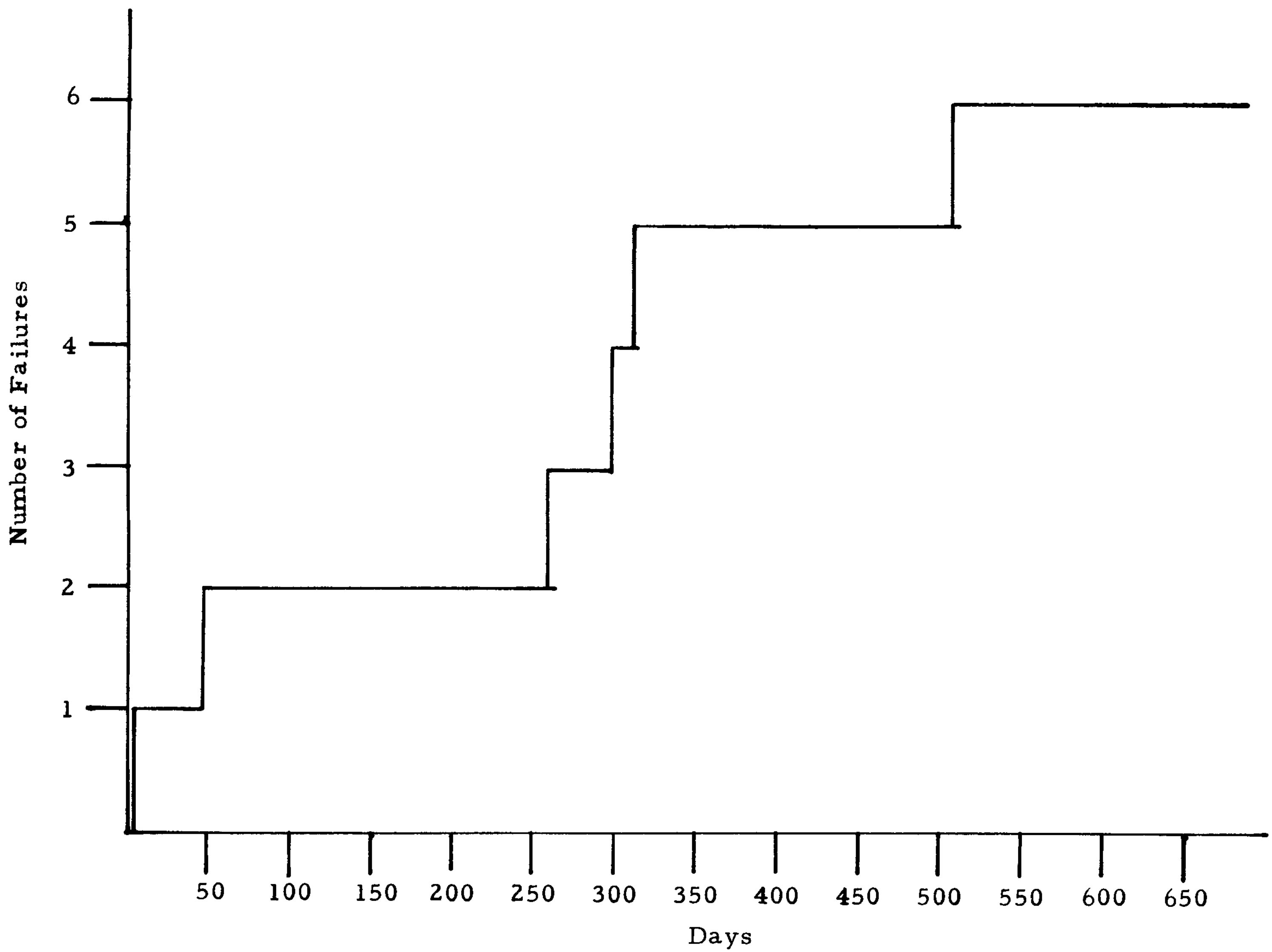


EXHIBIT 14 - CUMULATIVE DISTRIBUTION OF TIME-TO-FAILURE, MIKE PCB
P/N 24620492, OIS-AUDIO FUNCTIONAL SYSTEM

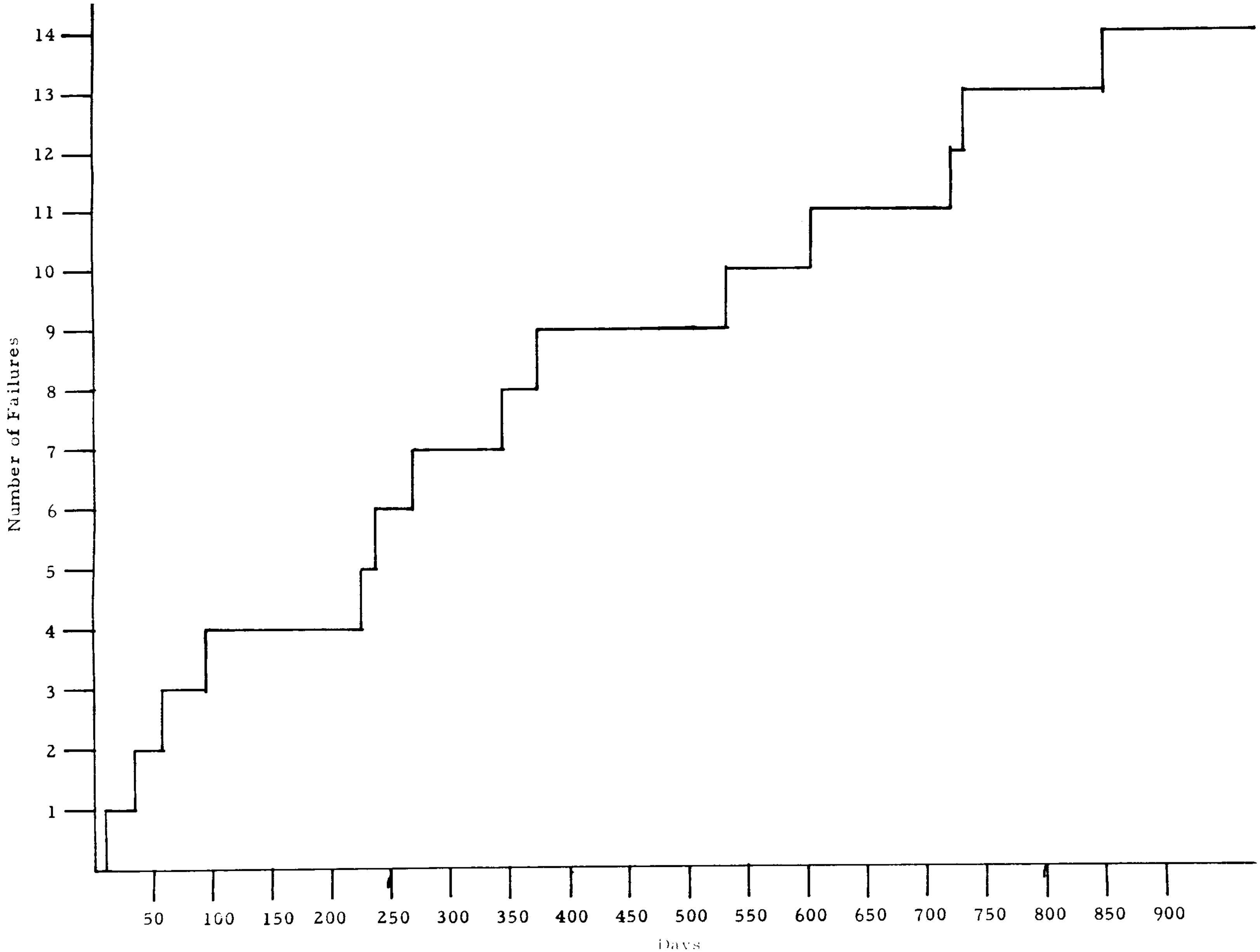


EXHIBIT 15 - CUMULATIVE DISTRIBUTION OF TIME-TO-FAILURE, BLUE OR RED AMPLIFIER P/N 173930, MEASURING FUNCTIONAL SYSTEM

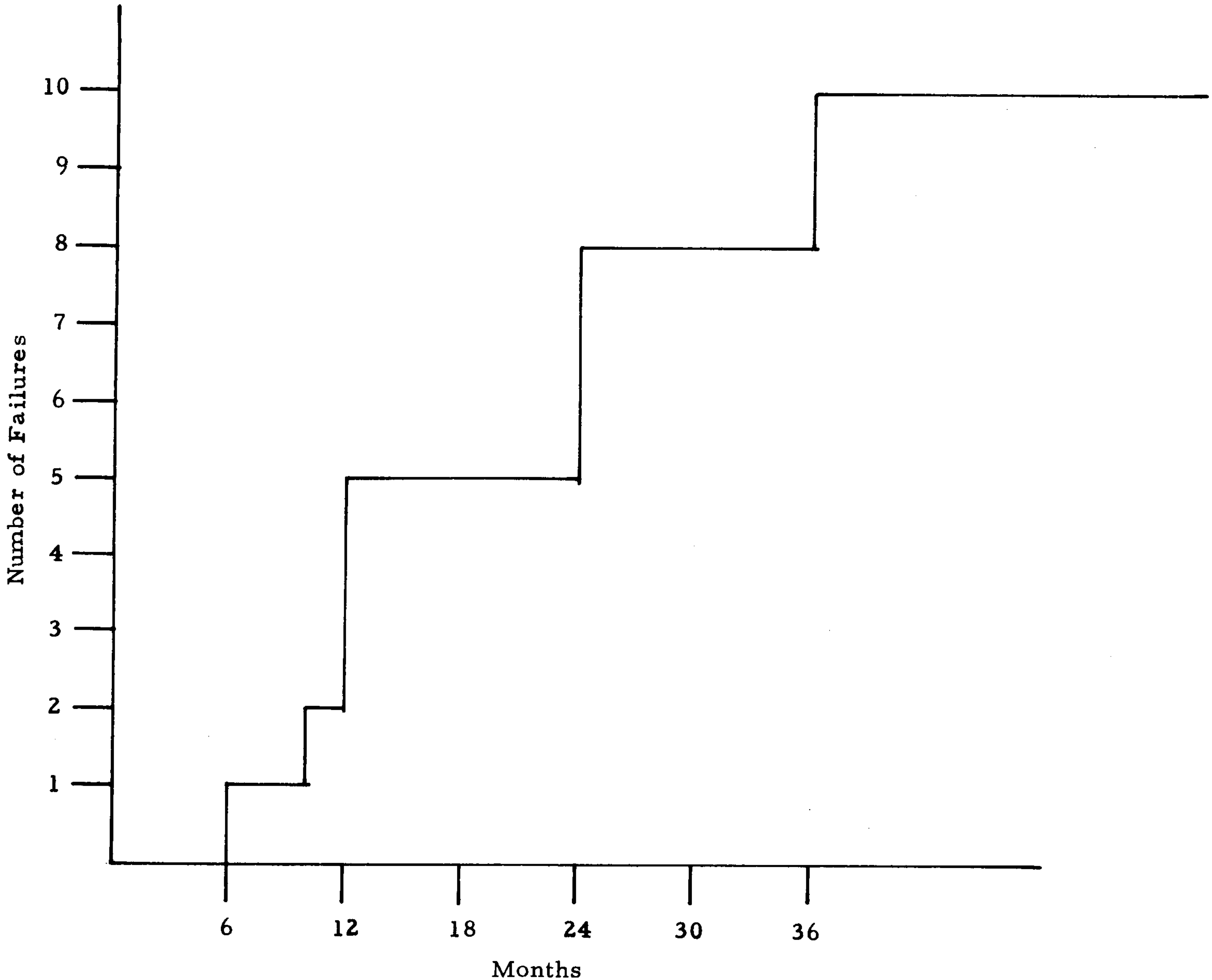


EXHIBIT 16 - CUMULATIVE DISTRIBUTION OF TIME-TO-FAILURE, AMPLIFIER P/N 723397-1, MEASURING FUNCTIONAL SYSTEM

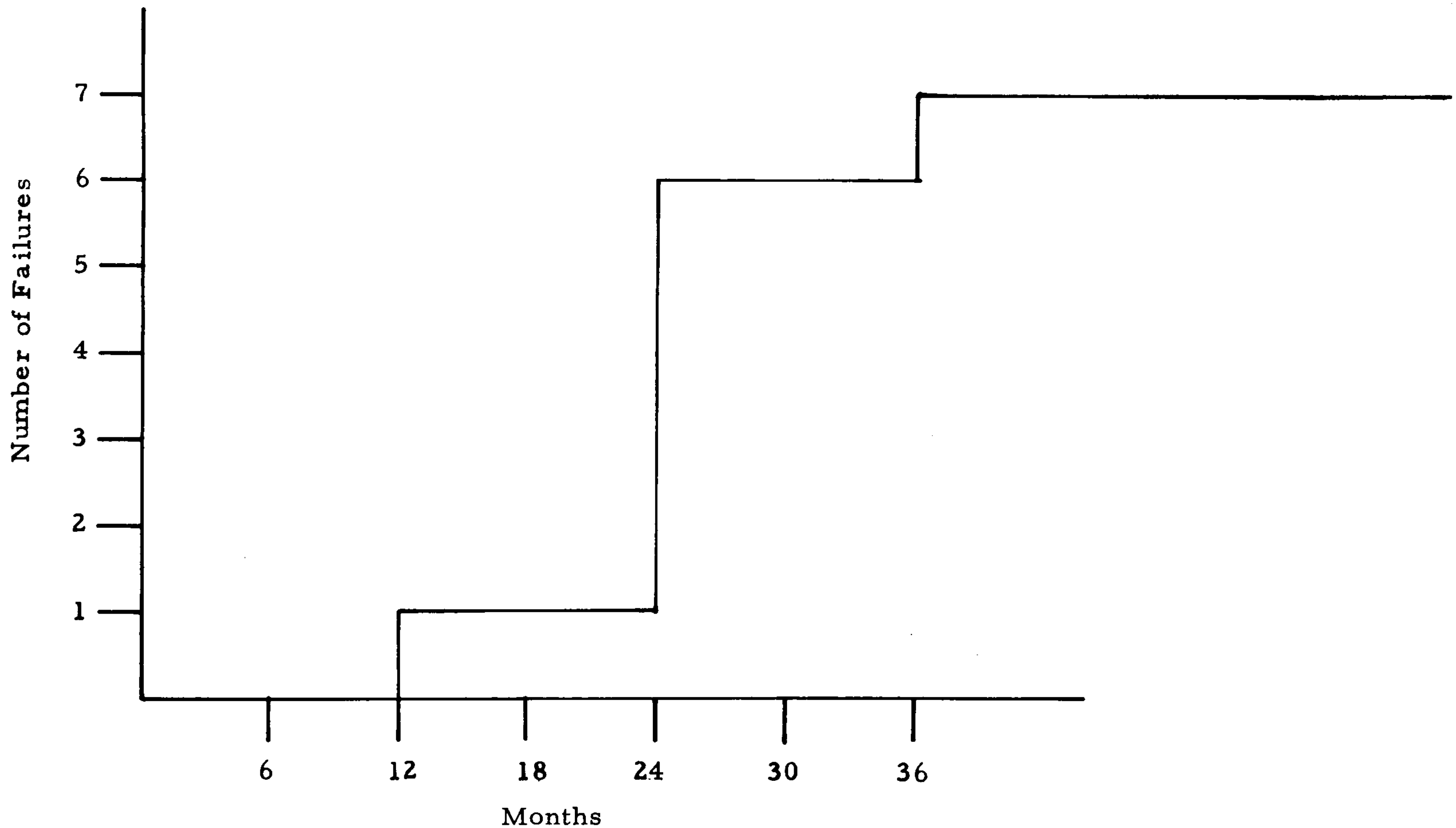


EXHIBIT 17 - CUMULATIVE DISTRIBUTION OF TIME-TO-FAILURE, AMPLIFIER P/N 356358-1, MEASURING FUNCTIONAL SYSTEM

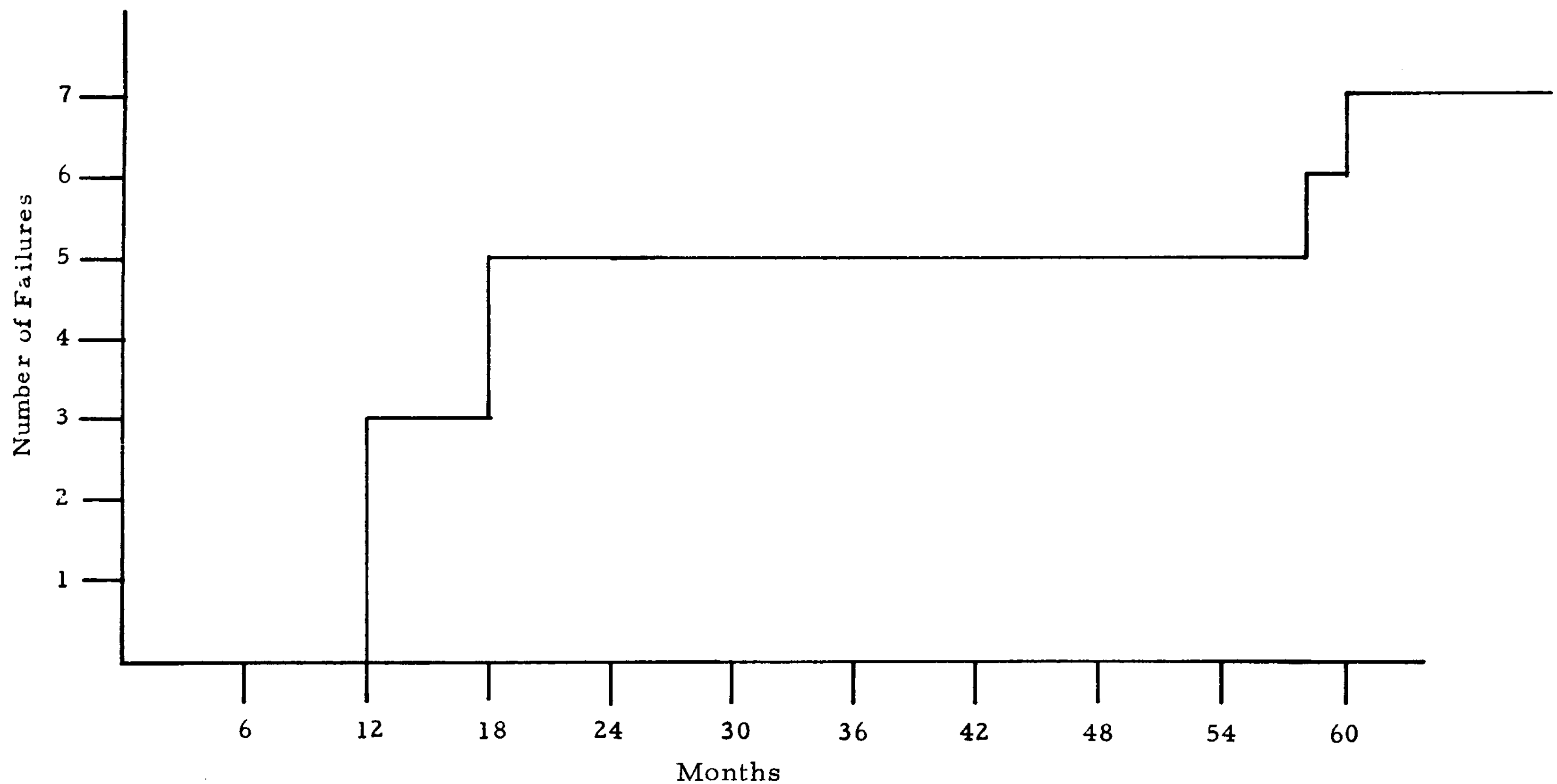


EXHIBIT 18 - CUMULATIVE DISTRIBUTION OF TIME-TO-FAILURE, AMPLIFIER P/N 356410-7, MEASURING FUNCTIONAL SYSTEM

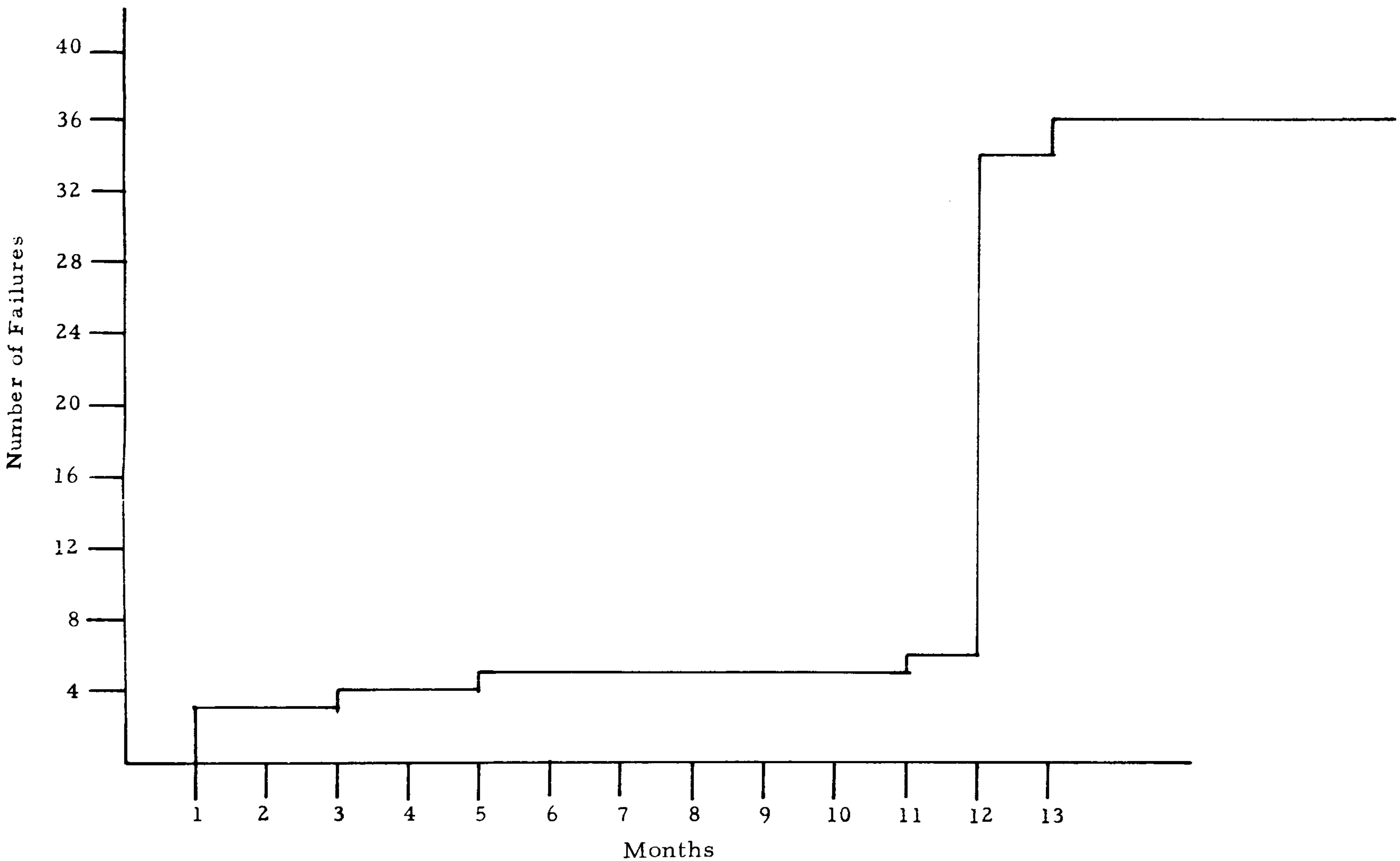


EXHIBIT 19 - CUMULATIVE DISTRIBUTION OF TIME-TO-FAILURE, MULTI-PLEXER AMPLIFIER P/N 20010 AND 20011, RANGE INSTRUMENTATION FUNCTIONAL SYSTEM

Of all the piece parts, capacitors appear to be the most troublesome, especially in the television system. They do not appear to be especially troublesome if the TV system is excluded. This could possibly be due to the number of capacitors, frequently large electrolytics, required in television equipment. Of all high-population piece parts, diodes appear to be least troublesome, even slightly less so than resistors.

A maintenance policy change occurred apparently in early 1967. Before that time, most replacements were piece parts; after that, modular replacement became fairly standard. The "modular replacement" column in Exhibit 20 reflects the number of such replacements and includes printed circuit boards and cards, in addition to those cases specifically indicating replacement of a module, amplifier, headset, regulator, etc. The module was either returned to the vendor for repair or the UCR on the module repair was not written against the amplifier. Thus, while it can be assumed that many modular replacements were due to failed piece parts, the type of failed parts cannot be determined. Of the total number of replacements, the ratio is 2/3 for piece parts and 1/3 for modules.

The large entry in the miscellaneous column for television (101) is due primarily to 57 photocell replacements. These were the UCR's in September 1967 against the AGC/DA amplifiers discussed earlier.

A fairly significant number of UCR's (106) reported problems due to part or component aging. Of these UCR's, roughly 60 percent were written against the television system. The parts involved were unknown in most cases, although it could be determined that capacitors accounted for roughly a fourth. It is not known whether the aged parts actually failed or whether they were replaced as a precautionary measure.

Four points should be noted which are significant in spite of the few UCR's associated with them. First, in only 13 cases was the cause of failure attributed to environment, where environment is defined as natural (lightning, rain, etc.) or artificial (improper ventilation, for instance). Hence, it does appear that environment has little effect on amplifiers at KSC, possibly because they are located within electronic enclosures.

EXHIBIT 20 - AMPLIFIER PART FAILURES BY FUNCTIONAL SYSTEM

	Piece-Parts							Modular Replace-ment
	Capa-citors	Tran-sistors	Resis-tors	Diodes	Tubes	Misc.	Unknown	
Television	377	114	30	38	93	101	468	234
OIS-Audio	173	212	37	43	19	30	19	156
OIS-RF	15	15	8	5	10	4	-	502
Range Instrumentation	13	24	1	-	17	8	40	100
Data Transmission	9	-	-	-	65	2	-	102
Telemetry	5	74	8	6	-	1	2	21
PA and Paging	39	16	29	4	103	21	31	4
Measuring	63	31	4	9	-	16	2	90
Totals:	694	486	117	105	307	183	562	1,209

Second, there were 12 cases of bad spares. While this is not significant in terms of the number of cases, it could be significant if it caused extended down-time during critical periods.

Third, in a few cases, less than 5 percent of the data, the problem observed during operation and reported on the UCR could not be reproduced during repair activities. This could reflect an unrealistic simulation of operating conditions in the repair environment or improper operations or maintenance procedures.

Finally, there were 42 cases of blown fuses or circuit breakers. The number of parts protected (that is, did not fail) from the problem resulting in the blown fuses or circuit breakers is unknown. It is assumed, however, that the protection prevented the occurrence of additional down-time. The significance to KSC in terms of "saved" down-time as a result of using circuit protection devices is an area which could be investigated further.

4. Component Population

The engineering analysis revealed 15 sub-populations within the amplifier data base for which FFR calculations can be made. There are 215 time-to-failure observations among 15 amplifier types. In 12 of these types the population is formed by part number of the amplifier. In the remaining three, two part numbers are combined. In each of these 3 cases, the amplifiers are structurally and functionally similar.

Exhibit 4 lists the 15 amplifier types and shows in each case that the number of UCR's with time observations is 10 percent or more of the total amplifier type UCR's.

5. Component Times

The 215 time observations listed in Exhibit 4 are depicted in Exhibits 5 through 19 as the cumulative time-to-failure distribution for each amplifier type. Three of the exhibits reflect a probable inspection at specified maintenance intervals: Exhibits 6 and 17 at 24 months, Exhibit 19 at 12 months.

The minimum, maximum and mean time-to-failure observations for each of the 15 populations is shown in Exhibit 21. The Television Switching amplifier data exhibits a significantly low mean time to failure. Since in this analysis an amplifier is considered failed if at least one part within it fails, the low mean time to failure is probably the result of the complexity of an output television amplifier. High power components are involved. The data do indicate, however, a cause for concern for this amplifier type.

No further analysis is provided for the amplifier types associated with the remaining 29 failure times available in the data base; no population groups of sufficient size for FFR calculation could be formed.

6. Component Failures

The problems associated with each of the 215 time observations are judged to represent an unsatisfactory condition (or failure) attributable to the associated amplifier types.

7. Failure Classification

All 2134 UCR's were classified on the basis of the narrative descriptions of the unsatisfactory conditions and the coded data elements "failure, repair disposition, recommend and reason." Tabulations were then made on the basis of problem classification vs. failure mode. The coded headings of the tabulations for problem classification are defined as follows.

NS (Normal Service). In this category are all those unsatisfactory conditions which arise as a result of normal field operation or for which insufficient information is available to assign it to any of the other four categories. Most amplifier unsatisfactory conditions due to failed piece-parts are included in this category. The part failure involved may have actually been due to a design problem (overstressing, for instance), but there is no way to determine this from the UCR.

OP (Operational Problem). UCR's in this category imply that the unsatisfactory condition was caused or exacerbated by the misuse, incorrect repair or mishandling of the amplifier on the part of the operating

EXHIBIT 21 - MEAN-TIME-FAILURE (DAYS) AND FFR PER 1000 HOURS FOR 15 AMPLIFIER POPULATIONS

Functional System	Amplifier Type	Part Number	Times to Failure Observations (Days)			FFR / 1000 hrs.
			Min.	Mean	Max.	
Television	Switching Amp	3207, 3207 A1 thru A5	5	249	917	0.167
	Switching Output Amp	BO 5390A	16	25.5	44	1.63
	Insert Amp	3207-A12	2	146	541	0.285
	Video Distribution Amp	D5864A, DA61PA	22	184	502	0.226
	Pulse Distribution Amp	5841A, 3202	100	279	707	0.149
	AGC/DA	AG7394A	13	121	452	0.346
OIS-RF	Audio IF Amp	758-0081-001	0	209	971	0.199
OIS-Audio	Headset PCB	24620496	12	136	531	0.307
	AIA PC Card	CO-0046	14	147	296	0.284
	Mike PCB	24620492	3	236	502	0.176
Measuring	Blue or Red Amp	173930	10	362	849	0.115
	Amplifier	723397-1	180	588	1,080	0.0709
	Amplifier	356358-1	360	720	1,080	0.0579
	Amplifier	356410-7	360	814	1,080	0.0512
Range Instrumentation	Multiplexer Amp	20010 and 20011	30	322	390	0.129

or maintenance (O and M) personnel. An example of a classification in this category is a wrong connection resulting from an error in an earlier repair.

QP (Quality Problem). This implies a fault which is neither inherent in the design nor the result of normal (or abnormal) operation. It is generally a manufacturing problem such as the wrong valued parts having been installed by the vendor.

DP (Design Problem). A fault which is inherent in and can be corrected by the amplifier design. An example of a classification in this category is an overheating problem because adequate precautions were not included in the design, even though the amplifier was intended for high-power use.

PM (Preventive Maintenance). This classification includes UCR's that detail conditions which, although not currently unsatisfactory in any operational sense, could become so in the future. An example here is an amplifier that was refurbished when the equipment was undergoing general overhaul.

Each UCR was further categorized according to one of the 16 failure modes listed in Exhibit 22. In establishing these 16 categories and in assigning each UCR to one of the 16, two ground rules were applied. First, the failure mode is that of the affected amplifier and not that of a part within the amplifier nor that of the system in which the amplifier is located. Second, the failure mode assignment for each UCR reflects as nearly as possible the actual information entered on the UCR.

Most of the failure modes listed in Exhibit 22 are self-explanatory, but a few clarifying comments are in order.

- Incorrect Output: Includes cases reporting distorted output, output out-of-spec, DC bounce on output, etc.
- Incorrect Gain: Includes cases reporting loss of gain, low gain, gain variations, incorrect AGC (automatic gain control), etc.
- Noisy: In addition to cases reporting noise conditions, includes ringing, humming and improper filtering.

EXHIBIT 22 - AMPLIFIER FAILURE MODE CATEGORIES

1. No Output
2. Incorrect Output
3. Incorrect Gain
4. Noisy
5. Intermittent
6. Unstable
7. Incorrect Frequency Response
8. Oscillations
9. Defective Power Supply
10. Blown Fuse
11. Incorrect Timing
12. Incorrect Manual Function
13. Inoperative
14. Function Unique
15. Unknown
16. Other

- o Defective Power Supply: Includes cases reporting a power problem, such as loss of regulation, power supply out-of-tolerance, loss of supply voltage(s), etc.
- o Incorrect Manual Function: Includes cases reporting inoperative switch, improper response to switching, loss of indication or incorrect indication, etc.
- o Function Unique: Includes cases reporting an effect that is applicable only to the specific system in which the amplifier is a part. In other words, the amplifier failure mode could not be determined other than as a symptom observed of the system within which the amplifier is functioning. Examples within this category include "video streaking," "no transmit," "poor recorder pen response," etc.
- o Other: Includes all failure modes that are reported less than 1 percent of the time. For the 2134 UCR's in the sample, this means that any failure mode appearing less than 20 or 21 times is included in this category. Examples are "out of adjustment," "clipping," "overheating," etc.

In assigning a failure mode to each UCR, several assumptions were required due to the nature of some of the entries. On many UCR's, failure mode information is restricted to the part level (such as "leaky capacitor") and therefore does not provide any indication of the reaction of the amplifier. In these cases it was assumed that the amplifier failure mode is "unknown" since it could not be determined from the UCR whether the part failure caused "no output," "incorrect gain," etc.

On many other UCR's, failure mode information is restricted to the system level and again, the failure mode of the amplifier cannot be determined. In all of these cases, however, there was sufficient information on the UCR's to justify the assumption that the failure mode was "function unique."

The tabulation of problem classification vs. failure mode for all amplifiers appears in Exhibit 23. A significant point to be noted from this exhibit is that almost all (97.3 percent) amplifier unsatisfactory

EXHIBIT 23 - CLASSIFICATION OF ALL AMPLIFIER UNSATISFACTORY CONDITIONS

	Proximate Cause of Failure[1]						
Failure Mode	NS	CP	QP	DP	PM	Total	%
No Output	417	2	4	1		424	19.8
Incorrect Output	217		1	1		219	10.2
Incorrect Gain	196		2			198	9.3
Noisy	312	2	3	1		318	14.9
Intermittent	57	1				58	2.7
Unstable	20					20	0.9
Incorrect Frequency Response	24			1		25	1.2
Oscillations	31		2			33	1.5
Defective Power Supply	26	3	1	1		31	1.5
Blown Fuse	31					31	1.5
Incorrect Timing	23		1			24	1.2
Incorrect Manual Function	22	1				23	1.1
Inoperative	123		8			131	6.1
Function Unique	464	2	2			468	21.9
Unknown	94	4	2	1		101	4.7
Other (each < 1% of total)	19				11	30	1.4
Total	2076	15	26	6	11	2134	100.0
%	97.3	0.7	1.2	0.3	0.5	100.0	

[1] See text, page A-28, for definition of descriptor codes.

conditions arise during normal service. This is largely due, however, to lack of information on the UCR so that a more proper assignment can be made. This may be due to insufficient information available to the repair personnel when completing the UCR. The repair technician may, for instance, have no way of knowing that a part he replaced has failed because of a QP problem unless the problem is quite obvious.

Of problems arising other than in normal service, QP has the greatest number, followed by O and M. This has little significance, however, due to the few occurrences and the uncertainty implicit in the Normal Service assignments.

Exhibit 24 depicts the failure mode classifications for all UCR's associated with the various amplifier types having installation times available. This exhibit is for normal service conditions only. Other classifications for these amplifier types can be made in only 17 instances. The bottom row of the exhibit indicates the percentage of normal service classifications for each amplifier type.

Function unique is the largest single failure mode group for amplifiers in general (over 20 percent) and roughly half of the various amplifier types indicate this same phenomenon. Since most entries in the function unique category reflect a description of only a system problem, the failure mode of the amplifier itself cannot be known with any certainty. This is also true of the "inoperative" failure mode since inoperative could mean loss of output, loss of supply power, or any number of other conditions. Combining the function unique and inoperative failure modes with the unknown category reveals that the true amplifier failure mode is not known for approximately one-third of all cases.

Excluding the three failure modes discussed above (i. e., function unique, inoperative and unknown), the categories "no output," "noisy," "incorrect output" and "incorrect gain," in that order, comprise the 4 leading failure modes and account for slightly over half of all assignments to amplifiers in general. The remaining 9 failure mode categories all contribute less than 3 percent each (and usually less than 2 percent) to the assignments to amplifiers in general. Except in a few individual cases, the assignments to the specific amplifier types follow this same trend.

	Television, Switching Amp.	Television, Switching Output Amp.	Television, Insert Amp.	Television, Video Dist. Amp.	Television, Pulse Dist. Amp.	Television, AGC/DA	OIS-RF, Audio IF Amp.	OIS-Audio, Headset PCB	OIS-Audio, AIA PC Cord	OIS-Audio, Mike PCB	Measuring, Blue or Red Amp.	Measuring, Amp No. 723397-1	Measuring, Amp. No. 356358-1	Measuring, Amp. No. 356410-7	Range Instrumentation, Multiplexer Amp.
No Output	8	10	3	14	11	46	62	33	1	15	1	1	2	-	7
Incorrect Output	5	2	2	7	4	2	32	4	1	-	15	-	6	1	26
Incorrect Gain	6	-	-	6	5	14	17	3	4	-	3	4	2	3	23
Noisy	14	1	5	9	1	1	101	14	9	19	8	-	-	-	1
Intermittant	6	-	1	-	1	1	-	-	1	1	2	-	-	-	-
Unstable	-	-	-	2	4	4	21	-	7	-	-	-	-	-	2
Incorrect Freq. Response	4	-	6	1	-	1	2	-	-	-	1	-	-	-	-
Oscillations	1	-	2	-	-	-	1	-	-	-	5	-	-	-	-
Defective Power Supply	1	1	1	7	7	-	-	-	-	-	1	-	-	1	-
Blown Fuse	4	1	-	2	-	1	3	-	-	-	-	-	-	-	-
Incorrect Timing	-	-	1	2	2	-	-	-	-	-	11	1	1	1	-
Incorrect Man. Func.	4	-	1	-	5	-	1	-	-	-	-	-	-	-	-
Inoperative	5	1	-	1	1	-	25	24	3	10	1	-	-	-	-
Function Unique	35	2	44	14	3	1	161	31	31	19	-	5	1	1	-
Unknown	3	1	6	1	-	1	20	4	1	1	6	-	-	-	1
Other	1	-	-	-	-	1	1	2	1	-	16	-	-	-	-
Total, Normal Service	97	19	72	66	44	73	447	115	57	65	70	11	12	7	60
Percentage of Total No. of UCR's Classified to Normal Service	100	100	97.3	98.5	100	100	99.1	97.5	96.6	94.2	97.2	100	100	100	100

EXHIBIT 24 - CLASSIFICATION OF UNSATISFACTORY CONDITIONS DURING NORMAL SERVICE BY AMPLIFIER TYPES WITH INSTALLATION TIMES

8. Field Failure Rate

Taking each of the permissible component times for each of the 15 amplifier populations as representing one time to failure, the mean time to failure (MTTF) may be found by summing the individual times to failure and dividing by the appropriate number of observations (that is, failures) for each amplifier type. The field failure rate (FFR) is the reciprocal of the MTTF.

The FFR estimates for the 15 amplifier populations are shown in Exhibit 25. The FFR is shown in the familiar form, field failures per 1000 hours. Combining the data for all 15 amplifiers provides the cover sheet data.

9. Confidence Factors

An examination of Exhibits 5 through 19 shows that the assumption of exponentially distributed times to failure is not unreasonable for most of the populations. This assumption is used in order to calculate the 90 percent confidence interval on the FFR for each of the 15 populations. The confidence intervals, together with associated FFR, are shown in Exhibit 25.

10. Resolution of FFR Rates

There is no evident indication of factors influencing the field failure rate for amplifiers. Environmental factors have negligible effect; quality control, personnel (O and M), or design problems occur in less than 3 percent of the data base. On the basis of the UCR information, the magnitude of the FFR's reflect normal service problems. The failure mode analysis offers little to aid in the isolation of influencing factors.

It is possible, of course, that many of the problems classified herein as normal service are indeed quality, design, and O and M problems. Determination of ways to reduce the amplifier FFR's should include investigations into supply and maintenance policies and procedures.

EXHIBIT 25 - FFR'S AND 90 PERCENT CONFIDENCE INTERVALS FOR 15 AMPLIFIER TYPES

Amplifier Type	FFR	90% CONFIDENCE INTERVAL (Per 1000 Hours)	
		Lower	Upper
Television			
Switching Amplifier: 3207, A1-A5	0.167	0.120	0.222
Switching Output Amplifier: BO-5390A	1.63	0.852	2.62
Insert Amplifier: 3207-A12	0.285	0.172	0.421
Video Distribution Amplifier: D5864A, DA61PA	0.226	0.113	0.372
Pulse Distribution Amplifier: 5841A, 3202	0.149	0.051	0.290
AGC/DA: AG7394A	0.346	0.180	0.555
OIS-RF			
Audio IF Amplifier: 758-0081-001	0.199	0.150	0.254
OIS-Audio			
Headset PCB: 24620496	0.307	0.172	0.473
AIA PC Card: CO-0046	0.284	0.148	0.455
Mike PCB: 24620492	0.176	0.077	0.309
Measuring			
Blue or Red Amplifier: 173930	0.115	0.069	0.170
Amplifier: 723397-1	0.0709	0.039	0.111
Amplifier: 356358-1	0.0579	0.027	0.098
Amplifier: 356410-7	0.0512	0.024	0.087
Range Instrumentation			
Multiplexer Amplifier: 20010, 20011	0.129	0.097	0.166
Overall Average	0.150	0.134	0.167

11. Repair Time

Approximately 90 percent of the UCR's (1,896) provided repair time data. Separate, rather than overall, repair times are reported since repair procedures differ among the various functional systems. For instance, repairing a tube-type video amplifier requires different techniques from repairing a modularized-transistor multiplexer amplifier. Repair time information for the various functional systems as well as the number of UCR's per system is given in Exhibit 26.

The highest mean repair time is for PA and Paging, and this occurred because of significant amounts of time to locate the failure.

Television exhibits the next highest mean repair time and this occurs for at least two reasons. First, the time-to-checkout is significant in many cases; it appears that this is due to complex alignment requirements. Second, modularization of TV equipment is not prevalent so that part replacement was required in a significant number of cases. In fact, in many cases, several parts had to be replaced. To shed more light on this, median repair times were computed for the television system for three cases: (1) overall, (2) when more than one part was replaced, and (3) when repair was by modular replacement. The results are as follows:

Median repair time when more than one part replaced:	~ 6-1/2 hours
Median repair time, overall:	~ 5 hours
Median repair time for modular replacement:	~ 1 hour

297 UCR's against the television system report replacement of more than one part; 142 UCR's report modular replacement.

Range instrumentation mean repair time is also high (4 hours, 18 min.) but this is due to two exceptionally lengthy repairs. If these two cases are excluded, the mean repair time becomes 1 hour, 24 min. The mean-time-to-repair for OIS-Audio (1 hour 36 min.) is somewhat large because it reflects two maintenance policies. After the repair policy changed to modular replacement in early 1967, the mean repair time became 30 minutes.

EXHIBIT 26 - REPAIR TIMES BY FUNCTIONAL SYSTEM

Functional System	No. of UCR's	Repair Time Min. Hrs.	Min. Min.	Mean Hrs.	Mean Min.	Max. Hrs.	Max. Min.
Television	532	-	3	6	7	50	-
OIS-RF	529	-	4	-	31	9	-
OIS-Audio	446	-	6	1	36	15	31
Data Transmission	154	-	2	-	29	2	30
Measuring	43	-	5	-	6	-	49
Range Instrumentation	98	-	5	4	18	168	30
PA and Paging	81	-	15	6	48	38	48
Telemetry	13	-	10	-	28	-	35
All of the above	1896	-	2	2	35	168	30

Sixty-seven UCR's reported "time awaiting replacement." These times ranged from a few minutes to, in one case, 8 months. A tabulation of this information is presented in Exhibit 27. The highest mean-time awaiting replacement (1.7 months) is for OIS-Audio since it contains the 8 month entry. This time becomes 57 hours when the 8 month entry is excluded. Television exhibits the next highest mean-time-awaiting-replacement, primarily because of 6 entries greater than 1 month. Excluding these 6 entries reduces the mean-time-awaiting-replacement to 2 hours 48 minutes. PA and Paging has a long mean awaiting time (67 hours) due to the 640 hour entry. When this entry is excluded, the mean awaiting time becomes 1.6 hours.

EXHIBIT 27 - REPLACEMENT AWAITING TIME BY FUNCTIONAL SYSTEM

Functional System	No. of UCR's	Time Awaiting Replacement					
		Min.		Mean		Max.	
		Hrs.	Min.	Hrs.	Min.	Hrs.	Min.
Television	38	-	15	334	-	1800	-
OIS-RF	0						
OIS-Audio	12	-	10	1.7 months		8 months	
Data Transmission	4	-	20	-	28	-	40
Measuring	0						
Range Instrumentation	0						
PA and Paging	11	-	15	67	-	640	-
Telemetry	2	-	15	-	30	-	45

RELIABILITY ASSESSMENT
OF
BATTERY

Date: 24 May 1972

Observed Field Failure Rate In Failures Per Thousand Hours Of Installed Component Time		0.108
Observed Failure Times, In Hours		
Mean		9,250
Minimum	1,460	
Maximum	17,250	
Number of Observations	9	
Observed Repair Times, In Hours		
Mean		1.48
Minimum	0	
Maximum	6	
Number of Observations	12	

FAILURE MODES AND CAUSES CONTRIBUTING TO THE OBSERVED FIELD FAILURE RATE AS A PERCENT OF THE TOTAL

	Failure Causes			
Failure Modes	Design Problem	Quality Problem	Normal Service	Total
Battery Wearout	0	0	40.8	40.8
Battery Post Problem	0	11.1	0	11.1
Acid Problem	3.7	0	0	3.7
Wiring Error	0	3.7	0	3.7
Safety Control	3.7	0	0	3.7
Overcharged-Boiloff	3.7	0	0	3.7
Shipping	0	3.7	0	3.7
Internal Short	0	0	3.7	3.7
Won't Maintain Charge	0	0	3.7	3.7
Cable Broken/Cut	3.7	0	7.4	11.1
Too Small Gauge	3.7	0	0	3.7
Battery Charger Mech. Misalignment	3.7	0	0	3.7
Battery Rack Acid Problem	3.7	0	0	3.7
Total	25.9	18.5	55.6	100.0

Number of Relevant UCRs: 27 Currency:(1) 26 April 1971

(1)Date of latest UCR run included in the assessment.

DESIGN BACKGROUND DATA

1. Component Description

The component considered in this assessment is restricted to electrical storage batteries used at all KSC locations. These components are listed as major item 360 in the old UCR system and as major item 116 in the new system.

2. Data Base

The KSC UCR data bank was polled for batteries in the major item category. This poll resulted in 26 UCR s of the old type and four of the new type. All of those UCRs are combined into one data base of 30 UCRs.

Three UCRs were coded "battery" incorrectly, referring instead to gaseous nitrogen and helium storage tank batteries; these UCRs have been removed from the data base. Of the remaining 27 UCRs, four referred to cable problems, one to a battery charger problem, one to a battery rack problem, seven to mobile radio battery wearout, and 14 to miscellaneous battery problems.

The earliest failure occurrence date among the 27 acceptable UCRs is 20 December 1965 and the most recent is 25 September 1970; the data retrieval was executed on 26 April 1971. No efforts were made to extend the data base beyond the results of this printout.

3. Engineering Analysis

Although there are very few data points in the data base, there are five subsets into which these data naturally fall. These are battery charger (1 UCR), battery rack (1 UCR), battery cables (4 UCRs), mobile radio batteries (7 UCRs), and miscellaneous, or other, batteries (14 UCRS). The battery charger, battery rack, and cable UCRs, while not specifically battery failures, will be carried throughout the analysis for completeness.

Among these five subsets there is little correlation of specific unsatisfactory conditions except for the mobile radio batteries. In this subset, all batteries suffered natural wearout and were replaced. It is for these failures that the most complete downtime data was given, which will be discussed in section eleven. Of the four cable UCRs, two refer to cables with broken internal wires, one to a cable of too small a gauge for the current requirements, and one to a cable whose locking nut cut the cable upon repeated usage. Corrective action on the first two UCRs was to have them shortened into usable sections. The miscellaneous battery failures were generally unalike except that three were found during initial inspection to have sealing material extruded up around the battery posts, due apparently to missing compression rings. Two of the 27 UCRs refer to acid corrosion problems, one to a battery case and one to a battery rack. In the first case, corrective action was the replacement of batteries with metal cases for those with plastic cases; in the second case, corrective action suggested replacing the metal rack with a wood-lead rack.

A summary of the data available from the 27 UCRs is given for selected categories in Exhibit 1.

4. Component Populations

Considering the 21 battery UCRs in the data base, there are only two separate component populations to which the data seems to easily relate; they are, namely, mobile radio batteries and all other batteries. A third component population is, of course, the set of all batteries.

Three additional component populations are presented by the battery cables (4 UCRs), battery charger (1 UCR), and battery rack (1 UCR).

5. Component Times

Three UCRs bore a "time" data element, one of which was of the old type and two of which were of the new type (entered as "Installed Time"). These three entries referred to batteries of the non-mobile-radio category and are tabulated with failure description below.

Time (Days)	Failure Description
54	Normal wearout
365	Over-charged due to a design change
300	Steel case suffered acid corrosion

EXHIBIT 1 - NUMBER OF DATA ELEMENTS FOR SELECTED CATEGORIES TAKEN FROM BATTERY UCRS

Category	Number of UCRs With Entry	
Total Number of UCRs	27	
Part Number	15(1)	
Serial Number	2(1)	
Vehicle	9	
Time or Age	7(1)	
Launch Complex	17	
Time to Locate	7(1)	Generally not the same UCRs
Time to Repair	7(1)	Generally not the same UCRs
Total Downtime	7(1)	Generally not the same UCRs
Manufacturer	21	
Functional System	22	
Next Assembly Name	22(1)	
Criticality	23(1)	

Note: (1) Not available on the four UCRs of the new type.

Six UCRs (different from the three above), three of the non-mobile-radio battery category, two referring to cables, and one referring to a battery rack, had "Age" entries. These are tabulated with failure descriptions below. All six UCRs were of the old type.

Battery Rack	12	Metal battery rack suffering from acid corrosion
Batteries	12	Battery bank unprotected by safety cover
	18	Internal shortcircuit
	24	Normal wearout
Cables	12	Internal wire broken
	12	Cable cut by locking nut

These six battery failures were due to normal wearout, and corrective action consisted of replacement with a like item.

The complete distribution of the 27 UCRs by failure date is given in Exhibit 2. Age entries are also indicated.

6. Component Failures

Of the 27 UCRs, all refer to legitimate failures as defined by this Reliability Assessment. However, perhaps one deserves further note. On 9 July 1966, a 275 volt storage battery was found to be missing a safety cover. The UCR indicated that such a cover was mandatory and classified the condition as a design problem. The criticality code was entered as "Loss of Vehicle or Life."

It should also be pointed out that in four cases the quantity rejected code was something other than "1". In two cases "0" was entered for initial inspection failures, and in two cases "2" was entered.

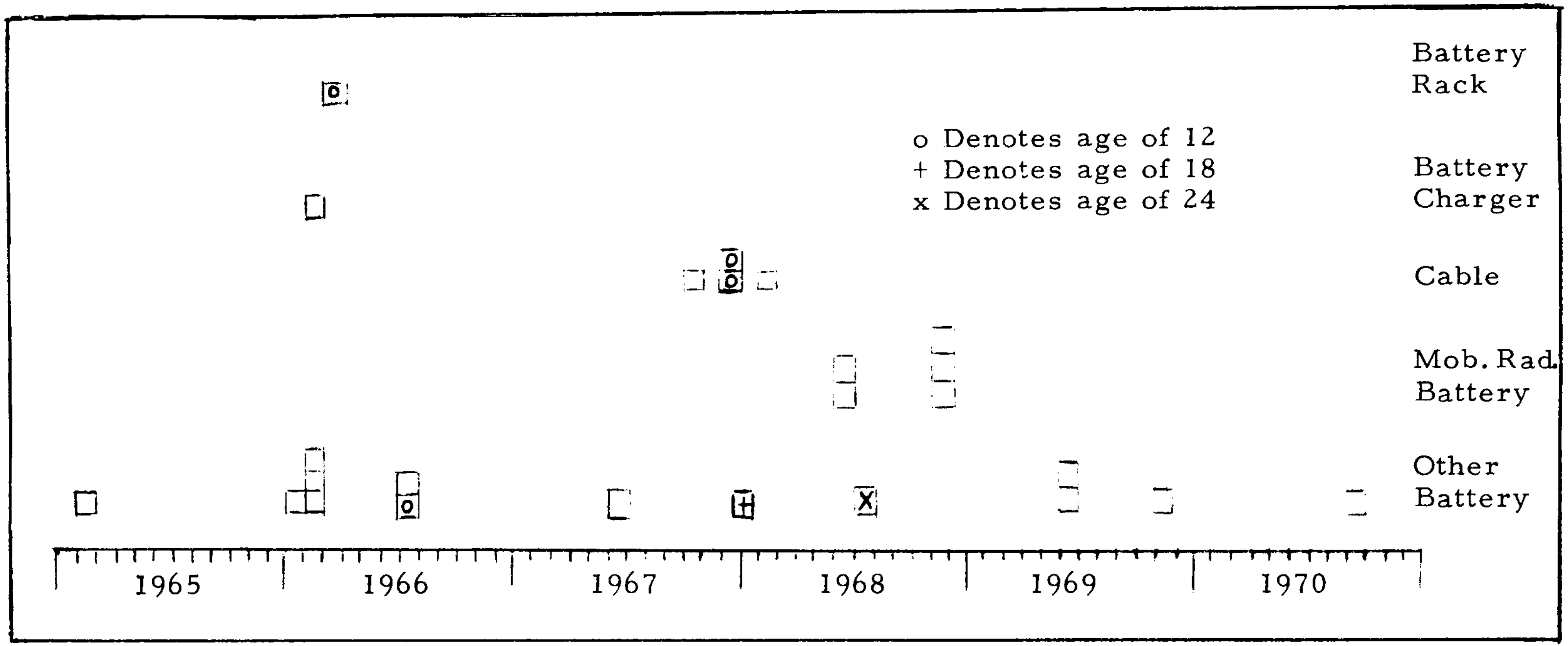


EXHIBIT 2 - DISTRIBUTION OF FAILURE BY OCCURRENCE DATE

In one of these cases two batteries in a ramp generator suffered normal wearout. In the other case, two cells of one 12-volt battery used as uninterrupted power supply in the Flight Training Building suffered normal wearout (internal short). Because of vagaries in the data, no attempt has been made to investigate battery failures in terms of individual cells, and because of the nature of the failure of the ramp generator batteries, this UCR is treated as a single failure.

The table below is a summary of the number of failures given by the data base.

	UCRs	Failures	Batteries
Battery Rack	1	1	0
Battery Charger	1	1	0
Cables	4	4	0
Batteries: Mobile Radio	7	7	7
Non-Mobile Radio	14	14	15
Total	27	27	22

7. Failure Classifications

All 27 failures have been put into three failure mode classifications. These are:

- Design Problem - a fault inherent in and correctable by component design;
- Normal Operation - a failure determined to be due to normal field operation;
- Quality Control - a fault due neither to design nor normal (abnormal) operational problems. Generally a manufacturing error.

Altogether, seven design problems, five quality control problems, and 15 normal operation problems were found.

The battery charger failure, the battery rack failure, two cable failures, and two of the non-mobile-radio battery failures were design problems. These last two were written on UCRs of the new type. All five of the quality control problems referred to non-mobile-radio batteries, and were found during initial inspection or cleaning operations. Two cable failures, six non-mobile-radio battery failures, and all seven mobile-radio battery failures were normal operation problems. Two of these non-mobile-radio battery failures were written in the new UCR format, but bore occurrence dates prior to 15 October 1969. A summary of the failure modes is given in Exhibit 3. It is noted that the failure of a battery due to no safety cover being installed (see discussion in section 6) has been classified as a design failure.

8. Field Failure Rates

Nine entries for the battery population UCRs carried a failure time or age. Combining these indiscriminately they are distributed as shown in Exhibit 4. The mean failure time, $\bar{t}$, is given by:

$$\bar{t} = \sum_{i=1}^{5} t_i \, f_i \Big/ n$$

where n = 9 and t_i and f_i are as given in the table. The value of $\bar{t}$ is 12-2/3 months. Taking the reciprocal of this value and converting units gives an estimated FFR of 0.107 failures per thousand hours.

9. FFR Confidence Intervals

From the tabulation given, the distribution of time-to-failure looks as though it is better described by a normal distribution rather than the usual exponential distribution. Therefore, the standard deviation, s, of the nine failure times is calculated as:

$$s = \left| \sum_{i=1}^{5} \frac{f_i(t_i - \bar{t})^2}{n-1} \right|^{1/2} = 5.9 \text{ months}$$

EXHIBIT 3 - TABULATION OF FAILURES BY FAILURE MODE

Failure Mode		Failure Description
Design		
Battery Rack 1.		Metal back corroded due to action of battery acid.
Battery Charger 1.		Misalignment of gear shaft due to inadequate mounting.
Cables 1.		Cable of too small a gauge to carry proper current.
2.		Locking nut cuts cable upon repeated usage.
Batteries, Other[1]	1.	No safety cover provided.
	2.	Overcharged/Electrolyte boiled off, due to design change.
	3.	Battery cases corroded due to action of battery acid.
Quality Control		
Batteries, Other[1]	1.	Wiring error
	2., 3., 4.	Sealant extruded at post due to missing compression ring.
	5.	Wrong type battery delivered due to shipping error.
Normal Operation		
Cable 1.	1.	Internal wires broken.
2.		
Batteries, M. R.	1., 2., 3., 4., 5., 6., 7.	Normal battery wearout.
Batteries, Other[1]	1., 2., 3., 4., 5., 6.	Normal battery wearout.
	7.	Internal short (two batteries in one application).

Note: (1) Batteries, Other refers to the non-mobile-radio batteries.

EXHIBIT 4 - EMPIRICAL TIME-TO-FAILURE DISTRIBUTION FOR BATTERIES

Index Number i	Failure Time t_i (months)	Number of Failures f_i
1	2	1
2	10	1
3	12	5
4	18	1
5	24	1

and 90 percent confidence limits on the mean are approximated by

$$L \leq \bar{t} \leq U$$

where $L = \bar{t} - 1.860s/\sqrt{n} = 9.0$ months
$U = \bar{t} + 1.860s/\sqrt{n} = 16.3$ months

Taking the reciprocal of those limits and converting to units of failures per thousand hours a 90-percent confidence interval on the mean FFR is given by

$$L = 0.084$$

$$U = 0.15$$

10. Resolution of FFR Factors

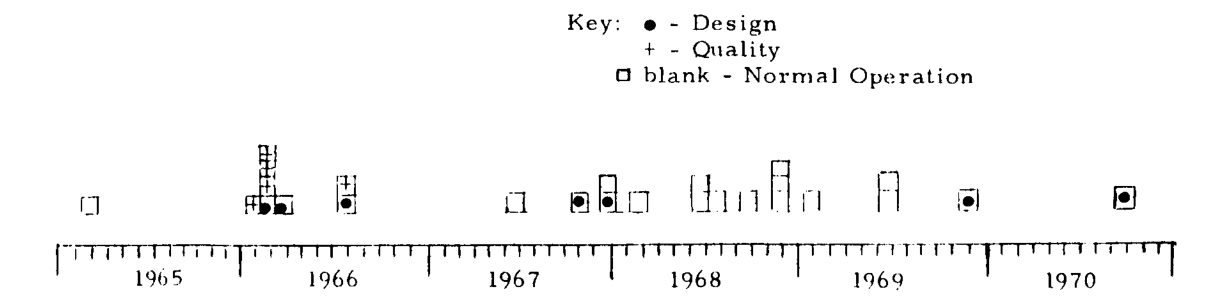
A number of tabulations and cross-comparisons of available data elements are listed in Exhibits 5 and 6. Exhibit 5 tabulates manufacturers against component population, failure modes, and criticality. Exhibit 6 graphs failure mode, component population (see Exhibit 2), and launch complex by occurrence date.

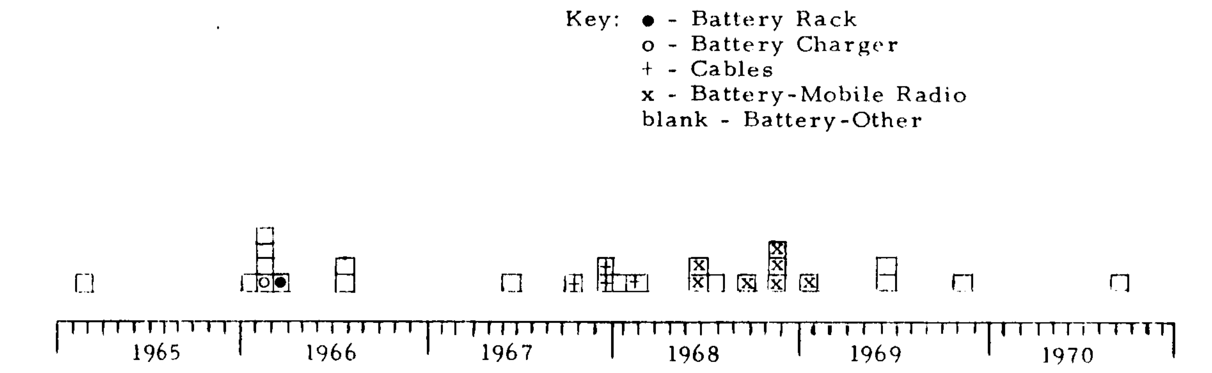
In only two cases was there any indication of repetitive problems. The first of these is the initial inspection discovery of extruded sealant around the battery post. The three occurrences of this problem are 12 February 1966, 24 February 1966, and 28 February 1966. The other case is the seven mobile radio batteries reported between 18 June 1968 and 28 January 1969. No radio appears twice. Furthermore, all other batteries appear to be in unlike applications with no part numbers or next assembly data, when given, occurring twice.

It is relatively clear from Exhibit 5 that quality problems have been solved. This does not substantially impact the field failure rate, however, since only one quality problem had an associated failure time and that was 12 months; very near the mean value.

	Total UCRs	Unknown	Gulton	Gen. Electric	Exide	Raytheon	Stokes	Mallory	Prestolite	Eveready	Gen. Battery	Dello-Remy	Chrysler	Byrne Door
Total No. of UCRs	27	6	5	5	2	1	1	1	1	1	1	1	1	1
Failure Mode														
Design	7	3	1	1	0	0	1	0	0	0	0	0	0	1
Normal Opn.	15	3	0	4	2	0	0	1	1	1	1	1	1	0
Quality	5	0	4	0	0	1	0	0	0	0	0	0	0	0
Criticality														
Loss of Veh/Life	1	0	0	0	0	0	1	0	0	0	0	0	0	0
CD Scrub/PI	1	0	0	0	0	0	0	1	0	0	0	0	0	0
LH/No I	4	0	1	0	2	0	0	0	0	0	0	0	0	1
DL-No CD/LE	8	2	1	4	0	0	0	0	0	1	0	0	0	0
No Priority	7	2	2	1	0	1	0	0	0	0	0	0	1	0
Unknown	6	2	1	0	0	0	0	0	1	0	1	1	0	0
Component Population														
Battery Rack	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Battery Charger	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Cables	4	2	0	1	0	0	0	0	0	0	0	0	1	0
Battery, Mob. Rad.	7	2	0	4	0	0	0	0	0	1	0	0	0	0
Battery, Other	14	2	4	0	2	1	1	1	1	0	1	1	0	0

EXHIBIT 5 - TABULATION OF MANUFACTURER VERSUS FAILURE MODE, CRITICALITY, AND COMPONENT POPULATION





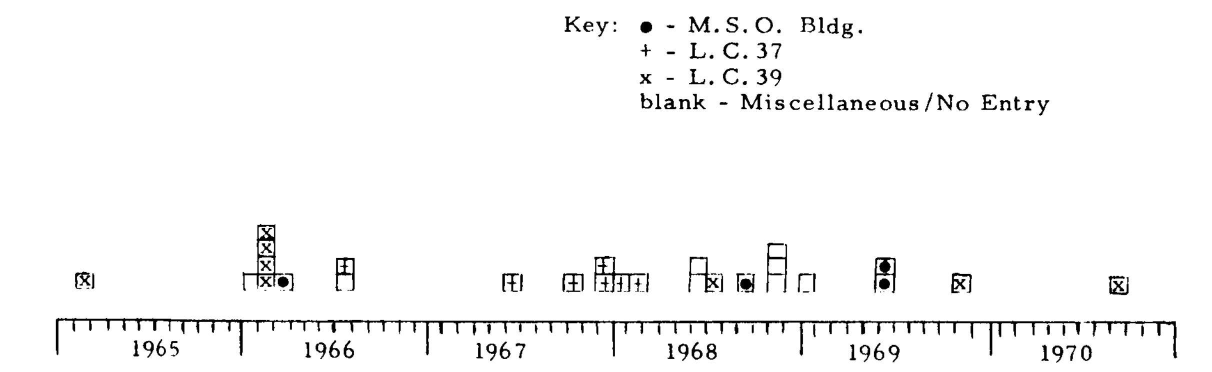


EXHIBIT 6 - GRAPH BY OCCURRENCE DATE OF FAILURE MODE (TOP), COMPONENT POPULATION (MIDDLE), AND LAUNCH COMPLEX (BOTTOM)

11. Repair Time

The most interesting time-related entries on these UCRs were "Time to Locate," "Time to Repair," and "Total Downtime." Twelve UCRs bore entries in these categories, five referring to non-mobile-radio batteries, six referring to mobile-radio batteries, and one referring to cables. Since this information is unavailable on UCRs of the new type, all 12 UCRs are of the old type. The entries as they appeared on the UCRs are given below; it should be noted, however, that "Total Downtime" is usually taken as the sum of the other two items. Considering total downtime to be at least the sum of time to repair and time to locate, it is seen that six mobile radios were down at least a total of 8 hours for an average of at least 1 hour and 20 minutes.

	Time to Locate	Time to Repair	Downtime
Cable:	1 hr.	1 hr.	1 hr.
Non-Mobile-Radio Batteries:	4 hrs.	2 hrs.	-
	1 hr.	-	1 hr.
	0 hr.	0 hr.	0 hr.
	15 min.	-	-
	30 min.	1 hr.	1 hr. 30 min.
Mobile-Radio Batteries:	20 min.	40 min.	-
	-	2 hr.	-
	-	-	1 hr.
	-	-	1 hr.
	-	-	1 hr.
	-	2 hr.	-

The six non-mobile-radio batteries caused a total downtime of 9 hours and 45 minutes or an average of just over an hour and a half each. Combining the data for all batteries indicates a mean downtime of 1.48 hours.

RELIABILITY ASSESSMENT
OF
CABLE ASSEMBLIES

Date: 24 May 1972

	Electrical	Mechanical
Observed Field Failure Rate In Failures Per Thousand Hours Of Installed Component Time	0.142	0.054
Observed Failure Times, In Hours		
Mean	7,450	17,000
Minimum	0	730
Maximum	43,800	35,000
Number of Observations	76	14
Observed Repair Times, In Hours		
Mean	3	8
Minimum	0	4
Maximum	106	14
Number of Observations	210	3

FAILURE MODES AND CAUSES CONTRIBUTING TO THE OBSERVED FIELD FAILURE RATE AS A PERCENT OF THE TOTAL

Problem Classification (Percent)	Electrical Cable Assemblies	Mechanical Cable Assemblies
Cause of Failure		
System Design	30	64
Cable Quality Control	25	-
Normal Operation	15	18
System Quality Control	12	9
Operation and Maintenance	10	9
All Others	8	-
Predominant Failure Modes		
Shorted	20	-
Damaged Cable	16	27
Defective Insulation	21	-
Broken	9	27
Defective Connections	16	-
Preventive Maintenance	-	46
All Others	18	-

Number of Relevant UCRs: 830 Currency:[1] 16 June 1969

[1] Date of latest UCR run included in the assessment.

DESIGN BACKGROUND DATA

1. Component Description

The device most often reported under the description "cable assembly" is the typical electrical cable consisting of a number of wires wrapped together and terminated at each end with a suitable connecting device. These are generally used to transmit power or signals from one "black box" to another. Also included under this component description are mechanical cable assemblies which are essentially wire ropes with suitable terminators used for support, etc. All devices are, of course, restricted to those used in KSC GSE.

2. Data Base

The UCR data bank retrieval on major item 397 brought forth 830 UCR's. Each unsatisfactory condition report is more or less pertinent to the component described above. The characteristics of the data base are commented on briefly in the following section.

3. Engineering Analysis

The 830 UCR's in the data base represent an extremely wide variety of cable assembly types and unsatisfactory conditions. Dates of occurrence range from early 1965 to early 1969. The overwhelming majority of data involves electrical cable assemblies; whereas only about 3 percent represent strictly mechanical cable assemblies. In some cases unsatisfactory connector conditions were included in the cable assembly data base; these UCR's are also included in this analysis.

A decided decrease in the rate of UCR occurrence from its peak in early 1966 to the limit of available data (early 1969) is quite evident. A monthly plot of UCR's versus time is given in Exhibit 1, normalized to the number of UCR's occurring in January 1966 to more readily enable comparisons to be made.

Nearly 60 percent of the UCR's originate from launch complex 39 and its environs with the bulk of the remainder coming from complexes 34 and 37. An extremely wide variety of functional systems, next assemblies, etc., are presented on the UCR's as would be expected from such a ubiquitous component as cable assemblies. Ninety-eight of the

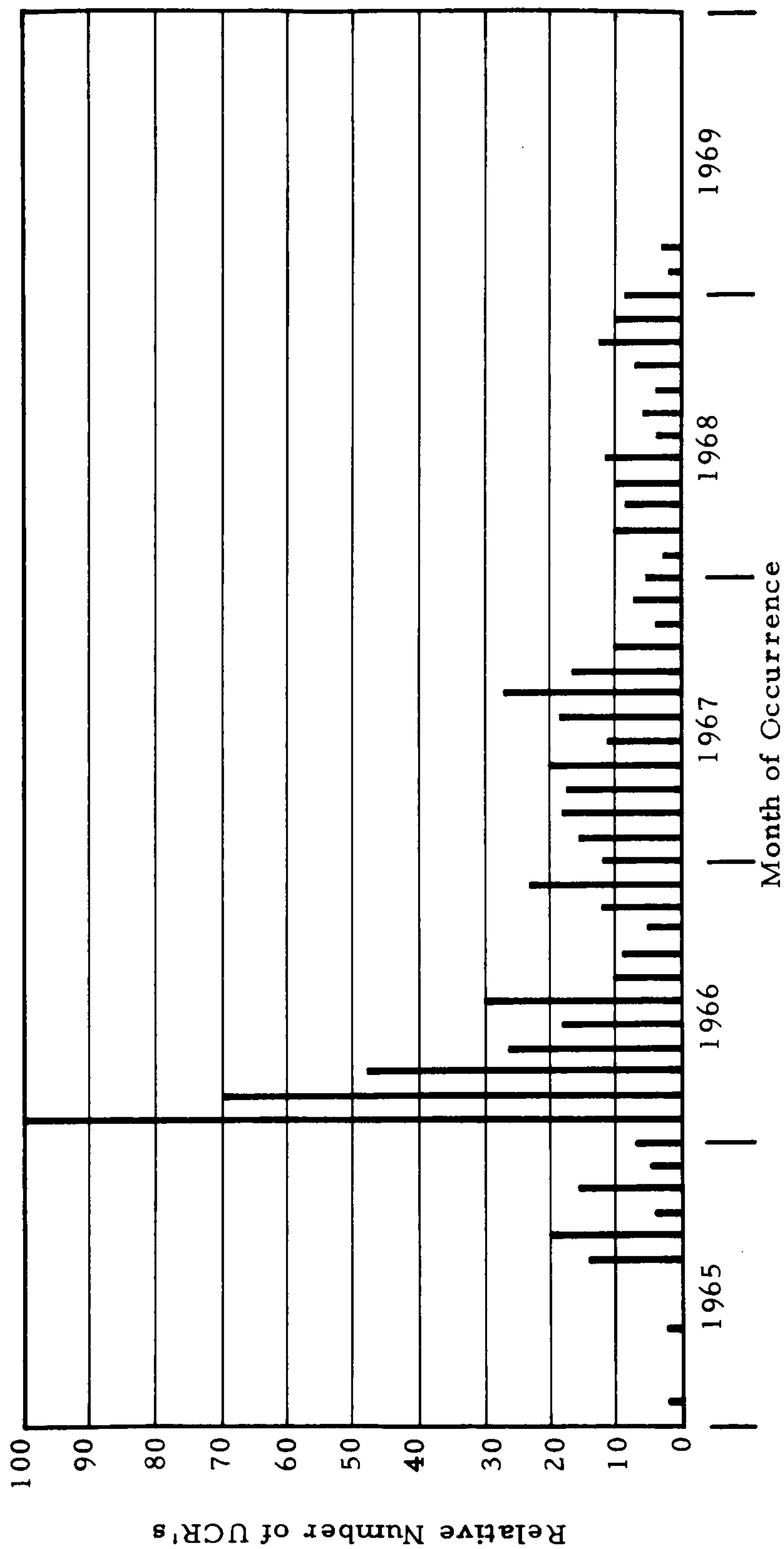


EXHIBIT 1 - UCR OCCURRENCE FREQUENCY VERSUS TIME

UCR's contain entries regarding component in-service time upon occurrence of the unsatisfactory condition and provide the time required to repair the unsatisfactory condition. These items are treated in more detail in the subsequent sections.

4. Component Populations

Other than the obvious dichotomy between mechanical and electrical cable assemblies there is no clear way to assign a given cable assembly to a unique sub-population of substantial size. An obvious classification would be cable length and capacity (number of wires) but neither of these factors is generally available. Part numbers are much too diverse to form the basis of population discrimination.

Furthermore, the quantity of available component in-service time data is not of sufficient magnitude to warrant the definition of numerous populations. Therefore, for the purposes of failure rate calculations only three subpopulations have been defined; (1) all heavy-duty mechanical cable assemblies, (2) electrical cable assemblies at launch complex 39, and (3) electrical cable assemblies at launch complexes 34 and 37.

5. Component Times

All available age entries are taken directly from the UCR printout and are shown in Exhibit 2 by the selected populations. Eleven entries which do not fit the categorization have been excluded. Decimal entries were recorded as hours on the UCR's and converted to months by dividing by 730 hours per month. Note the grouping of failure times at half-year intervals, particularly at 6, 12 and 24 months. This probably reflects the fact that most age entries are educated guesses rather than measurements and hence tend to group as shown. The entries indicating zero time reflect those items received bad from the manufacturer and detected during installation, etc.

6. Component Failures

All 87 UCR's for which component time information is tabulated above are judged to represent a failure of a cable assembly; furthermore, only one attributable failure is reported per UCR. The number of

EXHIBIT 2 - COMPONENT TIMES FOR VARIOUS CABLE ASSEMBLY POPULATIONS

	Cable Assemblies (Age at Failure Frequency in Months)		
		Electrical	
Age	Mechanical	LC39	LC34/37
0	-	2	14
0.114	-	-	1
0.137	-	-	1
1	1	4	2
2	-	4	-
2.58	-	1	-
2.65	-	-	1
3	-	-	1
3.55	-	-	1
5	-	1	1
6	-	4	5
9	-	1	1
11	1	1	-
12	-	5	5
14	1	1	-
15	-	-	2
16	-	1	-
18	-	2	2
24	4	3	4
30	-	1	1
36	3	-	1
40	-	-	1
48	1	-	-
60	-	-	1

failures for each population can be counted from Exhibit 2; the numbers are: 11 for mechanical cable assemblies, 31 for electrical cable assemblies at launch complex 39 and 45 for those at launch complexes 34 and 37.

7. Failure Classifications

Each of the 87 failures have been classified according to its failure mode, its failure mechanism and its failure cause. These are tabulated, by population, in Exhibit 3 and further summarized on the cover sheet. Note the extremely high incidence of failure causes other than normal operation and in particular the category referred to as system design.

The headings of Exhibit 3 are for the most part self-explanatory. The item heading called Preventive Maintenance under failure mode denotes a repair, or corrective action, undertaken in anticipation of a failure and thus is counted as a failure and included as a failure mode. The dichotomy between a "system" and "cable" under Failure Cause is intended to reflect those UCR's written against the cable assembly for which the cable assembly itself is not at fault but rather the cable/system interaction.

8. Field Failure Rates

Exhibit 2 contains all the data requisite for the calculation of field failure rates for the three selected cable assembly populations. The following tabulation (using a conversion factor of 730 hours per month) summarizes the calculations.

	Cable Assembly Population		
	Mechanical	Electrical	
		L.C. 39	L.C. 34/37
No. of Failures	11	31	45
Mean-Time-To-Failure (Months)	25.3	9.41	9.85
Failure Rate (failures/month)	0.040	0.106	0.101
Failure Rate (failures/1000 hours)	0.054	0.146	0.139

EXHIBIT 3 - CLASSIFICATION OF CABLE ASSEMBLY FAILURES

	Cable Assemblies		
		Electrical	
	Mechanical	LC39	LC34/37
Failure Mode			
Shorted	-	9	6
Damaged Cable	2	4	8
Preventive Maintenance	5	5	1
Defective Insulation	-	-	9
Broken Conductor(s)	-	4	3
Defective Connector	-	-	5
Poor Connection	-	4	-
Low Insulation Resistance	-	2	2
Mating Difficulty	-	-	3
Cable Too Short	-	1	2
Improper Assembly	-	-	2
Wrong Part	-	-	2
Cable Not Dynathermed	-	-	2
Broken Cable	2	-	-
Frayed or Broken Strands	2	-	-
Poor Continuity	-	1	-
Excessive Voltage Drop	-	1	-
Failure Source			
Improper Installation Design	7	9	4
Poor Installation or Maintenance	1	11	6
Defective Manufacture	-	3	13
Improper Cable Specification	1	3	7
Inadequate Interface Specification	-	4	1
Corrosion	-	-	3
Wear	2	-	1
Secondary Failure	-	-	1
Unknown	-	1	9

EXHIBIT 3 (Continued)

	Cable Assemblies		
		Electrical	
	Mechanical	LC39	LC34/37
Failure Cause			
System Design	7	16	7
Cable Quality Control	-	3	16
Normal Operation	2	2	9
System Quality Control	1	4	5
Operation and Maintenance	1	6	2
Cable Design	-	-	4
Unknown	-	-	2

The field failure rates for the two electrical cable assembly populations are clearly not significantly different. Hence, that data may be combined to give a composite field failure rate for electrical cables used in KSC GSE of 0.142 failures per 1000 hours (equivalent to an MTBF of 9.67 months).

9. FFR Confidence Intervals

Ninety percent confidence intervals are calculated for both mechanical and electrical cable assemblies under the assumption that the times to failure of each are adequately described by an exponential distribution. These limits are:

	Field Failure Rate (failure/1000 hours)		
	Lower Limit	Mean	Upper Limit
Mechanical Cable Assemblies	0.030	0.054	0.084
Electrical Cable Assemblies	0.116	0.142	0.169

10. Resolution of FFR Factors

On the basis of Exhibit 3 (supported by detailed examination of the UCR's) no more than one failure in 6 can be attributed simply to the inherent unreliability of cable assemblies. Indeed, over 1/3 of all failures can be attributed to system design, i.e., these failures would not have occurred if the pertinent piece of GSE were more adequately designed. Over 40 percent of the failures are directly associated with cable installation divided nearly equally between actual workmanship and faulty specifications.

Only ten percent of the Launch Complex 39 electrical cable assembly failures were attributed to defective manufacture whereas nearly 30 percent were so classified at Complexes 34 and 37. This phenomenon is also reflected in the greater proportion of zero-time failures at L.C. 34/37. It may indicate improved cable assembly manufacture or, perhaps, only different reporting procedures. Almost half of the mechanical cable assembly failures took the form of preventive maintenance, i.e., replacing the cable prior to an impending failure. Only two of 11 mechanical cable assembly failures were due primarily to simple wear-out.

In any event, solely by improving design, quality control, operation and maintenance both at KSC and at the point of cable assembly manufacture, it would be possible to reduce the cable assembly field failure rates given above by a factor of 6.

As noted previously the incidence of UCR occurrence is becoming less frequent; unfortunately, there are insufficient data to quantify this phenomena in terms of the field failure rate.

11. Repair Time

Nearly half of all the UCR's in the data base contain some information with respect to repair time induced by the cable assembly UCR. Exhibit 4 is a plot giving the cumulative frequency of total down time for all electrical cable assemblies. Exhibit 5 collects some repair time statistics of interest to the three selected sub-populations.

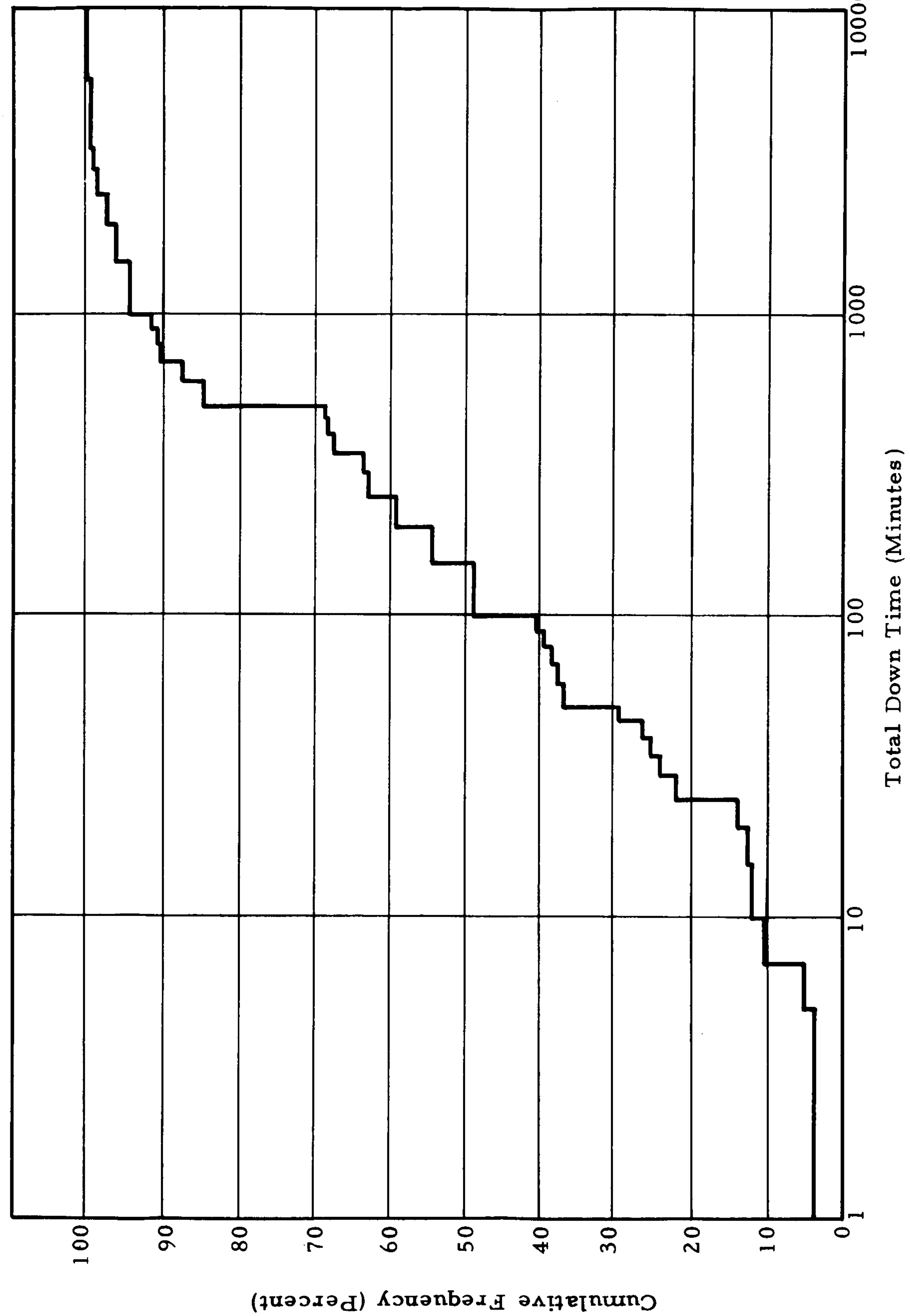


EXHIBIT 4 - CUMULATIVE DISTRIBUTION OF TOTAL CABLE ASSEMBLY DOWN TIME

EXHIBIT 5 - CABLE ASSEMBLY REPAIR TIME STATISTICS

	Number of Entries	Repair Time Element (Minutes)		
		Minimum	Mean	Maximum
Mechanical Cable Assemblies				
Time to Locate	4	0	5	15
Time to Repair	4	240	352	840
Total Down Time	3	240	480	840
Electrical Cable Assemblies				
Launch Complex 34/37				
Time to Locate	36	10	25	2,400
Time to Repair	25	30	180	2,880
Total Down Time	31	10	165	3,360
Launch Complex 39				
Time to Locate	21	0	60	780
Time to Repair	13	0	30	5,760
Total Down Time	17	0	45	6,360
All				
Time to Locate	349	0	30	15,000
Time to Repair	173	0	180	5,760
Total Down Time	210	0	172	6,360

RELIABILITY ASSESSMENT
OF
CAPACITORS

Date: 24 May 1972

Observed Field Failure Rate In Failures Per Thousand Hours Of Installed Component Time		0.072
Observed Failure Times, In Hours		
Mean		1.9
Minimum	1	
Maximum	120	
Number of Observations	122	

	TV Functional System		All Others	
Observed Repair Times, In Hours				
Mean		13.8		4.3
Minimum	0.08		0.05	
Maximum	696		77	
Number of Observations	202		203	

FAILURE MODES AND CAUSES CONTRIBUTING TO THE OBSERVED FIELD FAILURE RATE AS A PERCENT OF THE TOTAL

Condition and Operating Mode of Failure	Proximate Cause of Failure					
	Normal Service	C&M	Quality	Design	Preventative Maintenance	All
Overstressed, Electrical/Mechanical		0.40		0.25		0.65
Physically Damaged		0.05	0.15	20.1		20.2
Bad Solder Joints	0.95		0.65			1.6
Received Faulty			0.60			0.6
Incorrect Size/Not to Specs./Missing				1.3		1.3
Environmentally Damaged	0.15			0.05		0.2
Aged	3.3				2.9	6.2
Leaking	14.0				0.35	14.4
Short	6.8					6.8
Open	5.8					5.8
Cracked Insulation/Broken	0.35					0.35
Secondary	0.75					0.75
Unknown	39.6				1.3	41.0
All	71.8	0.45	1.40	21.7	4.6	100.0

Problem Classification (Percent)

Number of Relevant UCRs: 738   Currency:(1) 16 June 1969

(1)Date of latest UCR run included in the assessment.

DESIGN BACKGROUND DATA

1. Component Description

Capacitors, the major item analyzed in this section, are the familiar electrical devices which store a charge when operating in a DC circuit and alternately charges and discharges to present an impedance when operating in an AC circuit. The capacitors in the sample are the types used in electronic assemblies and in electrical power supplies and are found in various applications within KSC ground support equipment.

2. Data Base

The retrieval from the UCR data bank on major item code 810 resulted in 745 UCR's, seven of which were incorrectly coded, and thus eliminated. Each of the 738 UCR's used in the analysis reports an unsatisfactory condition deemed to be assignable to a capacitor(s). Less than 5% of the UCR's also report other piece parts as being associated with the problem being discussed.

The data base could be extended by considering other major item codes which are known to contain capacitors as piece parts, such as amplifiers (348), encoders (481), printed circuit boards (640). While capacitor failures not considered here (because they are reported elsewhere) are suspected to be significant in terms of number, the large sample size underlying this analysis is considered quite representative of the KSC capacitor problems.

The capacitor data base consists of 2,005 capacitor failures reported on 738 UCR's.

3. Engineering Analysis

A summary of pertinent data elements on the 738 UCR's is presented below.

The UCR's cover a calendar time span from early 1966 to early 1969. A discontinuity appears in the number of UCR's generated at the beginning of 1968. Exhibit 1 shows that the number of capacitor UCR's per month throughout 1966 and 1967 was relatively low, 4 per month on the average. In the 15-month period beginning January 1968,

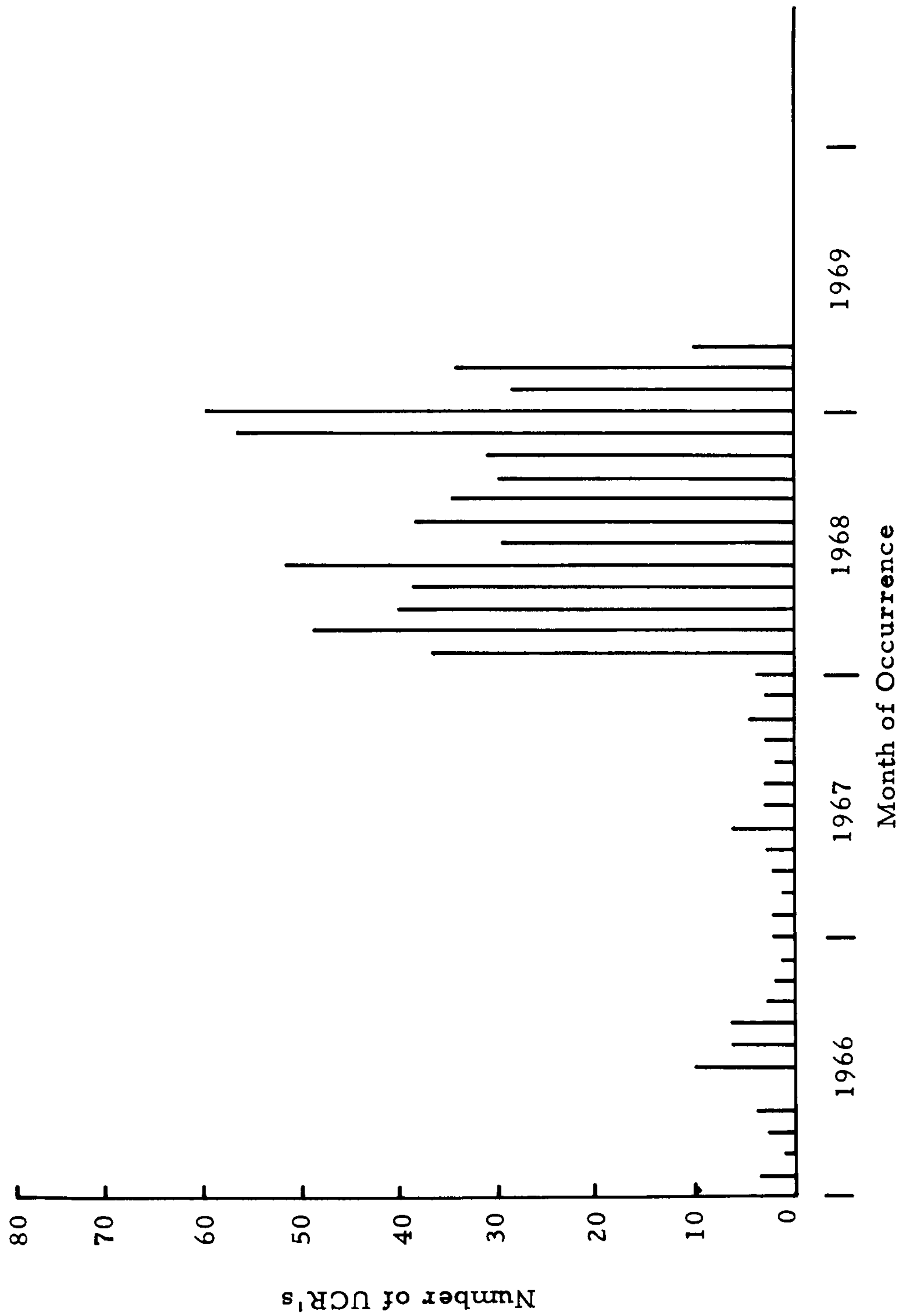


EXHIBIT 1 - UCR OCCURRENCE FREQUENCY VERSUS TIME

the average number of UCR's per month is 43. A possible explanation for this sudden and continued high level of UCR generation can be found in the observation that all UCR's written after the beginning of 1968 are prepared by FEC; all UCR's (except one) written prior to 1968 were prepared by an organization other than FEC. While it is possible that capacitors were added to the code table as a major item at the beginning of 1968, it is believed to be more likely that the discontinuity of Exhibit 1 reflects the increased emphasis placed on detail reporting by an organization newly assigned to the task. The discontinuity does not adversly affect the analysis herein but should be noted.

Nineteen functional systems are represented among the capacitor UCR's. Exhibit 2 shows the distribution of the UCR's and the associated capacitor failures by functional system with a further breakdown to next higher assembly for the Television Functional System. The Television Functional System accounts for 65% of the 738 UCR's and 64% of the 2,005 capacitor failures. All but 4 of the Television UCR's were generated after January 1968. The 453 failures of the Range Instrumentation Functional System occurred primarily before January 1968 (only 14 occurred after that date) and represent almost totally design problems associated with the equipment in which the capacitor was used.

No particular trend is evident among the capacitor failures that could be attributed to size and voltage. The problems occur on capacitors ranging in size from < 1.0 mfd to > 10,000 mfd and from < 15v to > 6,000v. Relatively little information is available for capacitor type. That at least 52% of the failing capacitors could be classified aluminum electrolytic from their brand names (i.e., MEC, Sprague TE Series, and Cornell Dubilier BR Series) may simply reflect the relative application frequency of this type of capacitor in the GSE.

Only 122 time or age entries were recorded on the UCR's. It is assumed in each case that these entries are time estimates logged against the next higher assembly in which the capacitor failed. A detailed analysis of all the next higher assemblies and their serial numbers identified on the UCR's resulted in no instances of repeat capacitor

EXHIBIT 2 - PARTIAL DISTRIBUTION OF CAPACITOR UCR'S AND FAILURES BY FUNCTIONAL SYSTEM AND NEXT HIGHER ASSEMBLY

FUNCTIONAL SYSTEM	Number of UCR's	Number of Failures
Television	482	1259
(Next Higher Assemblies)		
8" Monitor		261
Switching Amplifier		222
Insert Amplifier		217
Video Distribution Amplifier		177
Pulse Distribution Amplifier		69
DA-AGC Amplifiers		65
Demodulator		38
Power Supply		37
Phase Connector		29
Camera and Camera Control		23
21" Monitor		20
All Others (18 Next Assembly)		101
Range Instrumentation	77	453
Countdown Distribution	41	54
Data Transmission	35	69
OIS-RF	33	62
OIS Audio	15	21
Timing Distribution	13	13
P.A. and Paging	10	29
All Others (11 Functional Systems)	32	45
TOTAL	738	2005

failures (i.e., by the identical find number) from which further age data could be determined. The distribution of the 122 failure times is shown in Exhibit 3. Thirty-six of the 40 failures occurring at 24 months were reported as the result of maintenance action; it is probable that the actual date of failure occurrence is less than 24 months.

Over half of the UCR's (54%) were written against Launch Complex 39, with the Command Distribution Center, MSO Building and LC-34 contributing together another 24%. The remaining were essentially unclassified.

4. Component Population

The engineering analysis indicates that there is only one potential capacitor sub-population for which field failure rates (FFR's) can be calculated. This is not unexpected since there are only 68 UCR's with time or age entries. For these UCR's, representing 122 capacitor failures, the time entries are actually associated with the assembly in which the capacitor is used.

Were time entries available, sub-populations exist in sufficient size to warrant FFR calculations. Aluminum electrolytic capacitors, with 1,043 failures, are a good example. Also, categorization by size and voltage reveals such frequencies of occurrence as 253 failures of 50 mfd 50 volt capacitors and 82 failures of 500 mfd 15 volt capacitors. Unfortunately, insufficient data exist to derive FFR's for these, and similar, populations. In the sequel only those capacitors with time entries are treated in the FFR calculation and they are combined into a single sample.

5. Component Time

The 122 available time entries are each assumed to represent one-time-to-failure for the associated capacitors. These are combined and plotted in Exhibit 3. The underlying assumption here is that time-to-failure of the equipment reporting the capacitor failure can be assigned as the time-to-failure of the capacitor. The frequency of failures by time-to-failure in months is as follows:

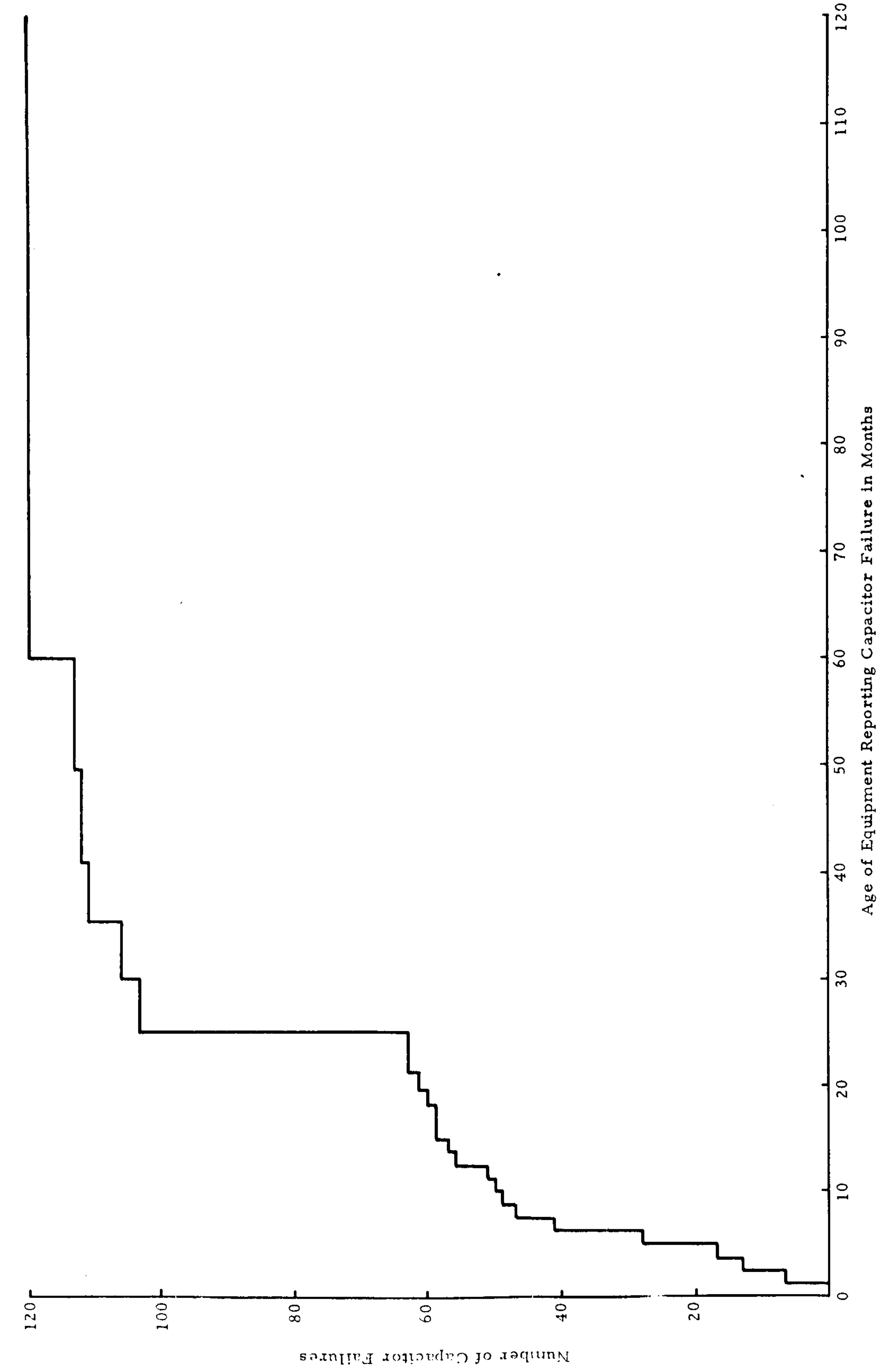


EXHIBIT 3 - CUMULATIVE DISTRIBUTION OF TIME-TO-FAILURE

Time-to-Failure (Months)	No. of Capacitor Failures	Time-to-Failure (Months)	No. of Capacitor Failures
1	7	15	2
2	6	18	1
3	4	20	1
4	11	21	1
6	13	24	40
7	6	40	3
8	2	36	5
10	1	42	1
11	1	48	1
12	6	60	8
14	1	120	1

6. Component Failures

Of the 122 capacitors with time entries, all are judged to represent an unsatisfactory condition, or failure. The large number of entries, 40, at 24 months is suspected of being the result of a scheduled inspection or tests and may represent unsatisfactory conditions occurring at some time less than 24 months. It may also represent a correction of a condition which has not yet resulted in equipment inoperation. From the narrative description on the UCR's, it is believed that the high frequency at 24 months can be attributed to the former reason.

7. Failure Classifications

Classifying all 738 UCR's on the basis of the narrative descriptions of the unsatisfactory condition report and the UCR coded data elements, "failure," "repair disposition," "recommend," and "reason" results in the tabulation of Exhibit 4.

The "cause of failure" headings in that exhibit are defined as follows.

NS (Normal Service). All conditions which arose as the result of normal field operation or for which insufficient information is available to assign it to any of the other categories.

O and M (Operational and Maintenance). Problems classified under this heading imply that the condition was caused by improper equipment usage by operating and maintenance personnel. This

EXHIBIT 4 - CAPACITOR FAILURE CLASSIFICATION BY CAUSE AND MODE

Condition and Operating Mode of Failure	Cause of Failure						
	NS	C&M	QP	DP	PM	Σ	%
Overstressed, Electrical/Mechanical		8		5		13	0.65
Physically Damaged		1	3	403		407	20.2
Bad Solder Joints	19		13			32	1.6
Received Faulty			12			12	0.6
Incorrect Size/ Not to Specifications				27		27	1.3
Environmentally Damaged	3			1		4	0.2
Aged	66				59	125	6.2
Leaking	281				7	288	14.4
Short	137					137	6.8
Open	116					116	5.8
Cracked/Broken Insulation	7					7	0.35
Secondary	15					15	0.75
Unknown	795				27	822	41.0
Σ	1439	9	28	436	93	2005	100.0
%	71.8	0.45	1.40	21.7	4.6	100.0	

includes such actions as wrong frequency applied, excessive voltage, and improper securing of the equipment.

QP (Quality Problem). A classification that implies a fault neither in the design of a capacitor or its next higher assembly nor the result of normal or abnormal operation. It is generally a manufacturing problem such as bad solder joints for a capacitor on a card, or a shipping and packaging problem such as physical damage.

DP (Design Problem). A fault which is inherent in and can be corrected by design of the equipment in which the capacitor is used. A particularly frequent problem (discovered and corrected prior to 1968) was improper ventilation of equipment resulting in an extreme heat condition in turn causing loss of capacitors.

PM (Preventive Maintenance). Those conditions in which the capacitor was removed to prevent possible inoperative equipment at a later date.

Each capacitor failure was further categorized according to one of the thirteen condition and operating modes of failure listed below.

1. Overstressed, electrical/mechanical
2. Physically damaged
3. Bad solder joints
4. Received faulty
5. Incorrect size/not to specifications
6. Environmentally damaged
7. Aged
8. Leaking
9. Short
10. Open
11. Cracked/broken insulation
12. Secondary (inoperative due to another failure)
13. Unknown

8. Field Failure Rates

Using each of the 122 capacitor failure times tabulated above as representing one capacitor time-to-failure (TTF), the mean TTF (MTTF) may be found by summing the times and dividing by 122. The FFR is the reciprocal of the MTTF. These two values are

MTTF = 19.1 months

FFR = 0.052 failures/month

Using a conversion factor of 730 hours per month,

MTTF = 13,900 hours

FFR = 72 failures/million hours

If the data presented on Exhibit 3 is adjusted to remove those failures appearing at 24 months that are suspected of being the result of maintenance actions, the MTTF calculation changes relatively little (from 19.1 months to 20 months). For purposes here all 122 data elements are used.

9. FFR Confidence Intervals

An exponential distribution of the times-to-failure is assumed. Since the MTTF is not significantly affected by adjusting the entries at 24 months, this assumption is not as unreasonable as it might appear from Exhibit 1. The 90% confidence interval on the FFR is from 61 to 82 failures per million hours.

10. Resolution of FFR Factors

Exhibit 4 shows that at least 1/4 of the total capacitor problems are due to other than normal service type problems. The 795 failures for which no failure mode could be determined were generated primarily after January 1968, and for this reason are believed to be the result of either normal service problems or preventive maintenance actions, rather than design or quality problems. A good assumption is that their mode of failure is probably distributed in proportion to the four highest modes of failures shown in Exhibit 4, excluding physically damaged, i.e., aged, leaking, short, and open.

11. Repair Times

The repair times associated with the capacitor UCR's are those times required to repair a larger assembly by replacing the failed capacitor(s). An analysis of the total repair times given on 505 of the

UCR's shows a significantly longer average repair time for those capacitor failures in the TV functional system than that required in the other 18 functional systems represented in the data base. The reason for this longer average repair time is two-fold. First, the repair, once the capacitor is located and replaced, requires considerable time for check-out and realignment, a requirement not so prevalent in the other functional systems. Second, over 60% of the TV UCR's have time entries in exact multiples of days (1/2, 1, 2), possibly reflecting scheduling of personnel rather than realistic repair times.

The average total repair time for equipments within the television functional system is 13.8 hours; in all others, 4.3 hours.

RELIABILITY ASSESSMENT
OF
CIRCUIT BREAKERS

Date: 24 May 1972

Observed Field Failure Rate In Failures Per Thousand Hours Of Installed Component Time		0.072
Observed Failure Times, In Hours		
Mean		13,980
Minimum	5	
Maximum	51,100	
Number of Observations	108	
Observed Repair Times, In Hours		
Mean		0.02
Minimum	5.51	
Maximum	120	
Number of Observations	77	

FAILURE MODES AND CAUSES CONTRIBUTING TO
THE OBSERVED FIELD FAILURE RATE
AS A PERCENT OF THE TOTAL

		Failure Causes				
		Normal Service	Operational Problem	Quality Problem	Design Problem	All
Failure Mode	Corrosion	6.8	-	-	-	6.8
	Improper Response	19.6	-	2.8	0.6	23.0
	Short	12.0	1.7	-	-	13.7
	Open	4.0	-	-	-	4.0
	Loose, Broken, or Burned Connection	5.7	-	0.6	-	6.3
	Inoperative	4.0	-	0.6	-	4.6
	Unsatisfactory Condition or Operation	14.2	-	1.7	5.7	21.6
	Construction Problem	1.7	0.6	4.0	2.8	9.1
	Wiring Failure	1.7	0.6	0.6	2.3	5.2
	Miscellaneous	5.7	-	-	-	5.7
	Total	75.4	2.9	10.3	11.4	100.0

Number of Relevant UCRs: 176 Currency:(1) 26 April 1971

(1)Date of latest UCR run included in the assessment.

DESIGN BACKGROUND DATA

1. Component Description

This analysis is concerned with the UCR major item, "Circuit Breakers and Fuses." A circuit breaker in this analysis is a switch that automatically interrupts an electric circuit under an infrequent abnormal condition. A fuse is an electrical safety device consisting of or including a wire or strip of fusile metal that melts and interrupts the circuit when the current becomes too strong. This analysis is restricted to circuit breakers and fuses used in KSC GSE.

2. Data Base

The UCR data bank retrieval on major item "Circuit Breakers and Fuses" brought forth 237 UCRs. Before 15 October 1969, this major item was coded as 805; after this date it was coded 143. Only 18 of the UCRs were written against occurrences after 15 October 1969. Among the 237 UCRs there were two duplicates. Fifty-nine additional UCRs were not included; 55 of these were integrated circuit failures, four were failures of components other than circuit breakers or fuses. Ten of the UCRs were written against fuses; all the rest were written against circuit breakers.

The data base for the analysis of the major item of concern consists, therefore, of 176 unsatisfactory condition reports, written mainly against circuit breakers and predominantly before 15 October 1969; i. e., written under the "old" UCR system.

3. Engineering Analysis

A complete tabulation and detailed scrutiny was given to each data element on the 176 major item UCRs. Only significant highlights are summarized here.

The UCRs span the period from late 1965 to mid 1970 as shown in Exhibits 1 and 2.

About 59 percent of the UCRs originated from launch complex 39; over 85 percent are from the Saturn V program. Twenty-two functional systems are represented in the UCR data, but 75 percent

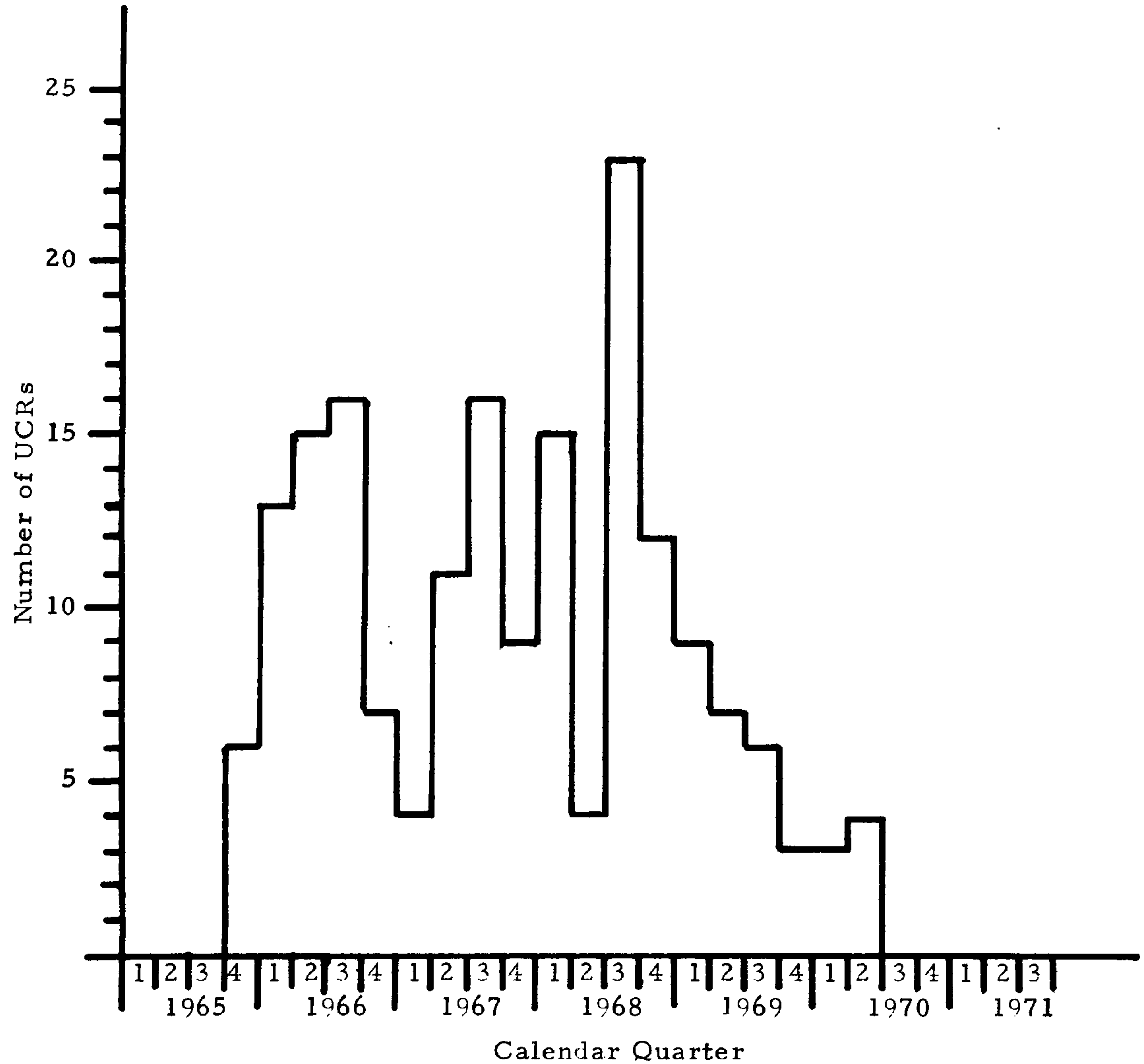


EXHIBIT 1 - NUMBER OF UCRS WITH CIRCUIT BREAKER OR FUSE FAILURES PER CALENDAR QUARTER FOR ALL COMPLEXES

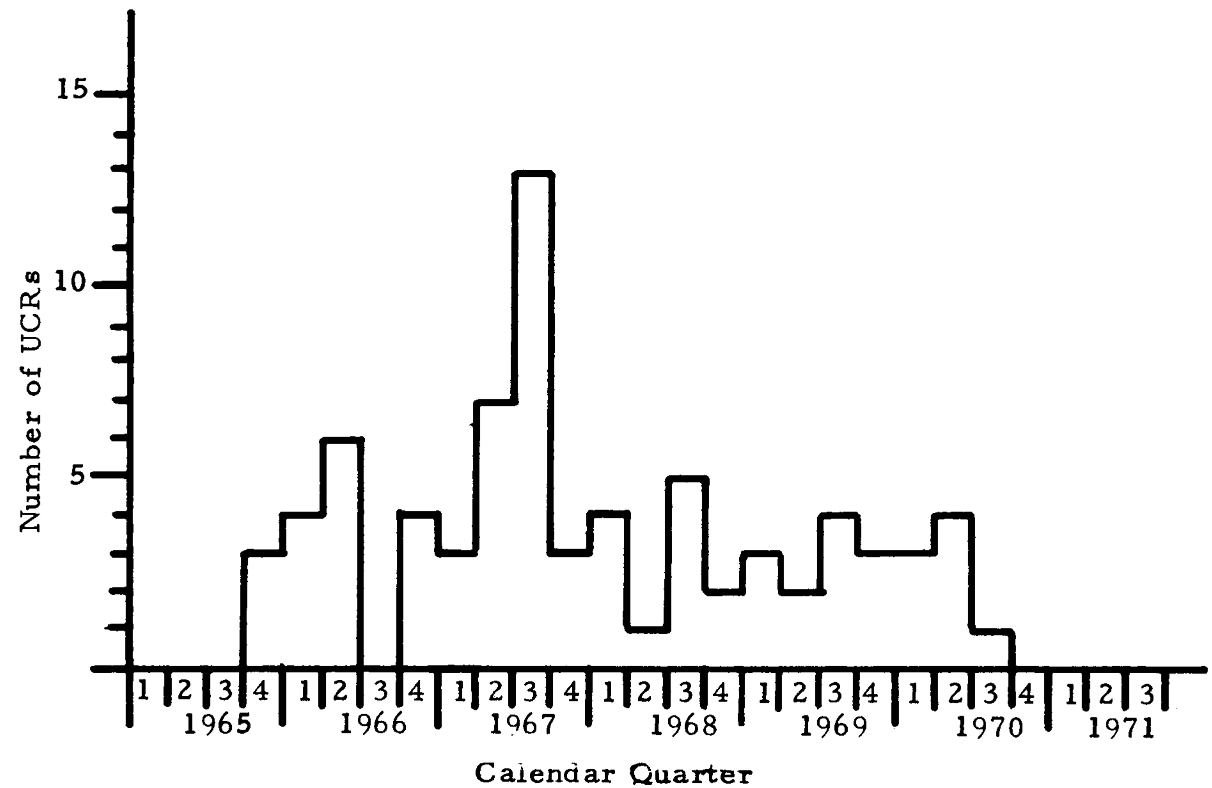


EXHIBIT 2 - NUMBER OF UCRS WITH CIRCUIT BREAKER OR FUSE FAILURES PER CALENDAR QUARTER FOR LAUNCH COMPLEX 39

of all UCRs come from the OIS-RF, Electrical Power Distribution, and Electrical Networks functional systems.

There were 108 time or age entries recorded on the 176 UCRs. These entries were all for circuit breakers. No times-to-failure were reported for fuses. Exhibit 3 shows the distribution of these entries assuming that each represents one circuit breaker time to failure.

4. Component Populations

The first attempt in defining component populations was to categorize the circuit breakers by their tripping limit. This attempt proved unsuccessful since about 65 percent of the UCRs gave no indication as to the limit, and for the other 35 percent there were 27 different limits and at most 10 UCRs within one limit.

Further investigation of the UCRs yielded the following four populations: (1) all circuit breakers and fuses at launch complex 39, (104 UCRs); (2) all circuit breakers and fuses at launch complex 37, (16 UCRs); (3) all circuit breakers and fuses at launch complex 34, (12 UCRs); and (4) all circuit breakers and fuses at locations other than LC39, LC37, and LC34 (44 UCRs).

5. Component Times

The 108 time observations previously mentioned are depicted in Exhibit 3 as the cumulative time-to-failure distribution for the composite population. Two of the subpopulations reflect a probable inspection at specified maintenance intervals; Launch Complex 39 at 12, 18, and 24 months; and Launch Complex 34 at 60 months.

The minimum, maximum, and mean-time-to-failure observations for each of the four populations is shown below:

Subpopulation	Min	Mean	Max
LC-39	325 hrs	10,584 hrs	26,280 hrs
LC-37	2,190 hrs	16,734 hrs	51,100 hrs
LC-34	730 hrs	28,642 hrs	51,100 hrs
Misc	5 hrs	8,964 hrs	26,280 hrs

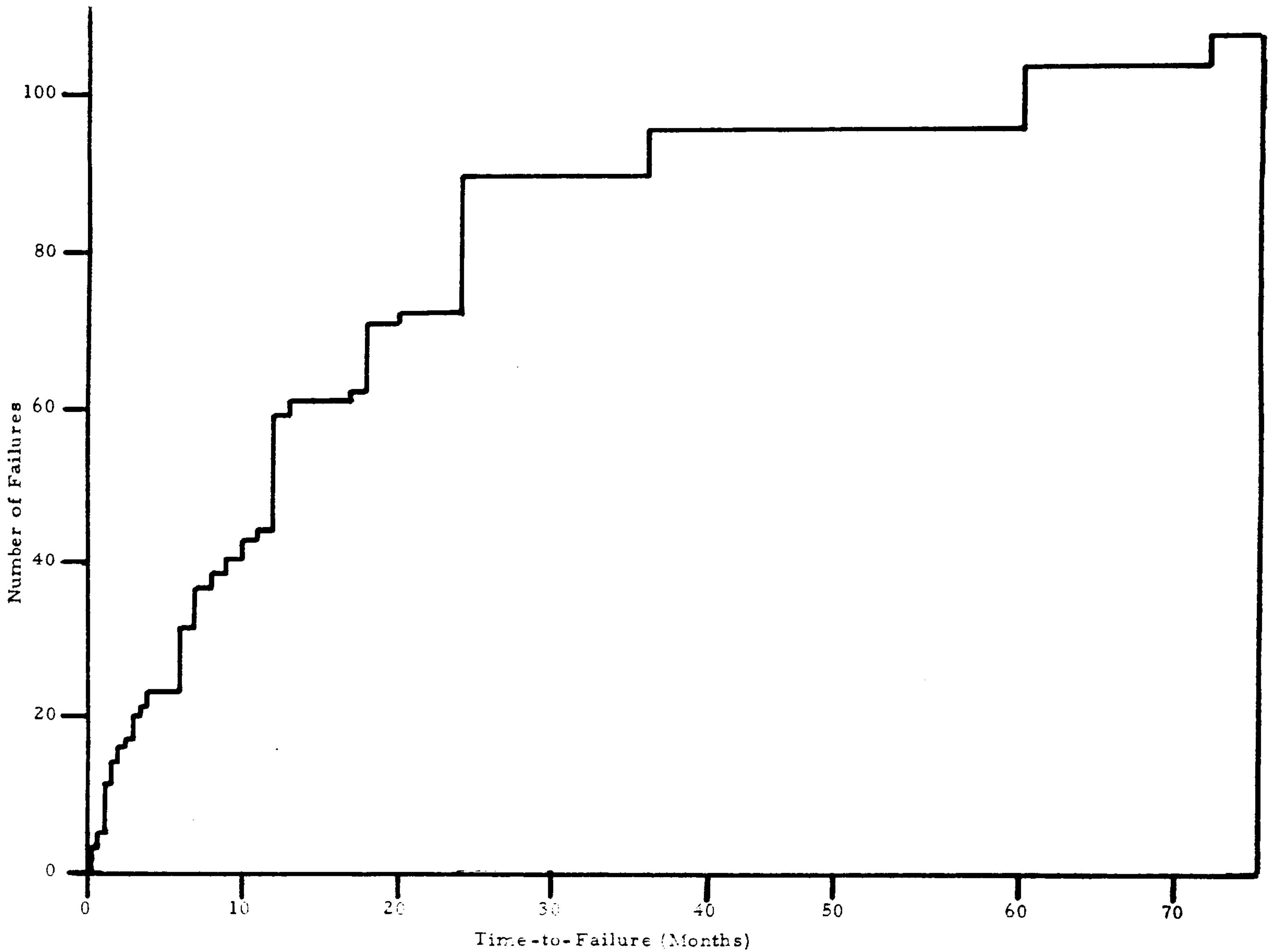


EXHIBIT 3 - CUMULATIVE DISTRIBUTION OF CIRCUIT BREAKER TIMES-TO-FAILURE FOR ALL LAUNCH COMPLEXES

6. Component Failures

Each UCR in the sample represented one circuit breaker or fuse failure. There were 166 circuit breaker failures and 10 fuse failures. The problems associated with each of the 108 time observations were judged to represent one and only one failure attributable to a circuit breaker.

7. Failure Classifications

Classifying all 176 UCRs on the basis of the narrative descriptions of the unsatisfactory conditions and the coded data elements "failure, repair disp., recommend, and reason" leads to the tabulation of Exhibit 4. The coded headings of that exhibit for problem classification are defined as follows:

DP (Design Problem). A fault which is inherent in, and can be corrected by, the circuit breaker or fuse design.

OP (Operational Problem). A fault due not directly to a circuit breaker or fuse, but instead due to the improper action of operating or maintenance personnel.

QP (Quality Problem). Implies a fault which is neither inherent in the design nor the result of normal (or abnormal) operation. It is generally a manufacturing problem such as a poor weld, not providing a locking device for a screw, or not tightening connecting bolts during assembly.

NS (Normal Service). In this category are put all those unsatisfactory conditions which arise as a result of normal field operation or for which insufficient information is available to assign it to any of the other three categories.

Each UCR was further categorized according to one of the ten failure modes listed below:

1. Corrosion
2. Improper Response
3. Short
4. Open
5. Connection poor, broken, loose, or burned

Failure Mode	Problem Classification: NS	OP	QP	DP	Σ	%
1	12				12	6.8
2	35		5	1	41	23.0
3	21	3			24	13.7
4	7				7	4.0
5	10		1		11	6.3
6	7		1		8	4.6
7	25		3	10	38	21.6
8	3	1	7	5	16	9.1
9	3	1	1	4	9	5.2
10	10				10	5.7
Σ	135	5	18	20	176	100
%	75.4	2.9	10.3	11.4	100	

EXHIBIT 4 - CLASSIFICATION OF ALL FAILURES

6. Inoperative
7. Unsatisfactory condition or operation
8. Construction problem
9. Wiring failure
10. Miscellaneous

Exhibit 5 is a tabulation of all failures at LC-39.

8. Field Failure Rates

Taking each of the number of permissible component times for each subpopulation as representing one circuit breaker time-to-failure (TTF), the mean TTF (MTTF) for each subpopulation may be found by summing the individual TTFs within each subpopulation and dividing by the number of permissible components for the corresponding subpopulation. The field failure rate (FFR) is the reciprocal of the MTTF. These values are tabulated in Exhibit 6.

Other than for the "miscellaneous" subpopulation, LC-39 had the highest FFR. One very interesting point is that the inclusion of installed time for UCRs after 15 October 1969, showed a marked increase in the FFR for LC-39.

For the overall population the field failure rate data is as follows:

MTTF = 13,900 hours

FFR = 72 failures/million hours

If the UCRs after 15 October 1969 are not included, these numbers are

MTTF = 16,000 hours

FFR = 62 failures/million hours

9. FFR Confidence Intervals

From Exhibit 3 it can be seen that the assumption of exponentially distributed times to failure is not unreasonable. Using this assumption the lower and upper confidence limits (90 percent confidence interval) on the FFR were obtained, see Exhibit 6.

10. Resolution of FFR Factors

From Exhibit 4, classifying the failures upon which the FFR is based, it can be seen that about 76 percent of the failures are "normal"

Failure Mode	NS	OP	QP	DP	Σ	%
	Problem Classification					
1	5				5	4.8
2	29		3	1	33	31.9
3	7	2			9	8.7
4	4				4	3.8
5	5		1		6	5.8
6	3		1		4	3.4
7	16		1	7	24	23.3
8	1		6	4	11	10.6
9		1	1	4	6	5.8
10	2				2	1.9
Σ	72	3	13	16	104	100
%	69.2	2.9	12.5	15.4	100	

EXHIBIT 5 - CLASSIFICATION OF FAILURES FOR LC-39

Complex	Number of Failures	Accumulative TTF(1) (Hours)	MTTF (Hours/ Failure)	FFR(1) (Failures/ 1,000 hrs.)	Lower Confidence Limit (Failures/ 1,000 hrs.)	Upper Confidence Limit (Failures/ 1,000 hrs.)
LC-39	49	633,640	12,930	0.077	0.060	0.096
	(61)[2]	(645,610)	(10,580)	(0.094)	(0.075)	(0.115)
LC-37	13	217,540	16,730	0.060	0.035	0.089
LC-34	17	486,910	28,640	0.035	0.022	0.050
Misc(3)	14	150,380	10,740	0.093	0.056	0.137
	(17)	(152,390)	(8,960)	(0.1 12)	(0.070)	(0.159)
Composite	93	1,488,470	16,000	0.062	0.052	0.073
	(108)	1,502,450	(13,900)	(0.072)	0.061	0.084

Notes: (1) Used conversion factor of 730 hours/month.
(2) Number in brackets represents the inclusion of new UCRs.
(3) Includes industrial area and MSOB.

EXHIBIT 6 - FIELD FAILURE RATE DATA FOR THE VARIOUS COMPLEXES

service type problems. This is equivalent to a failure rate of 57 (rather than the 72 calculated in section 8) failures per million hours for the entire circuit breaker population. The differences in this FFR for the four populations studied are large enough to indicate a significantly higher circuit breaker failure frequency at LC-39 that at LC-34 and LC-37. This may, however, simply indicate the more active status of LC-39 relative to the two other complexes.

11. Repair Time

A sizable amount of data was present with respect to repair time. Exhibit 7 shows the cumulative distribution of repair times. The mean repair time was 5.5 hours with 77 observations. The minimum repair time was 0.02 hours. The maximum repair time was 120 hours. The time to repair statistics for the various subpopulations is as follows:

	Time to Repair			
Population	Minimum	Mean	Maximum	No. of Observations
LC-39	0.02	2.3	8.0	37
LC-37	1.0	18	120	8
LC-34	0.58	2.1	8.0	8
Other Locations	0.03	7.3	120	24
Composite	0.02	5.5	120	77

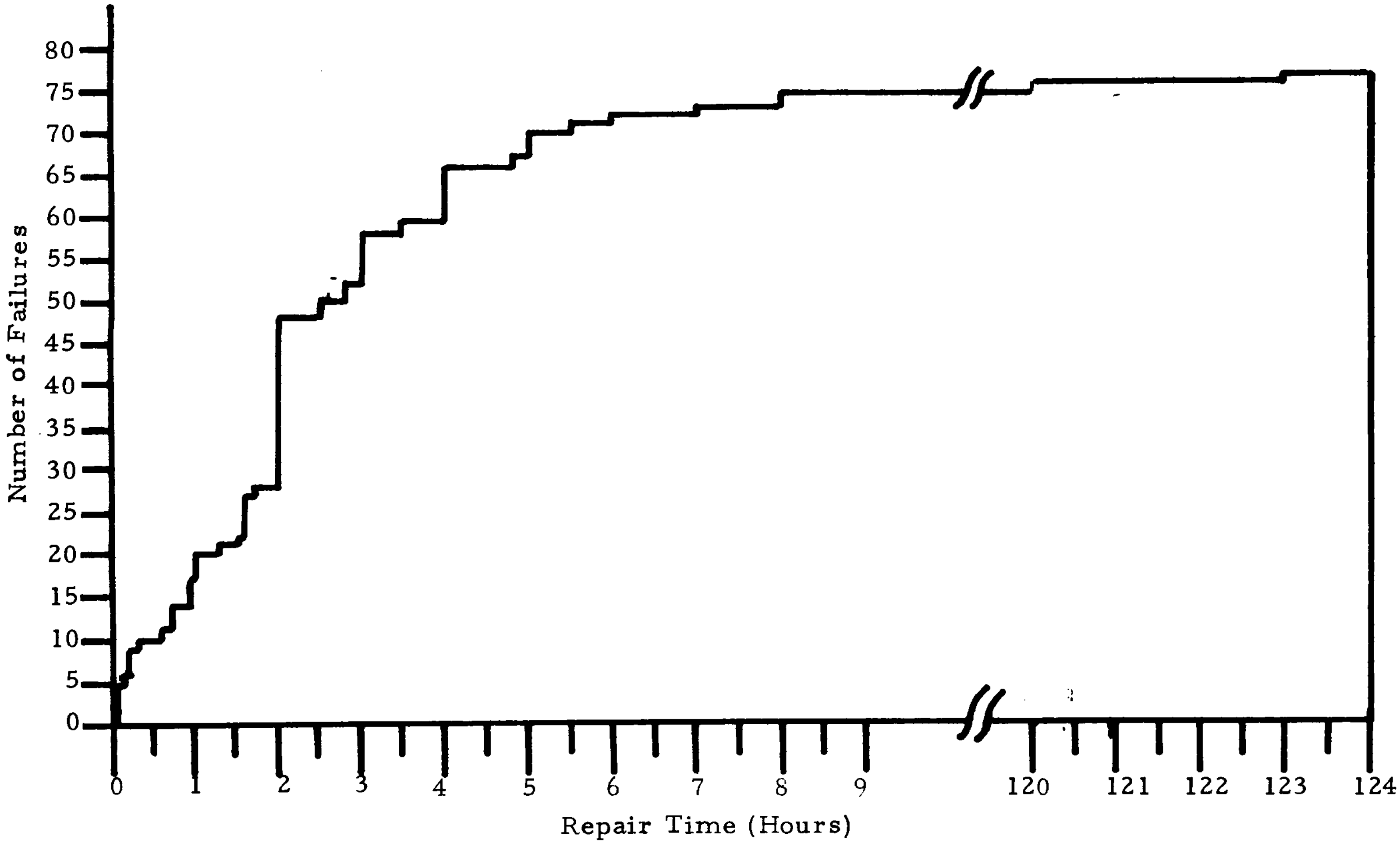


EXHIBIT 7 - CUMULATIVE DISTRIBUTION OF TOTAL REPAIR TIME FOR CIRCUIT BREAKERS

RELIABILITY ASSESSMENT
OF
COMPRESSORS

Date: 24 May 1972

Observed Field Failure Rate In Failures Per Thousand Hours Of Installed Component Time		0.117
Observed Failure Times, In Hours		
Mean		8550
Minimum	12	
Maximum	51,840	
Number of Observations	38	
Observed Repair Times, In Hours		
Mean		47.5
Minimum	1	
Maximum	264	
Number of Observations	21	

FAILURE MODES AND CAUSES CONTRIBUTING TO THE OBSERVED FIELD FAILURE RATE AS A PERCENT OF THE TOTAL

	Failure Cause				
Failure Mode	Normal Service	Design Problem	Quality Problem	Operational Problem	Total
Broken, Cracked Parts	17.5	-	1.3	-	18.8
Contamination, Corrosion	6.3	2.5	-	-	8.8
Design Deficiency	-	8.9	-	-	8.9
Electrical Problem	5.1	-	-	-	5.1
Inoperative, Poor Operation	12.7	-	-	-	12.7
Leaking Compressor	6.3	-	-	-	6.3
Motor Problem	7.6	-	1.3	-	8.9
Not to Specification	-	-	1.3	2.5	3.8
Valve Problem	7.6	-	1.3	-	8.9
Worn Parts	12.7	-	-	-	12.7
Other	3.8	-	-	1.3	5.1
Total	78.6	11.4	5.2	3.8	100.0

Number of Relevant UCRs: 76 Currency:[1] 13 May 1971

[1] Date of latest UCR run included in the assessment.

DESIGN BACKGROUND DATA

1. Component Description

The component population consists of mechanical devices used for increasing fluid pressure. Compressors are designated by major item code 829 on all unsatisfactory condition reports (UCRs) written prior to 15 October 1969, and by major code 151 on all UCRs written after 15 October 1969.

2. Data Base

Seventy-nine UCRs were obtained through the use of the "major item code" entry. There were 74 UCRs with major item code 829 and 5 UCRs with major item code 151. Three UCRs with major item code 829 had failures associated with electrical circuits such as video compression circuits. These UCRs are not included in the data base. Thus, the data base consists of 76 UCRs.

3. Engineering Analysis

Exhibit 1 presents the number of UCRs occurring per calendar quarter for compressors. After the third quarter of 1969, there were only two compressor failures with no reported failures after September 1970.

Forty-five percent of the UCRs occurred within launch complex 39. Launch complexes 34 and 37 each had 11 percent of the component population. The remaining compressor failures occurred at seven other locations.

Compressor failures occurred in 12 functional systems. The functional systems are:

Compressed air	27.6%
HE	26.4%
Air Conditioning Heat Ventilating	21.1%
HP Gas	9.2%
Other functional systems	15.7%

There were five failures for part number 85-HES-10 and four failures for part number 25275. Forty-four other part numbers had only one or two failures.

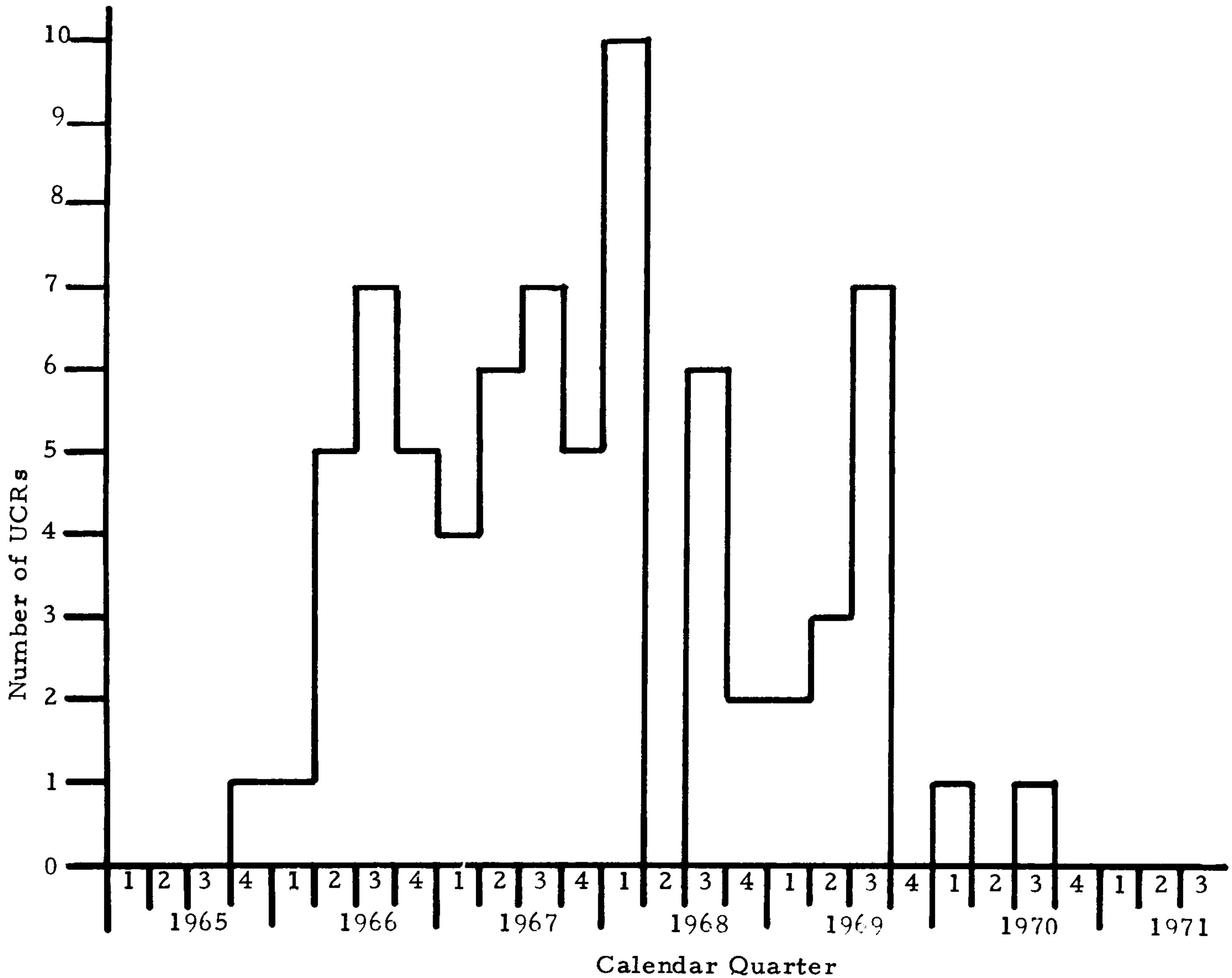


EXHIBIT 1 - NUMBER OF UCRS PER CALENDAR QUARTER

4. Component Populations

Only one component population was chosen for this reliability assessment--that of compressors.

5. Component Times

There were 38 entries for component times-to-failure (TTF). Thirty-seven TTFs were for failures occurring prior to 15 October 1969. The remaining TTF was from a failure occurring in November 1970.

Exhibit 2 presents the cumulative distribution of times-to-failure for all 38 compressor failures.

6. Component Failures

With the exception of one UCR, each UCR represent one failure. One UCR reported the failure of four different compressors. Thus, there are 79 compressor failures.

7. Failure Classifications

Each compressor failure was classified according to the cause of the failure. The failure causes and the number of failures due to each cause are:

Normal Service (63 failures)--failure occurred as a result of normal field operation or for which there is insufficient information available to assign the failure to any other category.

System Design (9 failures)--a failure in which the fault is inherent in and can be corrected by design action; such as, insufficient space for maintenance personnel to service a compressor.

Quality Problem (4 failures)--failure is a manufacturing problem; such as, compressor motor burned out in less than manufacturer-specified operational time.

Operational Problem (3 failures)--a failure occurred as a result of operation and maintenance personnel; such as, compressor equipment not installed to specifications.

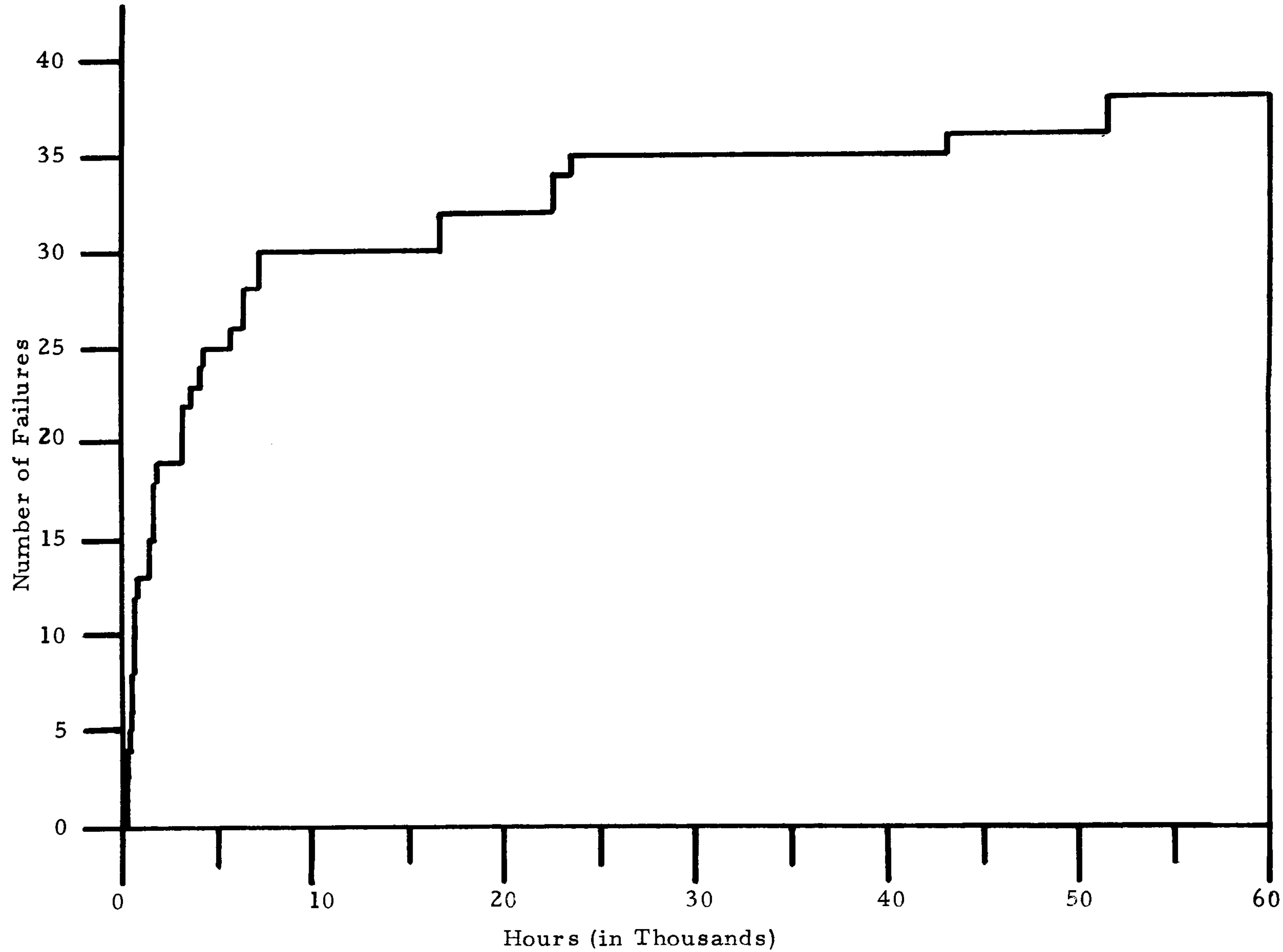


EXHIBIT 2 - CUMULATIVE DISTRIBUTION OF TIMES-TO-FAILURE FOR COMPRESSORS

In addition, the mode of each failure was determined. These modes and the quantity of failures involved are:

Broken, cracked parts (15 failures)--failure of compressor to operate due to broken or damaged parts.

Contamination, corrosion (7 failures)--parts of the compressor were corroded or contaminated such that it affected compressor performance.

Design deficiency (7 failures)--the compressor design is lacking in some feature preventing the unit from operating in the desired manner.

Inoperative, poor operation (10 failures)--compressor inoperative or operates poorly, information to further classify the mode of failure is not available.

Leaking compressor (5 failures)--compressor is leaking.

Motor problem (7 failures)--compressor failed due to a motor, includes burned out motor, motor windings open, etc.

Not to specification (3 failures)--compressor installation is not to specifications.

Valve problem (7 failures)--compressor failed due to valve problem.

Worn parts (10 failures)--compressor fails to operate due to worn parts.

Other (4 failures)--all other categories.

8. Field Failure Rate

Using the data of section 5, the field failure rate is determined by dividing the number of failures with time information (38) by the sum of the times-to-failure. The field failure rate is 0.117 failures/ 1,000 hours.

9. FFR Confidence Intervals

From Exhibit 2, it can be seen that the assumption of exponentially distributed times-to-failure is not unreasonable. Using this assumption, the 90 percent confidence interval is:

Upper limit	0.149 failures/1,000 hours
Lower limit	0.089 failures/1,000 hours

10. Resolution of FFR Factors

The current field failure rate may be different from that computed in Section 8 due to the fact that there is only one time-to-failure after October, 1969. This fact and the observation of the few failures reported after October, 1969, would seem to indicate that the field failure rate at the present time should be lower.

11. Repair Times

Twenty-one UCRs had repair time information. Exhibit 3 presents the cumulative distribution of times-to-repair (TTR) for the compressor population. The mean TTR is 47.5 hours. The minimum TTR is 1 hour. The maximum TTR is 264 hours.

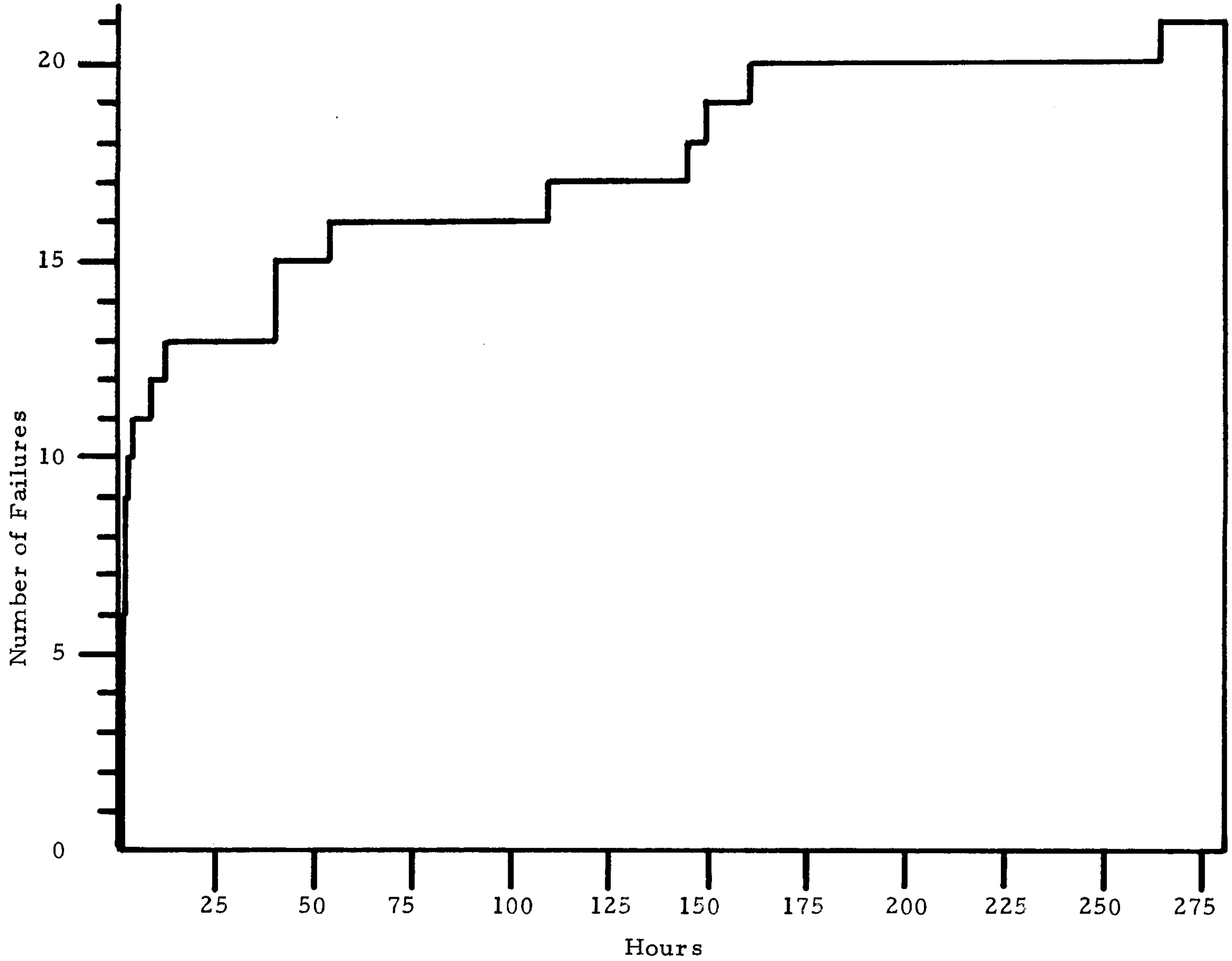


EXHIBIT 3 - CUMULATIVE DISTRIBUTION OF TIMES-TO-REPAIR

RELIABILITY ASSESSMENT OF CONNECTORS

Date: 24 May 1972

	Prior To 15 October 1969		After 15 October 1969	
Observed Field Failure Rate In Failures Per Thousand Hours Of Installed Component Time		0.134		1.98
Observed Failure Times, In Hours				
Mean		7,460		505
Minimum	70		60	
Maximum	26,280		1,395	
Number of Observations	25		6	
Observed Repair Times, In Hours				
Mean		3.33		
Minimum	0			
Maximum	36			
Number of Observations	100			

FAILURE MODES AND CAUSES CONTRIBUTING TO
THE OBSERVED FIELD FAILURE RATE
AS A PERCENT OF THE TOTAL

	Failure Cause					
Mode of Failure	Normal Service	Operational Problem	Quality Problem	Design Problem	Preventive Maintenance	All
Damaged Connector	19.6	8.6	-	1.8	-	30
Unsatisfactory Connection	13.5	-	9.2	3.1	1.2	27
Damaged Pins	9.2	8.6	1.8	3.6	-	23
Miscellaneous	8.0	-	2.5	0.6	1.2	12
Inoperative	7.5	-	-	-	-	12
All	58	17	14	9	2	100

Failure Classification (Percent)

Number of Relevant UCRs: 170 Currency:[1] 26 April 1971

[1]Date of latest UCR run included in the assessment.

DESIGN BACKGROUND DATA

1. Component Description

The component under analysis here is more precisely described as an electrical connector and includes all devices used to connect electrical power or signals from one equipment to another. Solder joints are excluded, as are mechanical connecting devices such as hose clamps, pipe joints, etc. The devices included are, of course, restricted to those used in KSC GSE.

Connectors are designated by major item code 423 for UCRs written prior to 15 October 1969, and by major item code 156 for UCRs written after 15 October 1969.

2. Data Base

The data base consists of 196 UCRs. Of these, 175 UCRs were obtained by retrieving all UCRs with major item code 423 from the set of UCRs written prior to 15 October 1969. The remaining 21 UCRs were obtained by retrieving those UCRs written after 15 October 1969 with major item code 156.

From the first set of UCRs, 11 of the 175 UCRs concerned failures of non-electrical connectors. Similarly in the second set, 15 of the 21 UCRs concerned failures of non-electrical connectors. These 26 UCRs are not considered in this reliability analysis. Thus, there are 170 unsatisfactory condition reports in the data base.

3. Engineering Analysis

Exhibit 1 presents the number of UCRs per calendar quarter. From the exhibit it can be seen that connector failures occur in bunches and that there is a significant drop in the number of connector failures after the third quarter of 1969.

Most UCRs originate from launch complex 39 (over 60 percent). Twenty-six functional systems are represented in the UCR data, but 60 percent of all UCRs come from the OIS-RF, Mobile Radio and Range Instrumentation Systems.

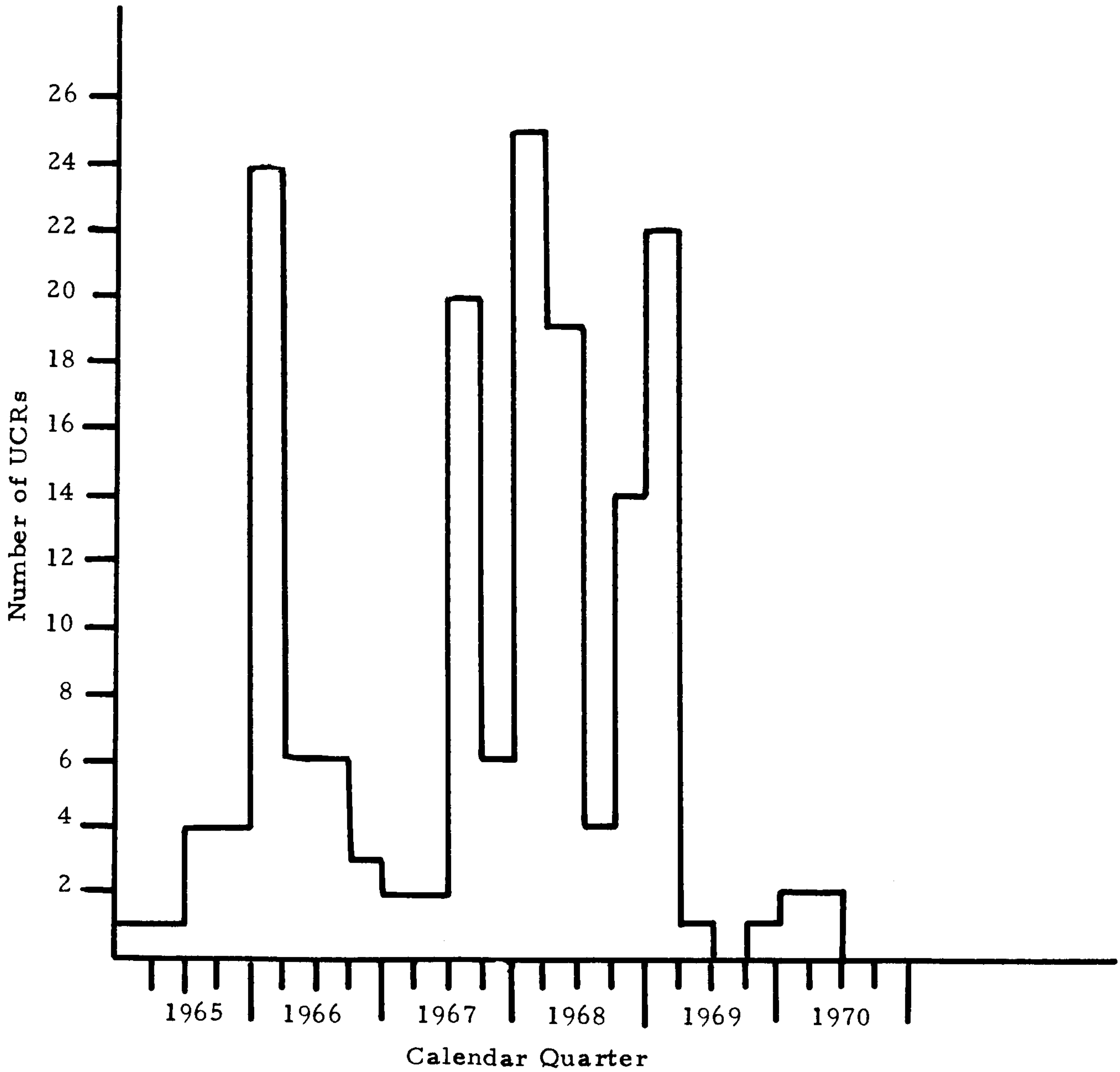


EXHIBIT 1 - NUMBER OF UCRS PER CALENDAR QUARTER

4. Component Populations

The engineering analysis indicates that there are no likely subpopulations for which field failure rates (FFR's) can be calculated in the general electrical connector population. Since there are only some 31 UCRs with time (or age) data, this is not surprising.

There is, however, one interesting division of the data for UCRs written prior to 15 October 1969 which, but for the lack of component time information in one segment, could form the basis for two subpopulations. This division is basically between those UCRs which carry the letters FEC under the "Reliab Use Only" data element and the letters QJ2 under "Organization," and those which do not. There are 71 UCRs in the latter category and hence 92 in the former. The first category unfortunately has only one component time related entry in the entire 92 UCRs.

The category containing the smaller group of UCRs appears to be representative of all connectors with the exception of three data elements. In addition to the two mentioned above, the smaller group of UCRs does not contain the letters DE or MJ in the Design Organization data element; the larger group contains one or the other of these two sets of letters and no others. The letters "FEC" represent the UCR originator and QJ2 is a code for the Communications Systems Branch. The KSC Design Centers represented by the code letters DE and MS are not defined in the current code tables.

Thus, although two populations of electrical connectors can be defined, it is not clear that they differ in any significant way, particularly as regards their reliability. Unfortunately, FFR's can only be estimated for the more general of the two populations.

In the sequel, where it is necessary to distinguish between those two populations, the more general will be designated population 1 and the other population 2.

A third population exists in the six UCRs of the new data base (i.e., UCRs written after 15 October 1969).

5. Component Times

There were 27 UCRs with time entries for failures occurring prior to 15 October 1969. Examination of the narrative portion of the UCRs indicates that two of these entries do not represent times-to-failure. The first of these (Age = 1 month) is indicated in the narrative section of its UCR to represent receipt of a wrong part which could not be installed at all. The second (Age = 6 months) UCR is actually a plea for the return of cannibalized parts. Exhibit 2 presents the cumulative distribution of connector times-to-failure for UCRs occurring prior to 15 October 1969. Exhibit 3 presents the cumulative distribution of the six connector times-to-failure recorded after 15 October 1969.

6. Component Failures

Of the 31 UCRs with installation times, all are judged to represent an unsatisfactory condition (or failure) attributable to a connector.

7. Failure Classifications

Classifying all 170 UCRs on the basis of the narrative description of the unsatisfactory conditions and the coded data elements "failure, repair disp., recommend, and reason" leads to the tabulation of Exhibit 4. The coded headings of that exhibit for problem classification are defined as follows:

DP (Design Problem). A fault which is inherent in, and can be corrected by, the connector design.

OP (Operational Problem). UCRs in this category imply that the unsatisfactory condition was caused or exacerbated by the misuse of the connector on the part of the operating or maintenance (O&M) personnel.

QP (Quality Problem). Implies a fault which is neither inherent in the design nor the result of normal (or abnormal) operation. It is generally a manufacturing problem such as a cold solder joint or improper connector assembly.

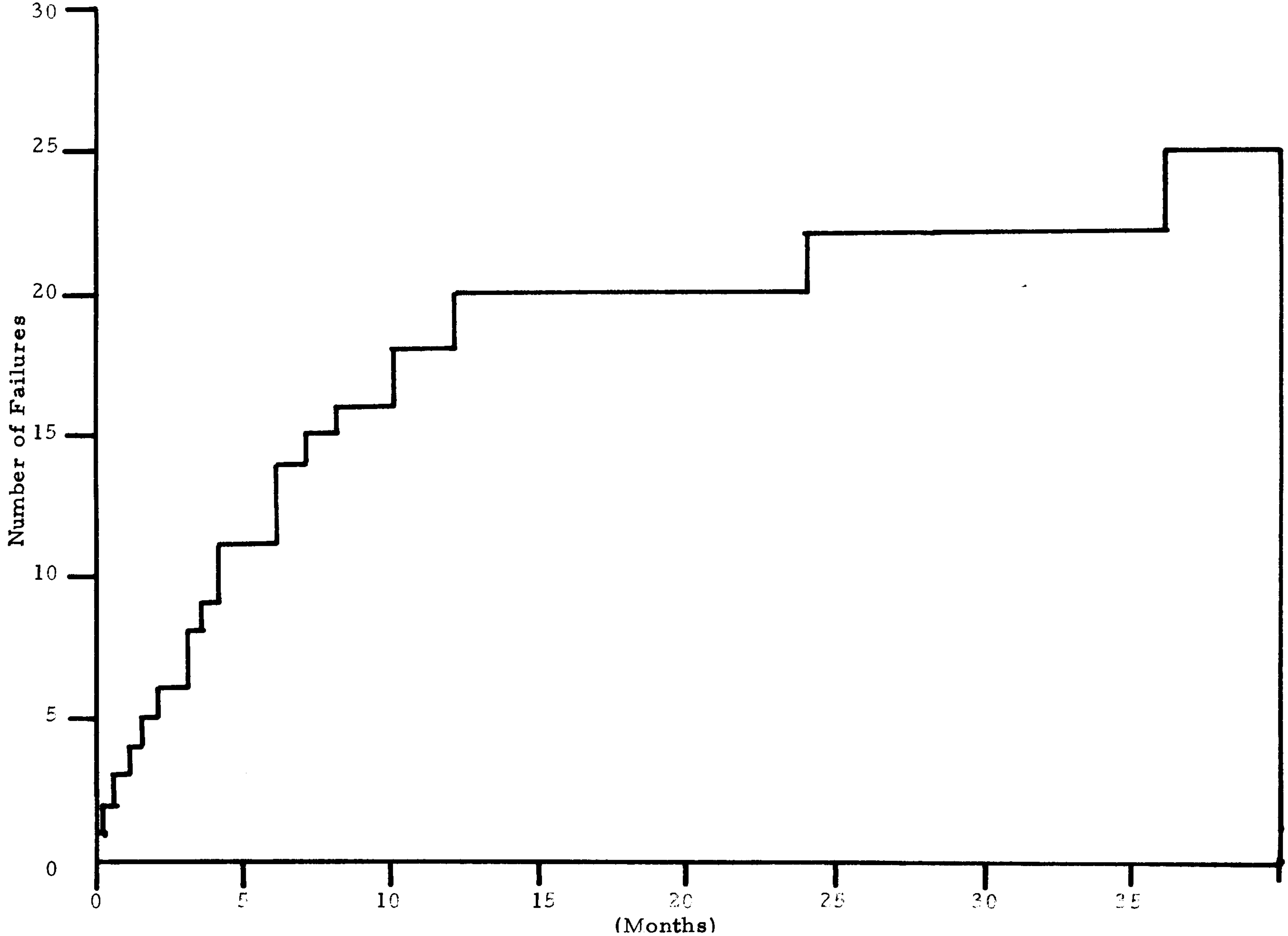


EXHIBIT 2 - CUMULATIVE DISTRIBUTION OF CONNECTOR TIMES-TO-FAILURE FOR FAILURES OCCURRING PRIOR TO 15 OCTOBER 1969

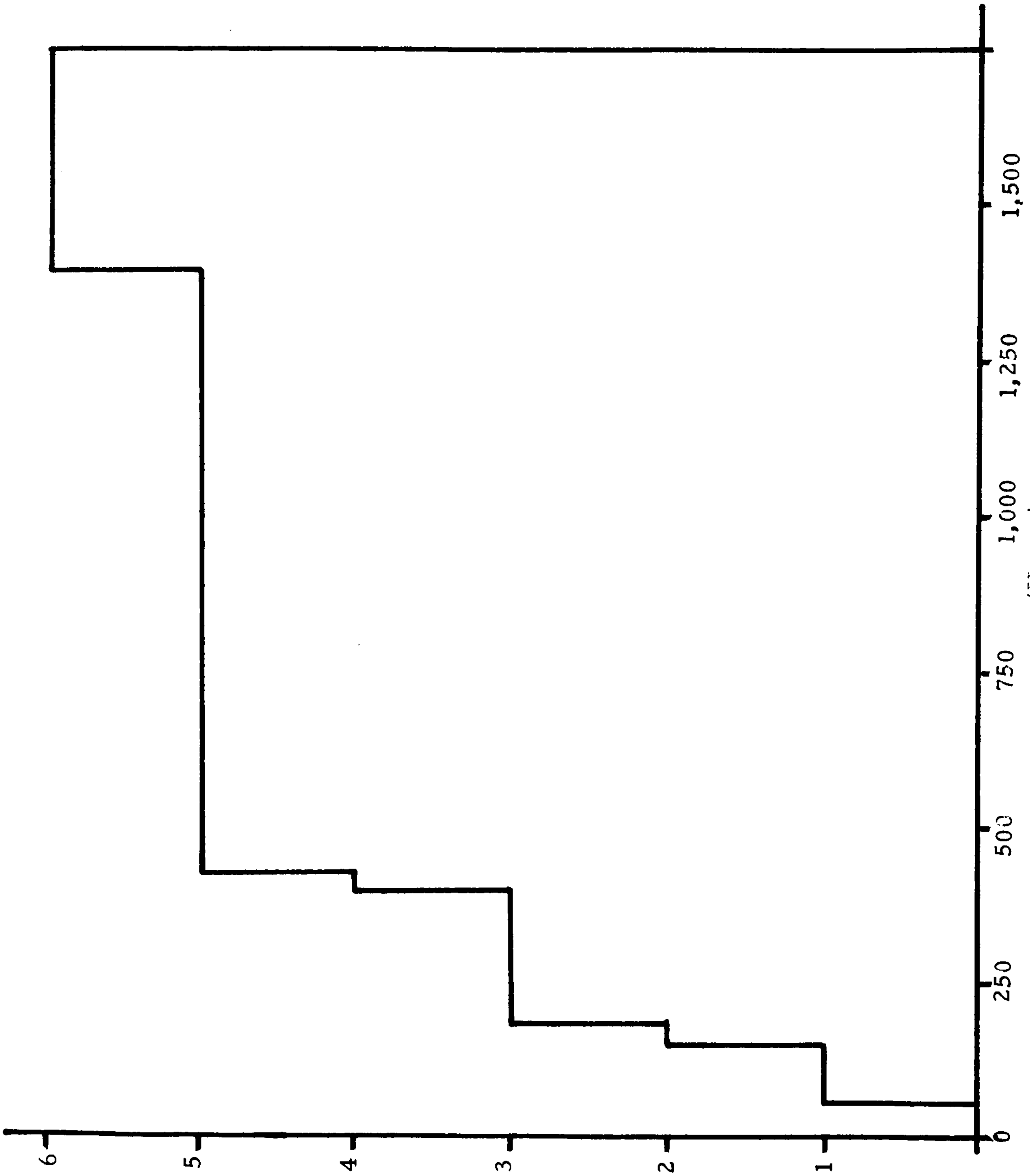


EXHIBIT 3 - CUMULATIVE DISTRIBUTION OF CONNECTOR TIMES-TO-FAILURE FOR FAILURES OCCURRING AFTER 15 OCTOBER 1969

Problem Classification

Failure Mode		DP	OP	QP	NS	PM	Σ	%
	1	6	14	3	16		39	23
	2	3		2	12		17	10
	3	1			8		9	5
	4			3			3	2
	5	12		9	2	2	15	9
	6	1		2	4		7	4
	7	3	14		32		49	28
	8	1		1	11		13	8
	9			2	1	2	5	3
	10				13		13	8
	Σ	17	28	22	99	4	170	100
	%	10	17	13	58	2	100	

Note: (1) See text for definition of descriptor codes.

EXHIBIT 4 - CLASSIFICATION OF ALL UNSATISFACTORY CONDITIONS BY DESCRIPTORS[(1)]

NS (Normal Service). In this category are put all those unsatisfactory conditions which arise as a result of normal field operation or for which insufficient information is available to assign it to any of the other three categories.

PM (Preventive Maintenance). A few UCRs detail conditions which, although not currently unsatisfactory in any operational sense, could become so in the future.

Each UCR was further categorized according to one of the 10 failure modes listed below:

(1) Connector pins damaged (broken, bent, smashed, mangled, etc.).

(2) Connection poor, broken, loose, intermittent, etc.

(3) Corrosion or contamination.

(4) Unsoldered or poorly soldered pins.

(5) Mating difficulty.

(6) Internal short or high conductivity.

(7) Broken case, dielectric or connector just damaged.

(8) Broken wire, lead or connector wire separation.

(9) Wrong or missing connectors or connector parts.

(10) Insufficient data to otherwise classify; inoperative, etc.

In addition, it was observed that 20 (or nearly 12 percent) of the unsatisfactory conditions were associated with the Cape environment, and 8 (about 4 percent) of the unsatisfactory conditions were the result of higher level design problems--cables too short, for example, thus putting an unnecessary stress on the connector.

Exhibit 5 is a similar tabulation for the two populations discussed earlier (the third population is not tabulated due to the paucity of the sample).

The differences in the two are reasonably clear. For example, population 2 includes only one quality problem in 92 UCRs, whereas nearly a third of the population 1 UCRs are so classified.

Exhibit 6 is yet another similar tabulation, this one restricted to those UCRs for which time or age entries (component times) were provided. Comparison of this exhibit with the previous one indicates the

Failure Mode	Population 1 Problem Classification: DP	OP	QP	NS	PM	Σ	%	Population 2 Problem Classification: DP	OP	QP	NS	PM	Σ	%
1	5	4	3	4		16	23	1	10		11		22	24
2	2		2	5		9	14	1			5		6	7
3				5		5	7				3		3	3
4			3			3	4							
5	1		9	1	2	13	18							
6	1		2	3		6	8				1		1	1
7	3	3		8		14	20		11		24		35	38
8			1			1	1	1			11		12	13
9			1			3	4			1	1		2	2
10				1		1	1				11		11	12
Σ	12	7	21	27	4	71	100	3	21	1	67		92	100
%	17	10	29	38	6	100		3	23	1	73		100	

EXHIBIT 5 - CLASSIFICATIONS OF ALL UNSATISFACTORY CONDITIONS BY DESCRIPTORS AND POPULATIONS

Problem Classification

Failure Mode	DP	OP	QP	NS	PM	Σ	%
1	3	3		3		9	27
2			1	3		4	12
3	1			2		3	9
4			1			1	3
5	1			2	1	4	12
6	1		1	2		4	12
7		1		2		3	9
8			1			1	3
9			1		2	3	9
10				1		1	3
	6	4	5	15	3	33	100
%	18	12	15	46	9	100	

EXHIBIT 6 - CLASSIFICATION OF UNSATISFACTORY CONDITIONS WITH COMPONENT TIMES

sample is quite representative of population 1 in all respects, but much less so for population 2, as would be expected.

8. Field Failure Rates

Taking each of the 31 permissible component times given in Exhibits 2 and 3 as representing one connector time-to-failure (TTF), the mean TTF (MTTF) may be found by adding the individual TTFs and dividing by the number of TTFs. The field failure rate (FFR) is the reciprocal of the MTTF. These calculations are performed separately for the 25 failures occurring prior to 15 October 1969, and for the six failures occurring after 15 October 1969. The resultant FFRs are:

Time Period	FFR
Prior to 15 October 1969	0.134 failures/1,000 hours
After 15 October 1969	1.98 failures/1,000 hours

9. FFR Confidence Intervals

From Exhibits 2 and 3 it can be seen that the assumption of exponentially distributed times-to-failure is not unreasonable. Using this assumption, the 90 percent confidence intervals on FFR are:

	(Failures/1,000 Hours)		
Time Period	Upper Limit	Mean	Lower Limit
Prior to 15 October 1969	0.181	0.134	0.093
After 15 October 1969	3.46	1.98	0.86

10. Resolution of FFR Factors

From Exhibit 6, a classification of the failures upon which the FFR is based, it can be seen that only 40 to 50 percent of the failures are "normal" service type problems. As much as 1/4 of this failure rate may in fact be due to the weather conditions inherent at the Cape.

The high failure rate for failures occurring after 15 October 1969, as compared with failures prior to 15 October 1969, may be partly due to the small quantity of failure data. Relevant connector failures may be included under other major item code classifications. These failures may also have a longer MTTF. No other reason is evident.

11. Repair Time

An unusual amount of data is present with respect to repair time for UCRs written prior to 15 October 1969. Exhibit 7 is a graphical presentation of total time to repair. From this graph the assumption of a log-normal distribution for the total down time parameter seems reasonable. Also, at least for connectors, the basic data indicate that repair time is much longer than "time to locate" (by a factor of 4 to 5). A median total down time of two hours is indicated. The mean down time is 3-1/3 hours.

There were no repair times for the UCRs with failures occurring after 15 October 1969.

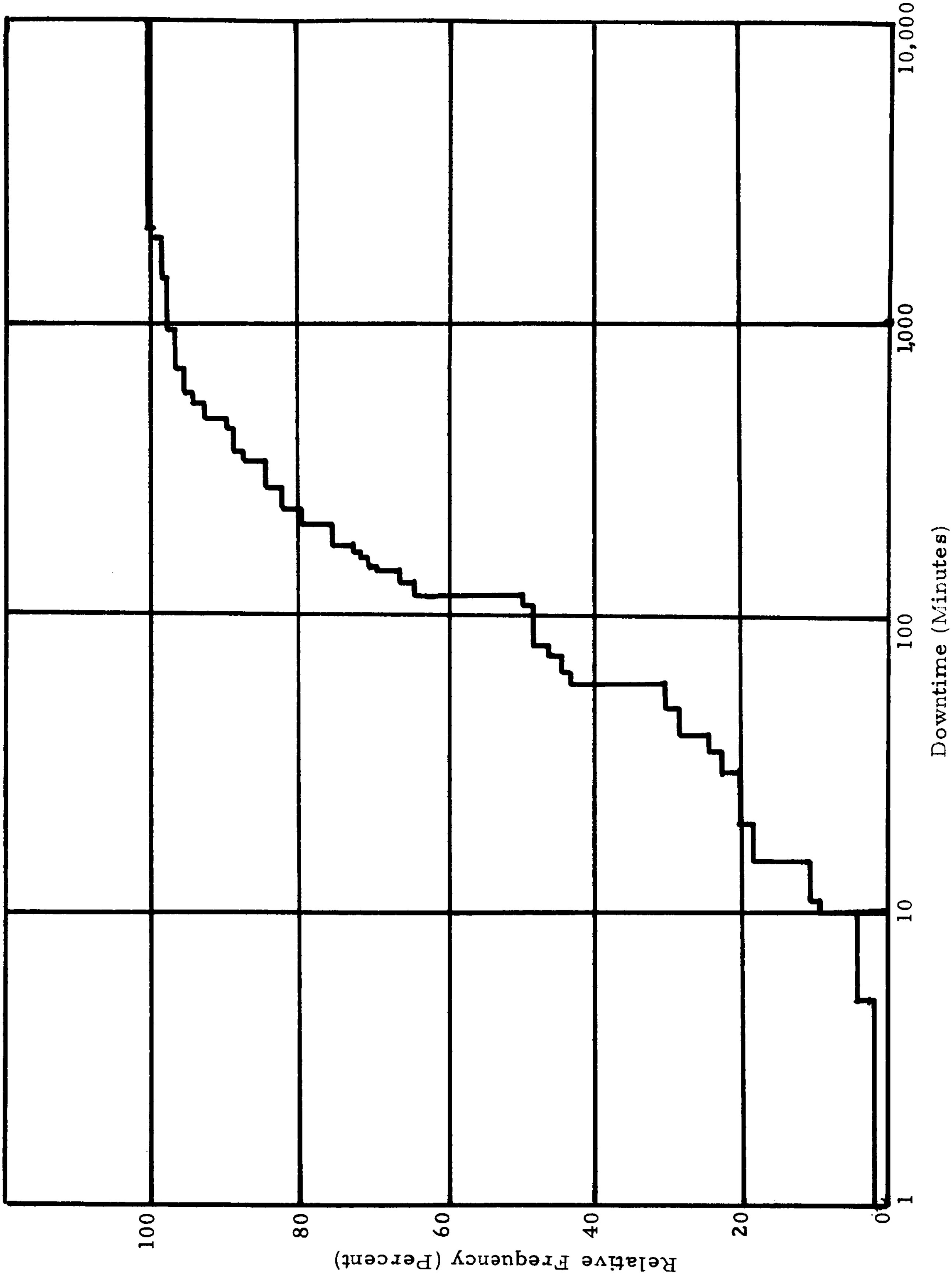


EXHIBIT 7 - CUMULATIVE FREQUENCY DISTRIBUTION OF TOTAL CONNECTOR DOWNTIME

RELIABILITY ASSESSMENT
OF
HOLDDOWN ARM SYSTEM

Date: 24 May 1972

Observed Field Failure Rate In Failures Per Thousand Hours Of Installed Component Time	Launch Complex 34	0.173
	Launch Complex 37	0.416
	Launch Complex 39	0.348

Observed Failure Times, In Hours

Mean		2,644
Minimum	0	
Maximum	18,344	
Number of Observations	31	

Observed Repair Times, In Hours (Launch Complexes 34 and 37 only)

Mean		22.3
Minimum	1	
Maximum	100	
Number of Observations	7	

Number of Relevant UCRs: 34   Currency:[1] 13 May 1971

[1] Date of latest UCR run included in the assessment.

DESIGN BACKGROUND DATA

1. Component Description

Holddown Arms (HDA) are located at Launch Complex 34, 37, and 39. The HDA are operated by a pneumatic system which is activated at LC-39 by helium at a pressure of 1,500 psig, and at LC-34 and 37, by helium at a pressure of 750 psig. Pneumatic separators (ball-lock mechanism) terminate the restraining action of the arm linkage mechanism. At a specified point in the countdown, the HDA system is pressurized with helium which causes activation of a pressure switch located on the Control Release Panel. The pressure switch closes the arming ignition circuit activating the engines. Following engine ignition, load reversal on the HDA assembly is effected due to engine thrust. The arms restrain the vehicle until full thrust of all five F-1 engines is obtained, at which point a release command is generated to actuate the solenoid valves. This permits the helium to energize the pneumatic separators releasing the ball-lock mechanisms. The arm linkage is then free to retract and release the vehicle for flight.

There are four HDA's at LC-34 and LC-37 and four HDA's on each Mobile Launcher at LC-39. The four arm assemblies are activated from a single pneumatic helium pressure system, with a Control Release Panel, at all three launch complexes.

2. Data Base

Thirty-six UCRs form the primary data base for evaluation of the HDA system. Data bank retrieval was made on functional system 17 for UCRs written prior to 15 October 1969, and on functional system 0400 for UCRs written after 15 October 1969. One UCR, written against an improperly installed pipe anchor in the industrial area was eliminated from the data base as irrelevant to the HDA reliability. UCRs KSC-084608 and KSC-091261 are identical in all respects and appear to be a report of the same unsatisfactory condition. As a consequence, KSC-091261 was eliminated from the data base.

3. Engineering Analysis

Exhibit 1 presents the number of UCRs occurring per calendar quarter.

In general, the UCRs are reasonably complete although written against major items; that is, at a lower level than the HDA system. Thus, it was necessary to deduce the impact of the unsatisfactory condition on the HDA system.

4. Component Populations

Although the total data base for the Holddown Arm systems is quite small, it is possible to separately consider the individual Holddown Arm systems. As a consequence, a categorization of UCRs can be made by launch complex, and Field Failure Rates (FFRs) determined for each HDA system. The categorization results in 20 UCRs applicable to LC-39, seven UCRs applicable to LC-37, and seven UCRs applicable to LC-34. Each of the populations includes all the Holddown Arms and the associated control and pressurization systems.

5. Component Time

Time or age entries on the UCRs were not utilized, since those entries are in reference to a constituent component age rather than the HDA system operational time. Time of failure occurrence is given in Exhibit 2 and times between failures in Exhibit 3.

6. Component Failures

Although 36 UCRs were evaluated, only 34 represent an unsatisfactory condition, and hence a failure, within the Holddown Arm systems. Each UCR is regarded as representing one unsatisfactory condition within a Holddown Arm system. These unsatisfactory conditions, or failures, are summarized by launch complex for each HDA system and presented in Exhibit 2, along with the part identification and date of occurrence. Exhibit 3 is a tabulation by launch complex of occurrence dates and days between occurrence by launch complex.

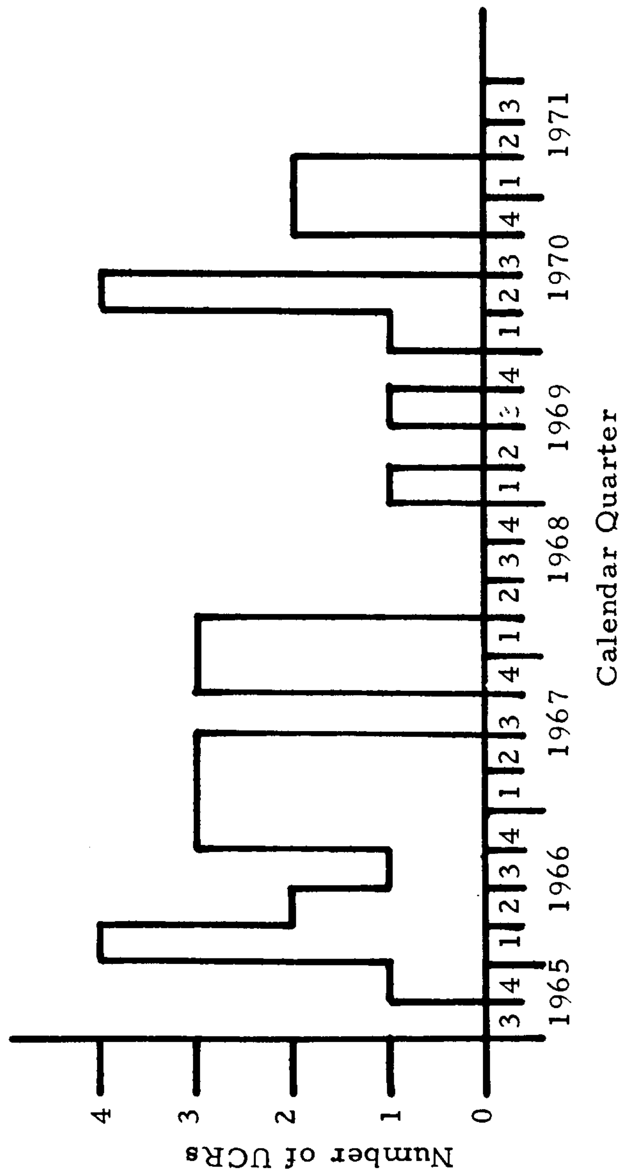


EXHIBIT 1 - NUMBER OF HOLDDOWN ARM UCRS PER CALENDAR QUARTER

EXHIBIT 2 - SUMMARY OF RELEVANT HOLDDOWN ARM SYSTEM FAILURES

Date	Launch Complex	Vehicle	Component	Number Rejected	Failure Description
12/23/65	LC-34	SA 201	Valve	1	Could not be fully opened or closed because of burrs on threads
1/20/66	LC-34	SA 201	Handle	1	Broke due to material defect
1/26/66	LC-39	None	Harness Assembly	1	Cable Connector pins bent
3/12/66	LC-39	None	Pneumatic Separator	1	Internal failure due to improper assembly
3/12/66	LC-39	None	Separator Link	1	Hole for separator pin is not per specifications (undersize)
4/14/66	LC-39	500F	Flex Hose Assembly	1	Thread damaged after hydrostatic test
6/0[illegible]/66	LC	SA 203	Holddown Release Switch	1	Contacts of cable assembly switch stick
7/26/66	LC-34	SA 202	HDA Release Limit Switch	1	Switch operates intermittently
10/21/66	LC-39	AS 501	Flat Head Screw	6	Screws sheared
10/21/66	LC-39	AS 501	Support Assembly	6	Cracked weld due to misalignment of lugs
12/9/66	LC-34	AS 204	Pressure Switch	1	Plug pin connector bent during connection
1/05/67	LC-34	AS 204	Separator	1	Separator ball locks, or piston risors too large
2/14/67	LC-39	AS 501	Cylinder (primary)	3	Internal leakage in excess of specifications
2/14/67	LC-39	AS 501	Cylinder (secondary)	4	Internal leakage in excess of specifications
4/14/67	LC-37	204 LM	Center Link	1	Manufacturing error didn't adhere to specs and damaged in transit
4/14/67	LC-37	204 LM	Lower Linkage	1	Broken screw (failed)
6/05/67	ML-1	AS 501	Hydraulic Pneumatic Assembly	3	Potting boots loose on connectors
10/18/67	ML-1	AS 501	Upper Link Pad	1	Three roots sheared under loaded weight of vehicle
10/18/67	ML-1	AS 501	Striker Plate	1	Bolts sheared--fatigue for retraction tests
10/20/67	LC-37	204 LM	Lower Linkage	4	Impact on lower linkage due to poor design
1/22/68	LC-37	--	Holddown Arm Base	1	Cracks in HDA base (failed)
1/31/68	LC-37	--	Valve Position Potentiometer	1	Cracked
2/10/69	LC-34	None	Casting	8	Extensive laminations in radius at base range design; poor design
8/28/69	LC-39	AS 508	Pneumatic Separator	1	Holddown arms not released in specified time
3/13/70	ML-3	AS 508	Dust Cap	1	Plating on dust cap flaking
4/9/70	ML-1	AS 508	Cable Assembly	1	Locking ring on connection failed to hold correctly
4/11/70	ML-3	AS 509	Holddown Arm No. 3	1	HDA cracked
5/4/70	LC-34	GSE	Plunger Block	1	Numerous cracks
5/7/70	ML-2	AS 509	Pressure Switch	2	Pressure switches activated
10/22/70	ML-2	GSE	Pneumatic Cylinder	1	Leaking in excess of specifications
12/1/70	ML-2	GSE	Hand Valve	1	Valve leaking across seat
1/12/71	ML-2	GSE	Actuator	1	Actuator bolts bent
3/4/71	ML-3	GSE	Pressure Switch	1	Failed to give deactivation indication

LC-39		LC-37		LC-34	
Occurrence Date	Days Between Occurrence	Occurrence Date	Days Between Occurrence	Occurrence Date	Days Between Occurrence
1/26/66	--	6/9/66	--	12/28/65	--
3/12/66	45	4/14/67	309	1/26/66	29
3/12/66	0	4/14/67	0	7/26/66	181
4/14/66	33	10/20/67	189	12/9/66	136
10/21/66	190	1/22/68	94	1/5/67	27
10/21/66	0	1/22/68	0	2/10/69	766
2/14/67	116	1/31/68	9	5/4/70	448
2/14/67	0				
6/5/67	111				
10/18/67	135				
10/18/67	0				
8/28/69	678				
3/13/70	197				
4/9/70	27				
4/11/70	2				
5/7/70	26				
10/22/70	168				
12/1/70	40				
1/12/71	42				
3/4/71	51				

EXHIBIT 3 - OCCURRENCE DATA AND DAYS BETWEEN OCCURRENCE FOR HDA SYSTEM FAILURES BY LAUNCH COMPLEX

7. Failure Classification

Classification of failures beyond that provided by Exhibit 2 is believed to not be particularly instructive, hence none is undertaken. The UCR does contain a more detailed failure classification than that provided in Exhibit 2; however, the data relates to the component within the Holddown Arm system. There are no predominate failure modes of the major items. Most of the failures appear to be normal service type problems rather than being due to faulty HDA design, operation or quality control.

8. Field Failure Rates

For all three launch complexes the mean-time-between-failures (MTBF) is derived as the mean of the individual times between failure.

The results of these MTBF calculations for the three launch complexes are:

LC-39:	119 days
LC-37:	100 days
LC-34:	241 days

The reciprocals of the MTBF's are presented in units of failures/1,000 hours. This represents the FFR. The field failure rates were found to be:

LC-39:	0.348 failures/1,000 hours
LC-37:	0.416 failures/1,000 hours
LC-34:	0.173 failures/1,000 hours

9. Confidence Factors

In the determination of the confidence factors the time between consecutive failures for the Holddown Arm system is assumed to be exponentially distributed. The following 90-percent confidence intervals were then obtained for the areas indicated:

	LC-39	LC-37	LC-34
	(Failures/1,000 Hours)		
Upper Confidence Limit	0.500	0.822	0.303
Lower Confidence Limit	0.229	0.228	0.076

10. Resolution of FFR Factors

Some consideration should be given to the possibility that HDA failures are being classified under a functional system other than the HDA, such as the Pneumatic System. Under these circumstances, a UCR run on the HDA functional system would not pick up all UCRs. They could all be detected only if a run was made on all the possible functional systems or hardware classifications within the HDA system. Then an identification of the parts within that run would have to be made. This is further complicated by the fact that it was found that HDA part numbers contained on the UCRs are often times in disagreement with the part numbers contained on the engineering drawings. This ultimately leads to the conclusion that unless all HDA component failures are classified as belonging to the HDA functional system, it may be impossible to identify all HDA system failures.

11. Repair Time

Some UCRs contained data on repair time. These data are summarized on the cover page of this RAC. However, since UCRs were written against major items, the time indicated is the repair time for the components and not the Holddown Arm system. However, it is reasonable to assume that upon completion of the component repair, the HDA would again be operational.

RELIABILITY ASSESSMENT
OF
PRESSURE SWITCHES

Date: 24 May 1972

Observed Field Failure Rate In Failures Per Thousand Hours Of Installed Component Time		0.10
Observed Failure Times, In Hours		
Mean		9,150
Minimum	0	
Maximum	43,800	
Number of Observations	50	
Observed Repair Times, In Hours		
Mean		6.72
Minimum	0.33	
Maximum	50	
Number of Observations	26	

FAILURE MODES AND CAUSES CONTRIBUTING TO
THE OBSERVED FIELD FAILURE RATE
AS A PERCENT OF THE TOTAL

	Mode of Failure	Proximate Cause of Failure: Normal Service	O&M	Quality	Design	All
Mode of Failure	Out of Tolerance	11.9	0	4.6	18.1	34.6
	Won't Deactivate	9.9	0	0	3.6	13.5
	Fails to Operate	8.2	0	4.1	0.5	12.8
	Erratic/Intermittent	6.7	0	2.6	0	9.3
	Other/Unknown	3.6	2.1	4.6	19.5	29.8
	All	40.3	2.1	15.9	41.7	100.0

Problem Classification (Percent)

Number of Relevant UCRs: 120   Currency:[1] 16 June 1969

[1] Date of latest UCR run included in the assessment.

DESIGN BACKGROUND DATA

1. Component Description

The pressure switches analyzed herein are a very common and somewhat troublesome item in the KSC ground support equipment; they are generally found in the "fluid" functional systems, e.g., N_2, O_2, H_2, hydraulic and pneumatic. Their function is to activate or deactivate a particular function dependent upon existing pressures. Their construction is often quite complex and their operating conditions far from ideal.

2. Data Base

By drawing upon the "major item" entry, 122 UCR's were retrieved from the UCR Data Bank as those associated with major item code 682, pressure switches. Two of these were discarded from all the subsequent analyses, one because it reported a knife switch failure, and one because it duplicated another UCR that was included. Of the remaining 120 UCR's, 6 are readily singled out as initial inspection failures on 6 different items of the same serial number; on each of these reports the failure-rate data is essentially the same. Consequently, in calculating failure-rate data, these 6 reports have been treated as contributing to a single entry.

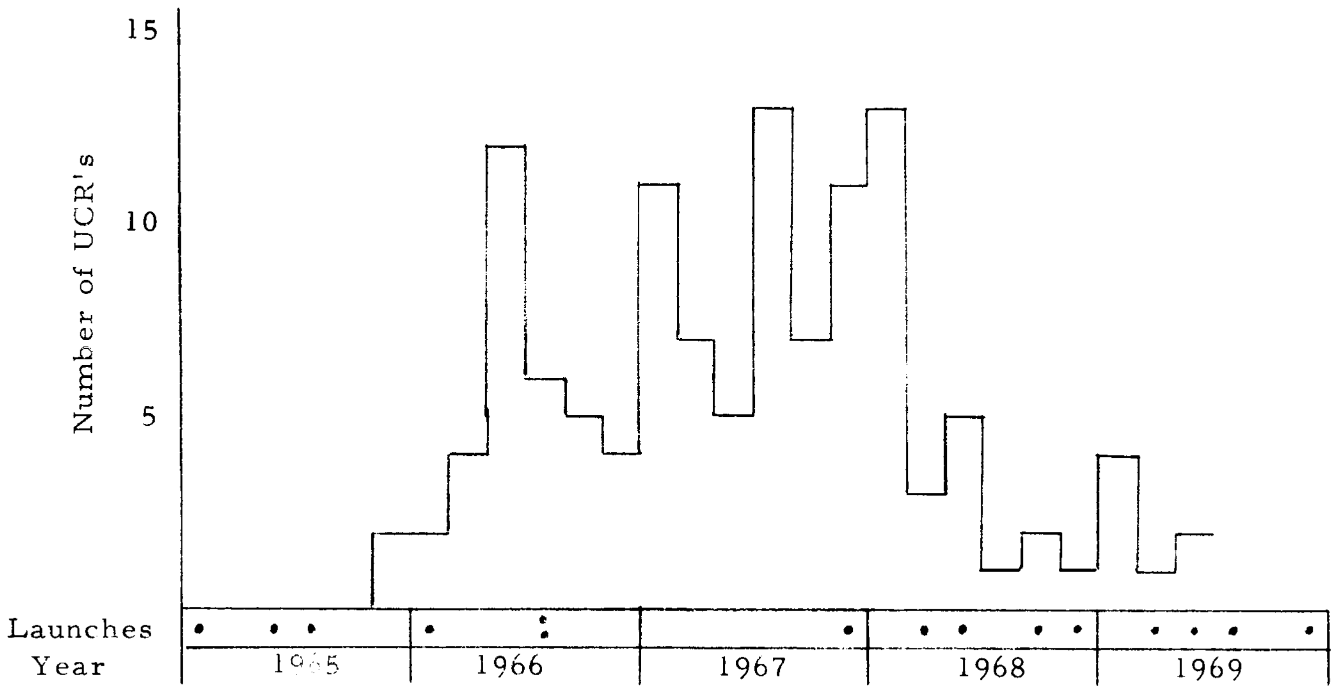
3. Engineering Analysis

Exhibit 1 is a tabulation of the data elements appearing on the UCR's. For example, of the 120 UCR's analyzed, 111 carry an entry for part number, 79 carry an entry for serial number, and 120 give an occurrence date. Of the 111 reports with a part number entry, however, only 75 give an entry of the type 75M*****; 24 different such part numbers are represented. The largest number of reports associated with any one part number is ten, and only four part numbers have more than six associated UCR's. The insufficiency of serial number, replacement part number, and replacement serial number data elements precludes a failure analysis by part number.

The following graph plots the occurrence dates of the 120 UCR's with the launch dates of fifteen Apollo spacecraft indicated for reference. There seems to be no strong correlation between these launch dates and

EXHIBIT 1 - NUMBER OF DATA ELEMENTS OCCURRING IN 120 PRESSURE SWITCH UCR'S

Part Number	111	Part Name	120	Failure Analysis	120
Serial Number	79	Manufacturer	114	Failure	120
Occurrence Data	120	Program	120	Repair Disposition	120
Vehicle	98	Stage	120	Recommendation	120
Non-Applicable Part Number	103	Functional System	117	Reason	120
Non-Applicable Serial Number	39	Non-Applicable Name	116	Narrative	120
Time	7	Operation	120		
Age	49	Organization	120		
Cycle	6	Criticality	114		
Closure Code	76	Design Organization	119		
Quantity Rejected	120	Design Find Number	100		
Approval Date	120	Replacement Part Number	57		
Launch Complex	120	Replacement Manufacturer	56		
Reference Representative Number	60	Non-Applicable Design Failure Number	43		
Replacement Serial Number	31	Non-Applicable Manufacturer	98		
Time to Locate	33	Replacement Part Name	80		
Time to Repair	39	Replacement Find Number	51		
Total Down Time	31	Disposition	120		
Compressed Air Code--Date	98				
Reliability Use Only	120				



the failure occurrence date. This observation is supported by Exhibit 2 which gives the distribution of UCR's by occurrence date and vehicle. This chart shows the span of months in which failures have occurred for each vehicle and the distribution of the 12.5% of UCR's indicating "NONE" as the entry in the vehicle data category.

A total of 194 pressure switches were rejected by the 120 UCR's with 99 UCR's (83%) rejecting only one switch. The distribution of rejections is given in the following table.

Quantity Rejected	1	2	3	4	5	20	22	Total 194
Number of UCR's	99	11	2	5	1	1	1	120

All 120 UCR's bear an entry in "Launch Complex;" 62 percent of them refer to L. C. 39. Of this 62 percent, however, 24 percent are assigned to Mobile Launcher 1, 2, or 3, and 9 percent are assigned to Pad A specifically; the remaining 29 percent are otherwise assigned. The complete distribution is given in the following table.

Months of Launch of Each Vehicle Is Indicated by a Solid Box

Vehicle	Total	1965-10	1965-11	1965-12	1966-1	1966-2	1966-3	1966-4	1966-5	1966-6	1966-7	1966-8	1966-9	1966-10	1966-11	1966-12	1967-1	1967-2	1967-3	1967-4	1967-5	1967-6	1967-7	1967-8	1967-9	1967-10	1967-11	1967-12
SA201	3		1			[2]																						
SA202	12						2			7		[3]																
SA203	2							1		[1]																		
SA204	6															1	5											
SA204LM	13																					1	5	1		2	4	
SA205	1																											
500F/F2	5								2				2					1										
AS501	19													1		1	3	2			1	2	3	2	1	1	[2]	
AS502	21																		1	1						2	2	3
AS503	9																											
AS504	1																											
AS505	5																											
AS506	1																											
None	15		1					2	2			2	2		1	1			2	2								
No Entry	5																		1			1		1		1		
Total	120																											

Vehicle	1968-1	1968-2	1968-3	1968-4	1968-5	1968-6	1968-7	1968-8	1968-9	1968-10	1968-11	1968-12	1969-1	1969-2	1969-3	1969-4	1969-5	1969-6	1969-7	1969-8
SA201																				
SA202																				
SA203																				
SA204						[ ]														
SA204LM																				
SA205						1				[ ]										
500F/F2																				
AS501																				
AS502	3	7	1	[ ]	1															
AS503	2	1		1	1	1			1	1	1	[ ]								
AS504													1		[ ]					
AS505														3			[2]			
AS506																1			[ ]	
None			1			1	1													
No Entry																				

EXHIBIT 2 - DISTRIBUTION OF PRESSURE SWITCH UCR'S BY VEHICLE AND FAILURE OCCURRENCE DATE

Launch Complex Entry	No. of UCR's	Quantity Rejected
L. C. 39	35	97
L. C. 39, Pad A	11	13
M. L. 1	8	8
M. L. 2	17	18
M. L. 3	4	7
Subtotal	75	143
L. C. 34	25	29
L. C. 37	16	16
M. S. O. Bldg.	2	4
Industrial Area	1	1
Launch Complex	1	1
Total	120	194

By percentages, then, 62 percent of the UCR's refer to L. C. 39, 21 percent to L. C. 34, and 16 percent to L. C. 37. With respect to the number of switches rejected, 74 percent refer to L. C. 39, 15 percent to L. C. 34, and 8 percent to L. C. 37.

The 120 UCR's distribute over 21 "Functional System" entries with the majority represented as follows: N_2, 22 percent; O_2, 15 percent; hydraulic, 12 percent. A complete tabulation is given in the following table; the quantity of pressure switches rejected is also indicated. The five "Miscellaneous" data elements are High Pressure Gas, Compressed Air, Launch Mast, Water and Sewage, and Hold Down Arms, each representing one UCR and one rejected switch.

Functional System	No. of UCR's	No. Switches Rejected
N_2	26	50
O_2	18	45
Hydraulic	14	16
Pneumatic	11	12
Environmental Control	11	11
H_2	9	13
Umbilical Swing Arms	8	11
Industrial Water (Fire X)	4	4
Special Test Equipment	2	3
Electrical Networks	2	2
Water Quench	2	2
Air Cond/Heat Vent	2	2
Primary Power	1	5
Propellant Sensing	1	4
Altitude Chamber	1	2
Miscellaneous	5	5
Unassigned	3	7
Total	120	194

The same type of table is presented below for criticality codes. It is interesting that the criticality category with the greatest number of UCRs does not show a proportional increase in the tabulation of the quantity of switches rejected; these additional switches are instead distributed among the more severe criticality classes, or are of unknown criticality.

Criticality	No. of UCR's	No. Switches Rejected
Loss of Vehicle or Life	3	5
CD Scrub/Personnel Injury	4	30
Launch Hold/No Injury	11	20
Data Loss - No CD/L Effect	57	69
No Priority	39	40
Unknown	6	30
Total	120	194

4. Component Populations

Based on the number and diversity of pressure switch unsatisfactory conditions, it is clear that no statistically relevant definition of pressure switch subpopulations or categorizations is particularly meaningful for purposes of field failure rate calculation; hence, none are defined. This implies, of course, that the reliability numerics derived subsequently are equally applicable (or non-applicable) to all pressure switches.

5. Component Times

Quite notable from Exhibit 1 is the general lack of time related data on the UCR's. Furthermore, all six of the "Cycle" entries and six of the seven "Time" entries rise from the six initial inspection failures mentioned earlier, and therefore make little contribution to the failure rate computations. The "Time/Age/Cycle" information is the time-to-failure data used in computing field failure rates, and Exhibit 3 is a plot of this information. The six initial inspection failures were counted individually and contribute to the steep initial slope of the graph. The

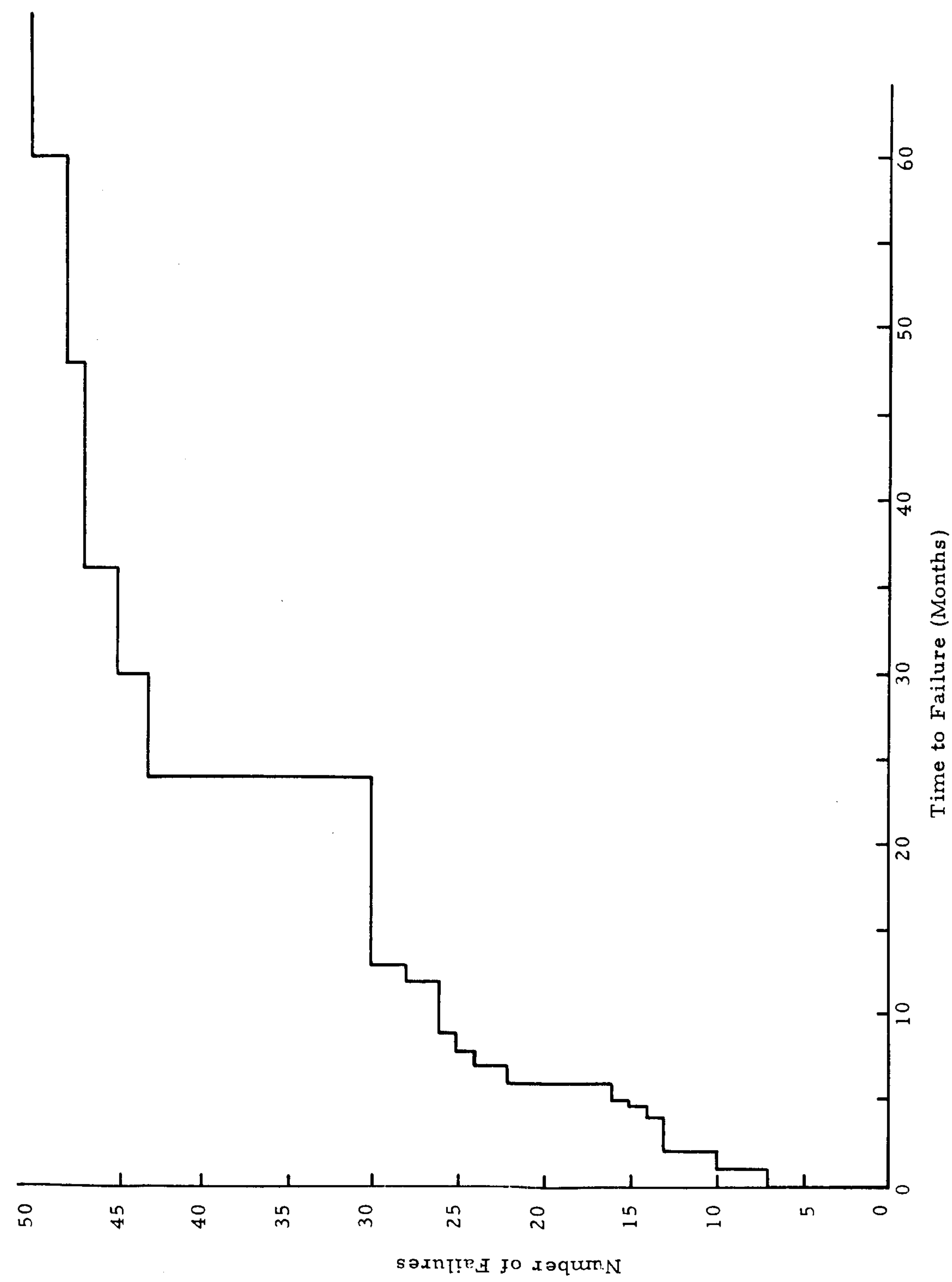


EXHIBIT 3 - CUMULATIVE DISTRIBUTION OF PRESSURE SWITCH TIMES-TO-FAILURE

abrupt increase in failures at twenty-four months evidences the 26 percent of the UCR's which gave this figure as the age of the associated pressure switches at the time of failure. Below is a tabulation of these "Time" and "Age" entries with the associated quantity of rejected pressure switches indicated. The dotted lines indicate the six initial inspection failures.

Age (mos.)	No. Rej.	Age (mos.)	No. Rej.	Age (mos)	No. Rej.	Age (mos.)	No. Rej.	Age (mos.)	No. Rej.
0	1	2	1	6	1	24	1	24	1
0	1	2	1	6	2	24	1	24	1
0	1	2	2	7	1	24	1	24	1
0	1	4	4	7	1	24	1	30	1
0	1	4.8	1	8	1	24	1	30	1
0	1	5	1	9	1	24	1	36	1
0	1	6	1	12	1	24	1	36	1
1	1	6	1	12	4	24	1	48	1
1	4	6	1	13	1	24	1	60	1
1	5	6	1	13	1	24	1	60	1

6. Component Failures

All 50 UCR's, tabulated above, are judged to represent at least one failure. Each UCR may, however, represent as many failures as there are number of switches rejected, also given in the above tabulation.

The UCR's themselves, and particularly the narrative portions thereof, could be used to support either assumption. Hence, both assumptions will be carried separately throughout the classification of failures and the calculation of the field failure rate. That is, it will be assumed that there are either 50 failures or 65 failures.

7. Failure Classification

An analysis of the narrative section of the 120 UCR's leads to a classification of the failures by failure mode and failure type. Results are shown in Exhibit 4. Those headings used for failure type are:

Design: A fault inherent in, and correctable by, a change in pressure switch or system design.

Quality: A fault neither the result of design nor operation *per se*. It is generally a manufacturing problem or a fabrication problem.

Operation: A fault due not directly to a pressure switch, but instead due to the improper action of operating or maintenance personnel.

Normal Service: A fault or condition arising in normal field operation, such as normal wear-out, or those conditions for which available information is inadequate to assign the problem to a failure type listed above.

Two sets of headings have been used, reflecting an operating mode and a condition mode. These sets of headings are tabulated below.

Operating Mode:	Out of Tolerance
	Won't Deactivate
	Fails to Operate
	Erratic/Intermittent
	Other/Unknown
Condition Mode:	Corroded
	Cracked/Leaking/Broken
	Wrong Switch for Requirements
	Switch Wrongly Assembled for Operation
	Normal Wear
	Switch Installed Wrong but Undamaged
	Other/Unknown

Several comments must be made regarding the condition mode classifications. Since these headings are intended to completely partition the 120 UCR's (194 failed switches), the most fundamental failure mode has been used rather than secondary modes. For example, switches corroded due to fluid entering the switch because it was broken in installation has been classified only as "Cracked/Leaking/Broken." The two entries appearing in this row and in the column "Operational"

EXHIBIT 4 - CLASSIFICATION OF PRESSURE SWITCH FAILURES BY FAILURE TYPE AND FAILURE MODE FOR TWO MODAL CLASSES[1]

Operating Mode		Number of UCR's					Number of Rejected SWS				
		Design	Quality	Operation	Normal Service	Total	Design	Quality	Operation	Normal Service	Total
Out of Total	#	8	8	0	17-2/3	33-2/3	35	9	0	23	67
	%	6.7	6.7	--	14.7	28.0	18.0	4.6	--	11.9	34.6
Won't Deactivate	#	3	0	0	18	21	7	0	0	19	26
	%	2.5	--	--	15.0	17.6	3.6	--	--	9.8	13.5
Fails to Operate	#	1	4-1/3	0	15	20-1/3	1	8	0	16	25
	%	0.8	3.6	--	12.5	16.9	0.5	4.1	--	8.2	12.8
Erratic/Intermittent	#	0	5	0	12	17	0	5	0	13	18
	%	--	4.2	--	10.0	14.2	--	2.6	--	6.7	9.3
Other/Unknown	#	10	8	3	7	28	38	9	4	7	58
	%	8.3	6.7	2.5	5.8	23.3	19.6	4.6	2.1	3.6	29.8
Total	#	22	25-1/3	3	69-2/3	120	81	31	4	78	194
	%	18.3	21.1	2.5	58.1	100	41.8	16.0	2.1	40.2	100
Condition Mode											
Corroded	#	6	3	0	9	18	9	6	0	9	24
	%	5.0	2.5	--	7.5	15.0	4.6	3.1	--	4.6	12.4
Cracked/Broken	#	3	5	2	8	18	24	6	2	8	40
	%	2.5	4.2	1.7	6.7	15.0	12.4	3.1	1.0	4.1	20.6
Wrong Switch for Requirement	#	8	1	0	0	9	39	2	0	0	41
	%	6.7	0.8	--	--	7.5	20.1	1.0	--	--	21.1
Switch Assembly Wrong	#	1	7-1/3	0	0	8-1/3	2	8	0	0	10
	%	0.8	6.1	--	--	6.9	1.0	4.1	--	--	5.2
Normal Wear	#	0	0	0	2	2	0	0	0	2	2
	%	--	--	--	1.7	1.7	--	--	--	1.0	1.0
Installed Wrong	#	0	0	1	0	1	0	0	2	0	2
	%	--	--	0.8	--	0.8	--	--	1.0	--	1.0
Other/Unknown	#	4	9	0	50-2/3	63-2/3	7	9	0	59	75
	%	3.3	7.5	--	42.2	53.[illegible]	3.6	4.6	--	30.4	38.7
Total	#	22	25-1/3	3	69-2/3	120	81	31	4	78	194
	%	18.3	21.1	2.5	58.1	100	41.8	16.0	2.1	40.2	100

Note: (1) Percentages do not necessarily add, due to rounding error.

in the matrix of Exhibit 4 are of this type. As expected, most entries in the mode "Wrong Switch for Requirements" are design problems, and most entries in the mode "Switch Wrongly Assembled for Operation" are quality or manufacturing problems. There are only two exceptions, one in each case. First, one UCR reported that two switches were procured wrongly (that is, not to design specifications) and so were classified as a quality problem; second, one UCR reported that two switches were wired into the system wrongly, as the design indicated, and so were classified as a design problem. All other entries are straightforward. It is to be noted that in those matrices presented in terms of the number of UCR's (as opposed to the number of switches rejected), fractions can appear; this is simply because one UCR may refer to several failed switches whose failure modes differ.

8. Field Failure Rates

The following table summarizes the ages-before-failure (in months) assuming that all 65 rejected pressure switches from the 50 UCR's that carried "Time" and "Age" entries are failures. Six of the items with age zero months are the six initial inspection failures discussed in the Engineering Analysis section.

Age in Months = A	No. of failed Switches = N	Product = A x N
0	7	0
1	10	10
2	4	8
4	4	16
4.8	1	4.8
5	1	5
6	7	42
7	2	14
8	1	8
9	1	9
12	5	60
13	2	26
24	13	312
30	2	60
36	2	72
48	1	48
60	2	120
Total	65 failures	814.8 months

Dividing 814.8 by 65 gives the mean time to failure (in months). The field failure rate (failures per month) is, then, the reciprocal of the mean time to failure.

Mean time to failure (MTTF): 12.5 months/failure
Field failure rate (FFR): 0.08 failures/month.

Converting to hours, using the rate of 730 hours/month, gives the following results.

MTTF: 9,150 hours/failure
FFR: 0.109 failures/1000 hours.

If each UCR is assumed to represent only one failure, the same sort of calculations will give the mean time between UCR. In this case, the total of the age-to-failures given on the 50 UCR's is 751.8 months. Dividing by 50 gives an average of 15.0 months/UCR or, taking the reciprocal, 0.067 UCR's/month. The following table summarizes these results after conversion to hours.

Mean time to UCR: 11,000 hours/UCR
Field UCR-rate: 0.091 UCR's/1000 hours.

Note that the final field failure rates under the two assumptions are quite similar and essentially bound the true field failure rate. Averaging the two values gives that recommended for use at this time, i. e., 0.1 failures per 1000 hours.

9. FFR Confidence Intervals

Exhibit 3 offers sufficient justification for the assumption of an exponentially distributed time to failure for pressure switches. Using this assumption and calculating the 90 percent confidence limits for the two cases presented above, i. e., (1) failures = rejects, and (2) failures = UCR's, and then averaging the two results in the following tabulation.

	Confidence Limits (90%)	
	Lower	Upper
Rejects = Failures	0.088	0.132
UCR's = Failures	0.071	0.113
Average	0.08	0.12

10. Resolution of FFR Factors

From Exhibit 4 it can be seen that design problems represent as great a problem, in terms of rejected switches, as normal operation. Quality problems account for approximately one UCR out of five, whereas operational and maintenance problems, in terms of their contribution to the field failure rate, are essentially negligible. Reducing design and quality problems to the level contributed by operations and maintenance would essentially halve the observed field failure rate.

Wear-out is not reported with sufficient frequency to indicate that it represents a problem for pressure switches. Corrosion, on the other hand, is reported often enough (10 to 15 percent of the failures) to indicate that the Cape Kennedy environment is a significant contribution to the pressure switch failure rate.

11. Repair Time

"Time to Locate," "Time to Repair," and "Total Down Time" data elements are present in an average of 29 percent of the UCR's. Exhibit 5 plots these entries on a semi-log scale; the graph demonstrates that it is reasonable to assume a log-normal distribution for these down-time parameters. Apparently, the "Time to Locate" element is less significant than the "Time to Repair" element in determining the down-time of the typical pressure switch. The range and mean times for these three categories are given in the following table.

	Max.	Ave.	Min.
Time to Locate (minutes)	360	56	~0
Time to Repair (minutes)	2880	278	5
Total Down Time (min.)	3000	404	20

The number of observations used in computing these figures are 28, 34, and 26, respectively.

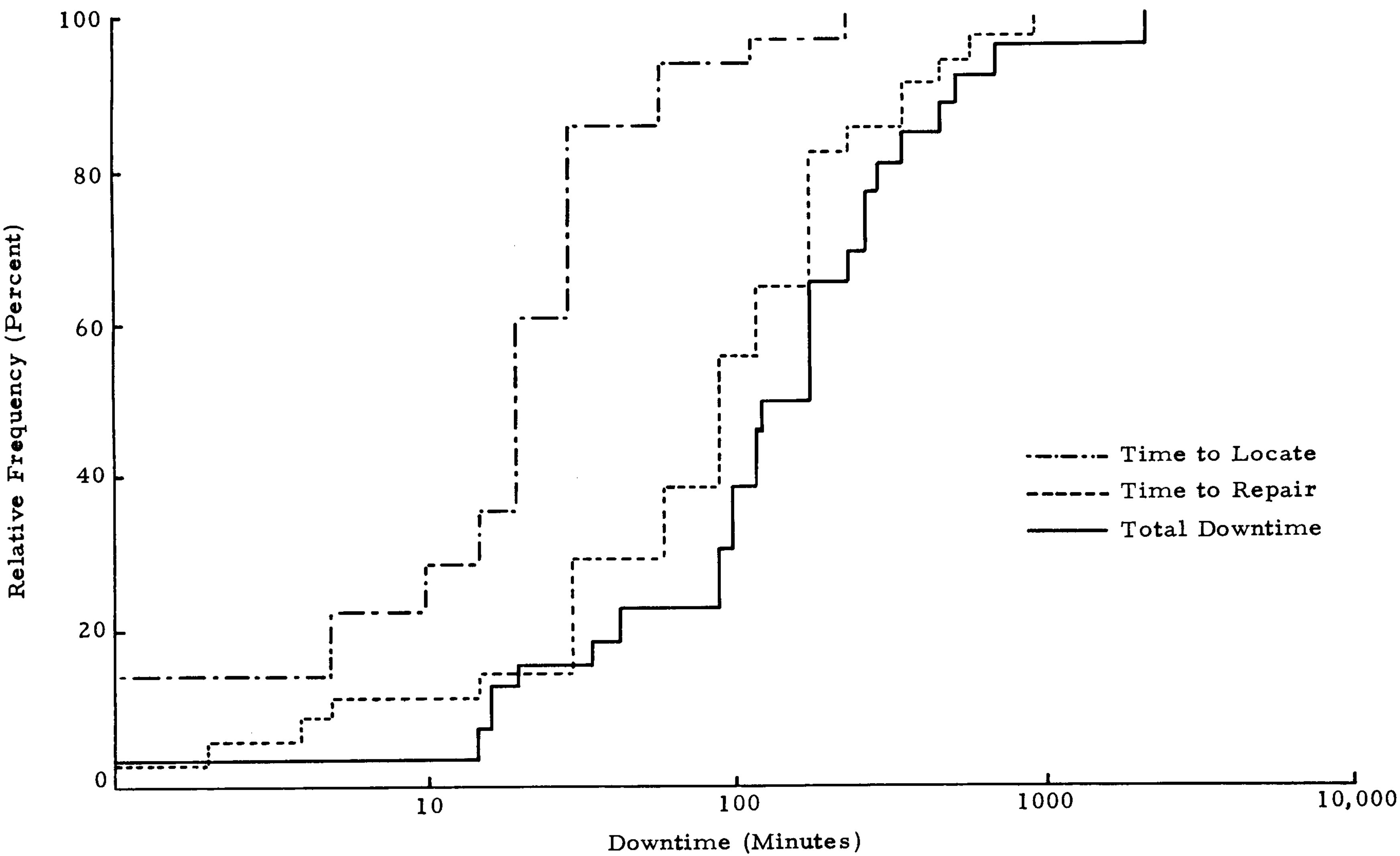


EXHIBIT 5 - CUMULATIVE FREQUENCY OF PRESSURE SWITCH DOWNTIME ELEMENTS

RELIABILITY ASSESSMENT
OF
PUMP ASSEMBLIES

Date: 24 May 1972

Observed Field Failure Rate In Failures Per Thousand Hours Of Installed Component Time		0.129
Observed Failure Times, In Hours		
Mean		7,769
Minimum	1	
Maximum	43,200	
Number of Observations	44	
Observed Repair Times, In Hours		
Mean		7.7
Minimum	1	
Maximum	24	
Number of Observations	12	

FAILURE MODES AND CAUSES CONTRIBUTING TO
THE OBSERVED FIELD FAILURE RATE
AS A PERCENT OF THE TOTAL

		Failure Cause				
		Normal Service	Design Problem	Quality Problem	Operational Problem	Total
Failure Mode	Bearing Problems	5.7	2.8	-	0.9	9.4
	Contamination, Corrosion	2.8	6.6	-	-	9.4
	Cracked or Broken Parts	13.3	-	2.8	0.9	17.0
	Defective or Worn Parts	13.3	0.9	0.9	-	15.1
	Design Deficiency	-	9.4	-	-	9.4
	Electrical Problem	6.6	1.9	-	-	8.5
	Inoperative	5.7	-	-	-	5.7
	Seal Problem	12.3	3.8	1.9	-	18.0
	Other	3.8	2.8	-	0.9	7.5
	Total	63.5	28.2	5.6	2.7	100.0

Failure Classification (Percent)

Number of Relevant UCRs: 103 Currency:(1) 13 May 1971

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(1) Date of latest UCR run included in the assessment.

DESIGN BACKGROUND DATA

1. Component Description

The component population consists of all devices used to pump water, air, or other liquids or gases for use at Kennedy Space Center. Pump assemblies are designated by major item code 918 on Unsatisfactory Condition Reports (UCRs) written prior to 15 October 1969, and by major item code 262 for UCRs written after 15 October 1969.

2. Data Base

The data base consists of 103 UCRs. Ninety-two UCRs were obtained by retrieving all UCRs occurring prior to 15 October 1969 with major item code 918. Eleven UCRs were obtained by retrieving all UCRs occurring after 15 October 1969 with major item code 262.

3. Engineering Analysis

Exhibit 1 presents the number of UCRs occurring per calendar quarter. Except for the peak at the third quarter of 1969, the number of failures decreased from the second quarter of 1968 with no failures reported from the third quarter of 1970.

Sixty-five percent of the UCRs reported failures within launch complex 39. Launch complexes 34 and 37 accounted for 12 percent.

Pump assembly UCRs were written against 20 functional systems. The table below indicates the distribution.

Functional System	Percentage of UCRs
N_2	26.4
O_2	13.2
H.P. Gas	12.2
Industrial Water (Firex)	5.8
Altitude Chambers	4.7
Hydraulics	2.8
RP-1	2.8
All Others	32.1

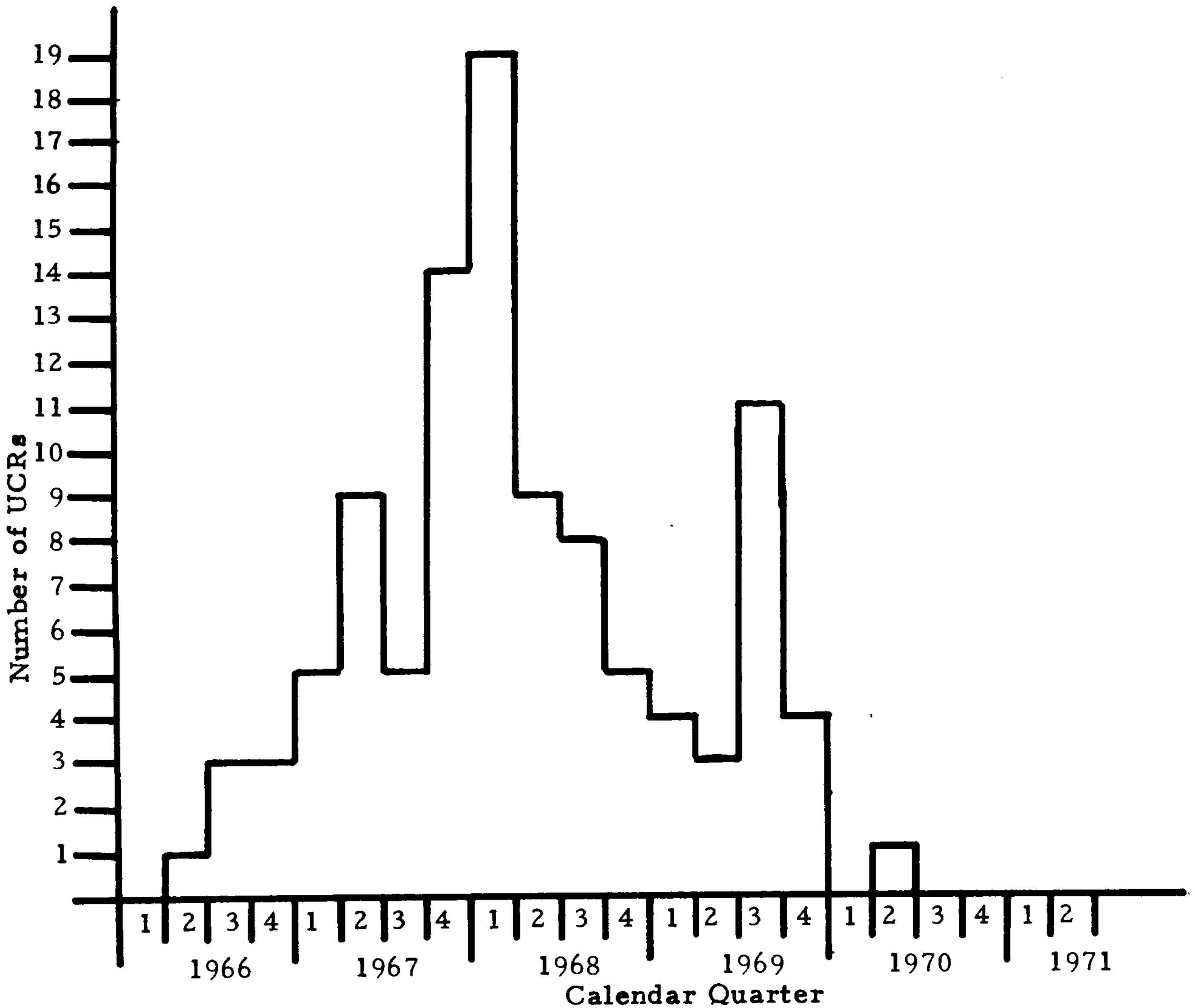

EXHIBIT 1 - NUMBER OF UCRS PER CALENDAR QUARTER

4. Component Populations

Only one component population was chosen for analysis - that of pump assemblies.

5. Component Times

Forty-four UCRs had time or age entries for pump assemblies. Exhibit 2 presents the cumulative distribution of component times. The component times range from 1 hour to 60 months (43, 200 hours).

6. Component Failures

There were 106 reported failures in the data base. One UCR reported four failures (each for a different pump assembly) while each of the remaining 102 UCRs reported one failure. Forty-four failures had relevant time-to-failure information, which is as indicated in Exhibit 2.

7. Failure Classifications

Failure causes were determined for each failure. The description of the failure causes and the number of failures per classification are:

Normal service (67 failures) - failure occurred as a result of normal field operation or there is insufficient information to assign it to any of the other three categories.

Design problem (30 failures) - a failure in which the fault is inherent in and can be corrected by design action; such as, wrong diameter pipe used for intake to pump.

Quality problem (6 failures) - a failure which is a manufacturing problem; such as, pump case cracked when received from vendor.

Operational problem (3 failures) - a failure which resulted from action of operation and maintenance personnel; such as, piston inserted wrong.

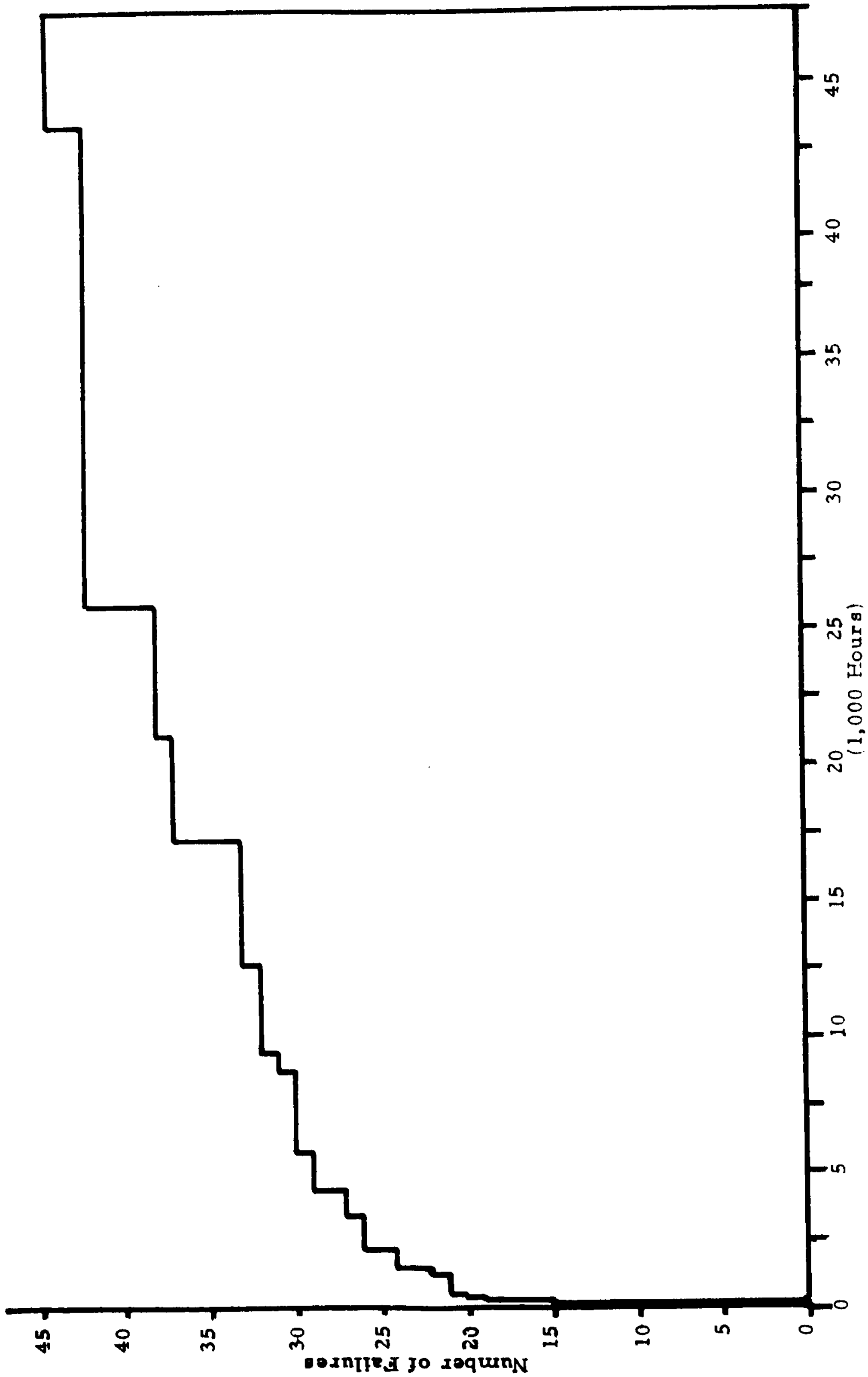

EXHIBIT 2 - CUMULATIVE TIME-TO-FAILURE DISTRIBUTION FOR PUMP ASSEMBLIES

In addition, the following failure modes were determined:

Bearing problems (10 failures) - failure occurred due to bearings, bearings noisy.

Contamination, corrosion (10 failures) - the pump failed due to a contaminate such as oil containing foreign particles or pump assembly parts were corroded.

Cracked or broken parts (18 failures) - pump parts are broken or cracked.

Defective or worn parts (16 failures) - pump parts are worn effecting pump performance.

Design deficiency (10 failures) - pump assembly does not operate in the desired manner due to the design; such as, wrong size pump for application.

Electrical problem (9 failures) - failure due to electrical problem.

Inoperative (6 failures) - pump fails to operate; further classification of problem is not evident.

Seal problem (19 failures) - seal is leaking or is defective.

Other (8 failures) - all other failure modes.

8. Field Failure Rates

Each of the 44 component times from section 5 represents one time-to-failure (TTF); hence, the field failure rate is derived by dividing the number of failures (44) by the sum of the TTFs. The field failure rate for pump assemblies is 0.129 failures/1,000 hours.

9. FFR Confidence Intervals

Exhibit 2 indicates that it is not unreasonable to assume the pump assembly time-to-failures are exponentially distributed. Thus, the 90 percent confidence limits are:

upper limit	0.161 failures/1,000 hours
lower limit	0.098 failures/1,000 hours

10. Resolution of FFR Factors

Forty-eight percent of the failures with TTF information had normal service failure causes. Forty-five percent had system design failure causes. Thus, by eliminating design problems the failure frequency of pump assemblies could be essentially halved even if no other reliability improvement efforts whatever were undertaken. There are no time-to-failure data for failures occurring after the third quarter of 1969 which has an adverse influence on the credibility of the field failure rate for current use.

11. Repair Time

Twelve UCRs had repair time information. The mean time-to-repair was 7.7 hours. The minimum time-to-repair was 1 hour while the maximum time-to-repair was 24 hours. Exhibit 3 presents the cumulative time-to-repair distribution for pump assemblies.

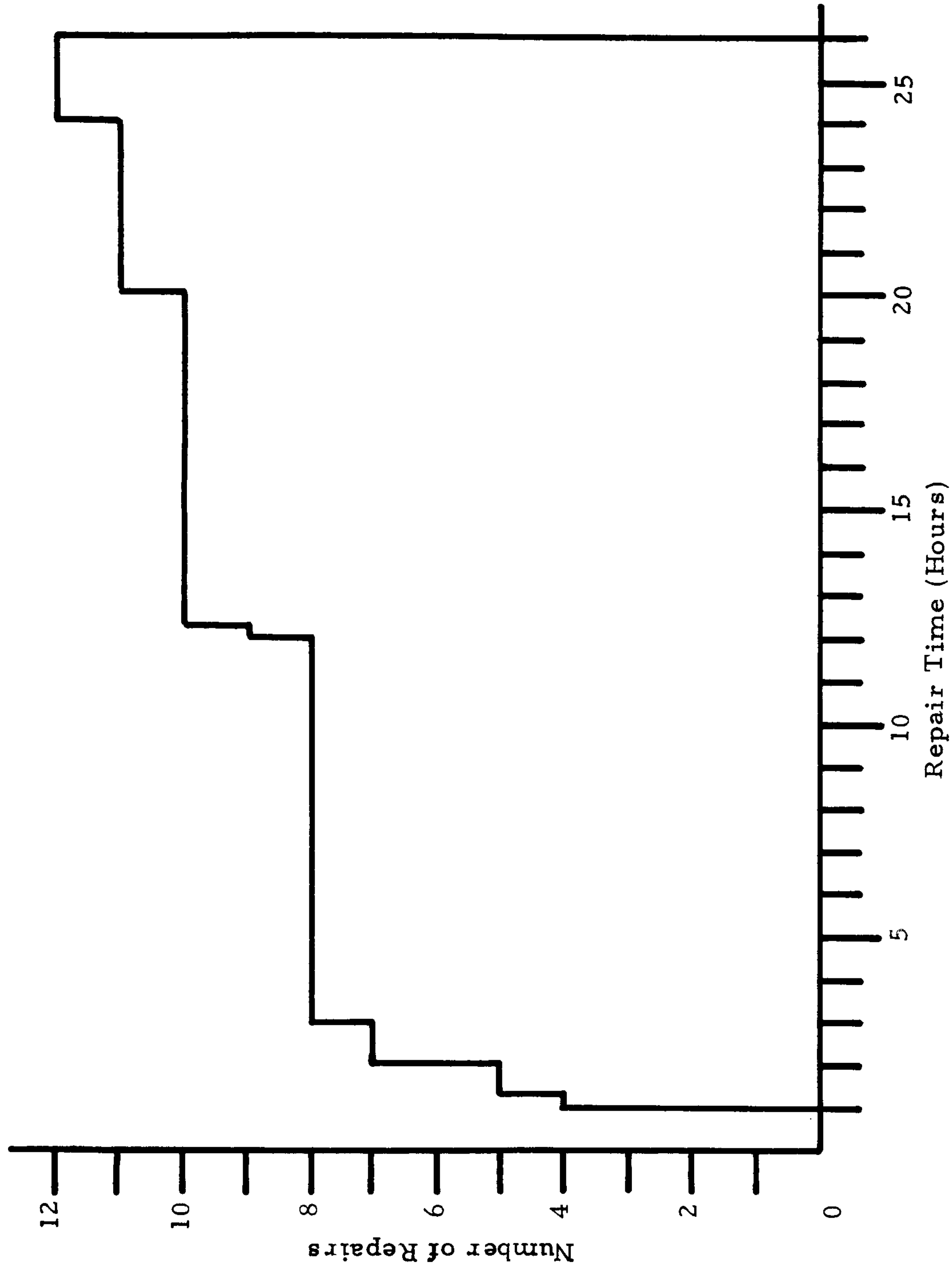

EXHIBIT 3 - CUMULATIVE TIME-TO-REPAIR DISTRIBUTION FOR PUMP ASSEMBLIES

RELIABILITY ASSESSMENT
OF
REGULATORS

Date: 24 May 1972

Observed Field Failure Rate
In Failures Per Thousand Hours
Of Installed Component Time
By Inlet Pressure Range

Inlet Pressure Range (psi)	Field Failure Rate
3000 or greater	0.23
750 to 3000	0.20
750 or less	0.13

FAILURE MODES AND CAUSES CONTRIBUTING TO
THE OBSERVED FIELD FAILURE RATE
AS A PERCENT OF THE TOTAL

Failure Mode	Normal Service	Design Problem	Quality Problem	Preventive Maintenance	Other	Total
Leakage, Internal	12.6					12.6
Leakage, External	6.3					6.3
Leakage, Seat	9.2					9.2
Pressure not Maintained	17.9					17.9
Incorrect Regulation	5.9					5.9
No Regulation	3.6					3.6
Faulty Bleed Adjustments	2.7					2.7
Removed for Preventive Maintenance				12.6		12.6
Part Misapplication		6.3				6.3
Part Cannot Operate to Specifications		2.7				2.7
Foreign Material			6.8			6.8
Installed with Known Problems			1.3			1.3
Contamination, Corrosion					2.3	2.3
Other	5.9	0.8	0.8	-	2.3	9.8
Total	64.7	9.8	8.9	12.6	4.6	100.0

Failure Classification (Percent)

Number of Relevant UCRs: 193 Currency:[1] 10 April 1968

[1] Date of latest UCR run included in the assessment.

DESIGN BACKGROUND DATA

1. Component Description

Regulators were one of two lower level items selected for analysis. The selection was made from two standpoints--(1) mechanical and electromechanical regulators are a high population item of GSE (satisfying the study definition of a component, and (2) regulators are identified as a major item on the UCR (code 639 for UCRs written prior to 15 October 1969) facilitating data retrieval from the UCR file. In addition, regulators are used in many applications and in various locations throughout KSC.

2. Data Base

The request of the data bank for all UCRs written against regulators resulted in 587 UCRs. This number was reduced to 193 UCRs for purposes of analysis by eliminating (1) all non-KSC UCRs, (2) electrical regulators, and (3) incorrectly coded UCRs.

3. Engineering Analysis

The 193 UCRs are distributed among 79 different part numbers; nine of the 193 UCRs have no entry for part number. Exhibit 1 shows that only 14 of the different part numbers have UCR frequencies of four or more.

The small sample sizes limit the calculation by part number of FFRs to five different part numbers. A grouping of part numbers by a number of component characteristics was considered; the resultant decision was to group regulators by inlet pressure ranges of high, medium, and low. Two considerations were involved in this decision.

The first is the supposition that regulators designed to withstand similar pressures can be expected to possess other design similarities in addition to structural strength. Regulator differentiation with respect to type of fluid, i.e., nitrogen, oxygen, hydrogen, water, etc., proved to be an unacceptable criterion for grouping because a number of regulators were found in different fluid systems. For example, part numbers 75M50305 and 75M51168-1 are used in both helium and nitrogen systems;

EXHIBIT 1 - NUMBER OF REGULATOR UCRS BY PART NUMBERS

Part Number (P/N)	Number of UCR's
75M50165-13	17
75M11856	9
75M51102	8
75M08410-1	7
75M08410-1B	7
75M11859	7
75M50305-1	6
75M11875	5
75M04839-4	4
Model 77-4	4
Model 77-3	4
75M07000-2	4
75M08829	4
75M51168-1	4
	90
All Others, 3 or Less	103
Total	193

part number M-13955-AE, in both water and nitrogen. The information available via UCRs preclude examination of any characteristic other than pressure.

The second consideration was derived through examination of the regulator population as determined from the Pad 34/Vehicle 205 find book.[1] The exercise tabulated the regulators by inlet pressure in order to establish the distribution; information on inlet pressure was obtained from the "Remarks" column of the find number index. Of the 196 "Regulator" entries, the inlet pressure could be determined for 126. The remaining 70 could not be determined by this method. The results grouped quite well, as follows:

Inlet Pressure	Number
6,000	32
Between 6,000 and 3,000	7
3,000	34
Between 3,000 and 750	10
750	26
Below 750	17
Total	126

Based on these results, the decision was made to group the regulator data base into pressure ranges--high, medium, and low, corresponding approximately to 6,000, 3,000, and 750 psi, respectively. Exhibit 2 shows the distribution of the 193 UCRs of this study by inlet pressure regulation.

4. Component Populations

Ideally, FFRs for regulators would be computed for each different part number among the total regulator population. Unfortunately, the resultant data base prohibits this procedure except for five part number

[1] "Wearout Analysis Approach" 1 page copy, no other identification.

EXHIBIT 2 - DISTRIBUTION OF REGULATOR UCR'S BY LOW, MEDIUM, AND HIGH INPUT PRESSURE RANGE

Low	($\leq$ 750 psi input)	30
Medium	(750 < P < 3,000 psi input)	45
High	($\geq$ 3,000 psi input)	93
		168
Eliminated		25
15 Electromechanical Regulators		
8 Range Unknown		
2 Data Inaccuracies		
Total		193

groupings or populations of the regulators for which FFRs might be derived. Section 3 describes the principal groupings chosen for use here--three populations of regulators determined by value of inlet pressure. A final population consisting of all electromechanical regulators is also utilized.

a. Components Defined by Part Number

Part numbers are requested on the UCR and, with few exceptions, do appear. As reported elsewhere in this document, a wide variety of part number formats is contained within the data base. The most frequently occurring format, 75MXXXXX, appears to be related to drawing numbers. The first step in grouping the UCRs by part number resulted in the 90 UCRs shown in Exhibit 1 where each part number has a frequency of four UCRs or more. These 14 part numbers do represent components on the basis of the study definition and have a sufficiently large data base to be candidates for FFR calculation.

b. Component Defined by Inlet Pressure

In searching for an alternate component definition under which FFRs might be generated, it was postulated that regulators designed to withstand similar pressures can be expected to possess other design similarities in addition to structural strength.

Engineering analysis of the 193 UCRs in the data base revealed that three groups could be formed corresponding to low, medium, and high inlet pressure. Low inlet pressure is defined as 750 psi or less; medium, as greater than 750 psi, but less than 3,000 psi; high, as 3,000 psi or greater. Exhibit 2 shows that 168 of the UCRs could be so classified. The three categories--low, medium, and high--represent three alternate regulator populations, each of which is a candidate for FFR calculations.

c. Electromechanical Regulators

Among the 105 UCRs with a frequency of three or less in Exhibit 1, there are 15 UCRs written against electromechanical regulators. Because these as a group can be said to "function in a defined manner relative to the overall equipment operation" electromechanical regulators also represent a candidate population for FFR calculation.

5. Component Times

In-service time data for the regulator data base depend directly on information available on the UCR. Two UCR blocks are provided for recording time associated with the major items, age and time. In those UCRs where age entries occur, it is assumed that the number of months the major item has been installed in its recorded position at the time the UCR was written. Time entries are in terms of hours and minutes; as with age entries, it is assumed here that the time reflects the time to failure[1] of the major item in its position at the time of UCR generation.

It is possible to check the validity of this assumption and, in some instances, to deduce additional time estimates. To illustrate this, regulator part number 75M50165-13 will be used as an example. There are 17 UCRs written against this component, each representing one regulator. Generally, no time or cycle information is given; 10 of the UCRs give the data element of age, representing the number of months the component has been installed in the next higher assembly. All the UCRs give date of occurrence and part number and disposition; 13 give the part serial number. From these data additional time estimates for three regulators can be deduced, and nine of the age entries can be validated. This is done by constructing a detailed time profile chart by regulator serial number. This profile is shown in Exhibit 3.

The exhibit is to be interpreted as follows. The vertical line occurring at the right end of a bar denotes the date of a component failure and removal. The vertical line at the left end of a bar denotes date of installation. Wavy lines terminating a bar on the left indicate an unknown date of installation. Wavy lines terminating a bar on the right indicate that the status of the unit is unknown after the last vertical line. A vertical line in the middle of a bar denotes a failed unit that was repaired in place. The 13 bars terminated by vertical lines at both ends are

[1] "Failure" is used here to mean any unsatisfactory condition.

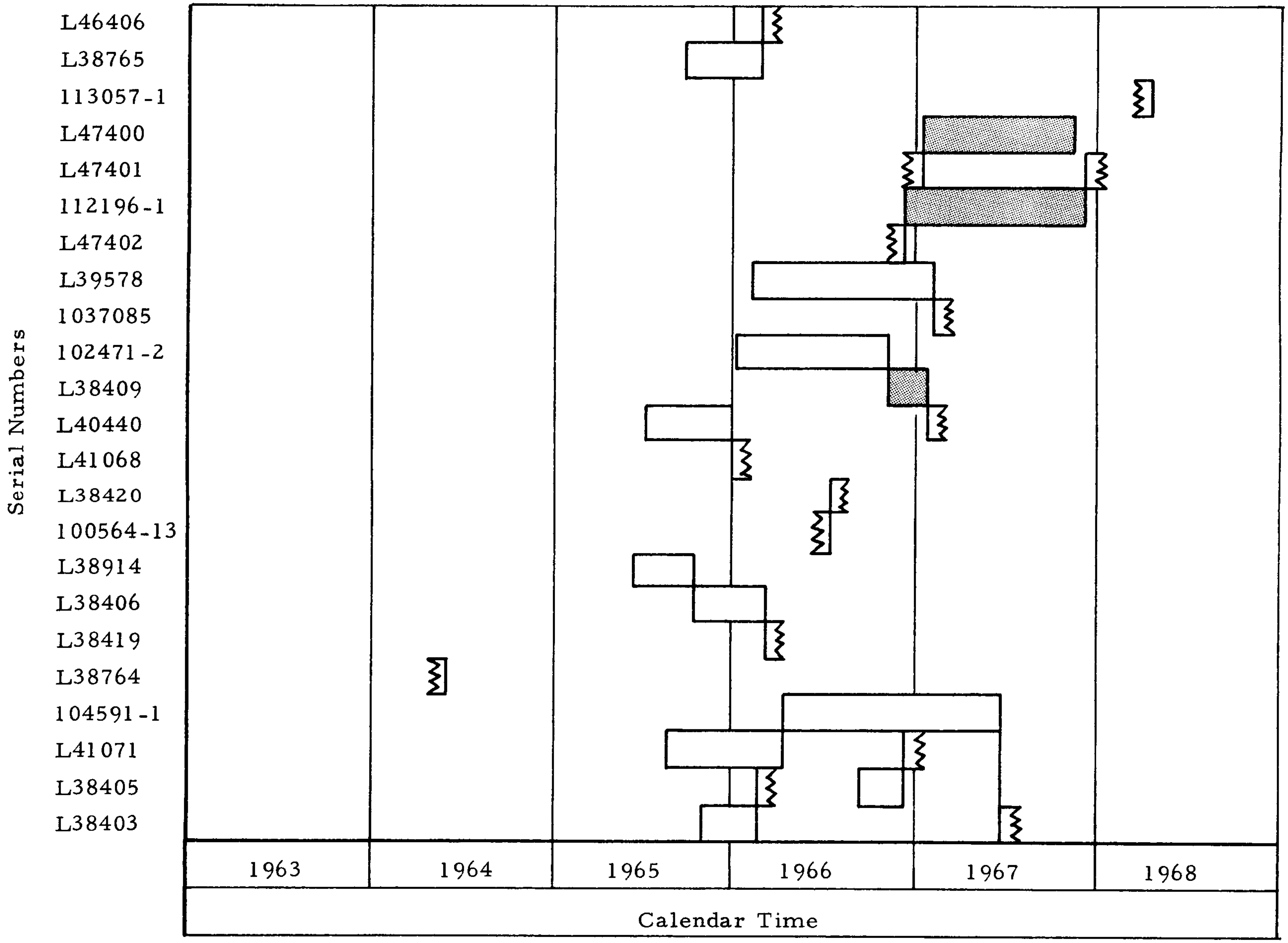

EXHIBIT 3 - TIME PROFILE OF REGULATOR, PART NUMBER 75M50165-13

indicative of in-service times to failure (or age) of the associated regulators listed by serial number.

Since the date of installation is not given directly in the UCR, the lengths of the bars were determined either by subtracting the age, where given, from the UCR date of occurrence or by the following expedient. When a regulator is replaced, the date of installation is established for the replacement unit. If the replacement unit fails at a later date and its serial number appears on both UCRs, its in-service time or age is approximately the difference between the two UCR dates of occurrence.

Derivations of in-service time for each of the three regulator groupings are discussed in the following subsections.

a. Components Defined by Part Number

Exhibit 4 shows the number of component times or ages available for the part numbers of Exhibit 1.

Disregarding for the moment the question of whether or not the 114 regulators in Exhibit 4 represent failures, it can be seen that seven of the part numbers have no, or only one component time or age estimate and must, therefore, be eliminated from the FFR calculations by part number.

It is important to note that the problem here is not a fault of the UCR system; time estimates are required. Those UCRs with blank time and age entries may result either from lack of information available to the UCR originator or because the originator considers the entry to be of little value. It is a fact that approximately 38 percent of the 193 regulator UCRs have such entries; it seems reasonable to assume, therefore, that this information is available. Furthermore, time estimates can often be deduced if the serial numbers for the part and its replacement are given. However, only 71 of the 193 regulator UCRs recorded replacement part serial numbers.

b. Components Defined by Inlet Pressure

Exhibit 5 shows the number of component time estimates available for the regulators grouped according to inlet pressure ranges. FFRs for these groups can be generated.

EXHIBIT 4 - NUMBER OF REGULATORS WITH TIME ESIMATES AVAILABLE FOR PART NUMBERS ON 90 UCRS

P/N	Number of UCR's	Number of Regulators	Number of Regulators With Time or Age Entries	Number of Regulators Where Time Can Be Deduced
75M50165-13	17	17	10	3
75M11856	9	13	0	4
75M51102	8	10	0	1
75M08410-1,-1B	14	28	0	8
75M11859	7	7	0	0
75M50305-1	6	6	5	0
75M11875	5	8	0	1
75M04839-4	4	4	4	-
Model 77-4	4	4	4	-
Model 77-3	4	4	0	0
75M07000-2	4	4	0	0
75-M08829	4	4	0	0
75M51168-1	4	5	0	0
Totals	90	114	23	17

EXHIBIT 5 - NUMBER OF REGULATORS WITH TIME ESTIMATES AVAILABLE FOR LOW, MEDIUM, AND HIGH INLET PRESSURE RANGES

Range of Inlet Pressure		Number of UCR's	Number of Regulators	Number of Regulators With Time or Age Entries	Number of Regulators Where Time Can Be Deduced
High:	$\geq$3,000 psi	93	116	31	15
Medium:	$750<P<3,000$ psi	45	48	16	3
Low:	$\leq$750 psi	30	58	36	0
Totals		168	222	83	18

c. Electromechanical Regulators

Of the 15 electromechanical regulator UCRs representing 22 regulators, 20 have age or time entries. Pending identification of failures among the 22 regulators, FFRs can also be calculated for this group.

6. Component Failures

An engineering analysis of each of the 193 regulator UCRs was performed to determine which UCRs, in fact, represent regulator failures. As stated elsewhere, the definition of a field failure for this study is "the inability of a component to perform its defined function regardless of cause." Included in this definition are regulators not capable of performing their function because they are defective, either at installation or after some elapsed period, and regulators unable to perform their function because of part misapplication (design problems) or because of problems in the realm of quality control.

The engineering analysis of the UCRs identified design problems, quality control problems, and defective parts, as well as those UCRs that cannot be classified as field failures. The UCR system provides for essentially this same type of classification; unfortunately, too many coding irregularities exist to permit sorting the UCRs on the basis of the codes provided in the UCR block, "reason for report."

The number of identified failures for each of the regulator groups previously defined as candidates for FFR calculations is given in the following paragraphs.

a. Components Defined by Part Number

Six part numbers have a sufficient number of UCRs and associated time estimates to potentially permit an FFR calculation, depending on the number of failures involved.

(1) Part Number 75M50165-13

This component is a cold gas regulator; a total of 17 UCRs are written against 75M50165-13.

Sixteen of the UCRs are coded by the UCR originator as "failed item." Engineering analysis by the study team indicates that, in fact, all of the 17 are failures.[1]

(2) Part Number 75M11856

This component is a cold gas regulator, used in the tail service mast assemblies. Thirteen regulators are involved on nine UCRs. Each of the 13 regulators are identified as failures under the study definition, with two representing conditions existing prior to installation and thus assigned to the category of quality control.

(3) Part Number 75M08410-1, -1B

Part numbers 75M08410-1 and -1B are also cold gas regulators used in the umbilical swing arm assemblies; all 14 UCRs were originated at LC-39. Twenty-eight regulators are involved, 15 of which were reported on one UCR. These 15 regulators were disassembled for modification and are not considered to represent regulator failures. Eight of the modified regulators were reinstalled and failed at a later date. These eight and the remaining five unmodified regulators are all considered to be failures.

(4) Part Number 75M50305-1

This is a cold gas regulator used in the helium and pneumatic functional systems at LC-34 and LC-37. Six UCRs report problems on six regulators; all are classified as failures.

Two data inconsistencies are evident in the anlysis of the six UCRs. Serial number 3677 reported failed on 23 September 1966. It is used as a replacement for a failed regulator on 16 December 1966, presumably after repair. On 21 November 1967, it is used again as a replacement in a different position than in December 1966. In the intervening year,

[1] The discrepancy is coded "operational problem"; the narrative reads in part, "... regulator could not be adjusted to produce higher (required) output... possible causes... a leaking diaphragm or defective internal relief valve."

no record is given concerning the regulator. It seems likely that S/N 3677 did incur another problem during the interval 16 December 1966 to 21 November 1967; the incident is not reported via the UCR system.

The second data inconsistency concerns two regulators reported on consecutive UCR numbers, having the same serial number and the same find number, but with different next assembly numbers and replacement serial numbers. There are instances of different next assembly numbers having identical find numbers (e.g., TSMs). The existence of two different regulators is assumed for this study.

(5) Part Number 75M04839-4, -1

This component is a cold gas regulator used in the helium functional system at LC-34. Four UCRs are written against the -4; three against the -1. The problem being reported on the seven UCRs involves the regulators in the pneumatic control distribution assembly. Since all seven regulators are interchanged in similar positions, the group is considered appropriate for FFR calculations.

The UCR events are important to the determination of the number of failures for this component. On 19 February 1966, S/N 2 of 75M04839-1 (F/N 1592) incurred internal leakage, as did S/N 2 of 75M04839-4 (F/N 1593). They were replaced with S/N 14 and S/N 16, respectively. On 21 February 1966, S/N 5 (F/N 1616) and S/N 1 (F/N 1617) were removed; investigation of the first two failures revealed that the helium "had caused a problem with the rubber on diaphragm plate," and S/N 5 and 1 were removed to "ensure no failure of system 2 before launch." They were, however, replaced with the original two regulators. On 26 February 1966, these two regulators incurred the same failure mode they had experienced on the 19 of February. The assumption for this study is that two failures occurred on 19 February after seven months of service, were repaired and reinstalled, and experienced two additional failures in five days. The seventh UCR also represents a failure; thus, a total of five failures are identified for this component.

(6) Part Number Model 77-4

Model 77-4 is a 1,000 GPM set point reference regulator used in the nitrogen functional system at Pad A, LC-39. The four UCRs, all with age entries, report the same design problem against four regulators. Since only one failure event occurs, the component is eliminated for FFR calculation purposes.

b. Component Defined by Inlet Pressure

Identification of failures for the alternative method of grouping the regulator data base (by range of inlet pressure) is accomplished by engineering analysis similar to that performed for the UCRs grouped by part number. Each of the UCRs for the three pressure ranges was examined and classified as a failure.

Since the FFR calculations of Section 8 below are limited to those regulators where time estimates are available, only these regulators of the total 222 (see Exhibit 5) are classified below as failures or non-failures.

(1) High-Pressure Regulators

Among the 116 high-pressure regulators of Exhibit 5, there are 46 with time estimates. Forty-four of these are identified as failures.

(2) Medium-Pressure Regulators

There are 19 regulators with time estimates among the 48 medium-pressure regulators of Exhibit 5. All are classified as failures appropriate for FFR calculations.

(3) Low-Pressure Regulators

All 36 low-pressure regulators with time entries (see Exhibit 5) are classified as failures and form the base for the FFR calculations presented below.

c. Electromechanical Regulators

All 20 electromechanical regulators with time estimates are failures under the definition of this study and are the basis of the FFR calculated below.

7. Failure Classifications

An engineering analysis was performed using the information on each UCR. Exhibit 6 presents five major classifications of problems recorded on the regulator UCRs that were grouped previously according to high-, medium-, and low-inlet pressure.

The first classification, identified as "defective part," is by far the largest category. Two major subcategories are possible: (1) regulators where the observed problem occurs during some prescribed procedure, i.e., initial component test, system test, or normal operation; and (2) regulators which were removed from an installation for preventive maintenance, generally precipitated by a related regulator problem. Of these two major subcategories, the first has a sufficient number and variety of unsatisfactory conditions to permit a further breakdown.

Each of the titles listed represents a defective part observation; they are not of the same levels, but do give a reasonable description based on the UCR information. Brief remarks concerning each category are in order.

In the three leakage categories, the 20 seat-leakage problems are so identified as the result of a failure analysis reported on the UCR. The 13 external leakage observations are primarily defective "O" rings. The internal leakage category (28 entries), however, is not as clearly defined; the exact location of the leak could not be determined from the entries. Diaphragms, "O" rings, or the seats may be the problem.

Problems classified as "pressure not maintained" indicate variations in pressure, resulting perhaps from insufficient lubrication or a combination of functional forces; "incorrect regulation" reflects constant error in pressure. The "no regulation" category includes regulators with no output pressure and is primarily indicative of ruptured diaphragms.

"Vibration" or noisy regulators may be the result of the seat material used, contamination, or the number of cycles the regulators have undergone. "Mechanical binding" includes regulator problems where the buildup of mechanical or structural tolerances is exceeded,

EXHIBIT 6 - PROBLEM CLASSIFICATION FOR REGULATORS

	Inlet Pressure Range			
	High No.	Medium No.	Low No.	Total %
Defective Part--Problem Observation				
Normal Service				
Leakage, internal	20	3	5	
Leakage, external	11	1	2	
Leakage, seat	15	3	2	
Pressure not maintained	27	9	4	
Incorrect regulation	0	11	2	
No regulation	6	1	1	
Vibration	2	1	0	
Mechanical	3	1	3	
Faulty bleed adjustments	6	0	0	
Pressure Spike	0	2	0	
Broken part	0	1	0	
Removed for preventive maintenance	2	0	26	
Total	92	33	45	77
Design Problems				
Part misapplication	0	8	6	
Part can not operate to specifications	1	4	1	
Wrong part	0	1	0	
Missing part	0	1	0	
Total	1	14	7	10
Quality Control				
Improper assembly	1	0	0	
Slots, scores	1	0	0	
Foreign material	15	0	0	
Installed with known problems	3	0	0	
Total	20	0	0	9
Contamination-Corrosion Total	3	1	1	2
Unable to Classify Total	0	0	5	2
Page Total	116	48	58	100 percent

or corrosion or the lack of lubrication is present. The remaining categories are self-explanatory.

In each of the above groups, no further determination could be made as to the cause of the problem. It is entirely possible, for example, that manufacturing processes or human errors are contributing factors. For the present, however, 77 percent of the 222 regulators of Exhibit 6 are classified as defective parts.

Design problems account for 10 percent of the reported problems on UCRs, including part misapplications of various types and, in one instance, operation of a system without a required regulator. Problems associated with quality control activities (e. g., improper assembly, foreign material), account for 9 percent of the total problems; identified corrosion and contamination involve 2 percent of the observed problems. The remaining 2 percent of the UCRs contained insufficient information for classification. Problems reported in the UCRs for electromechanical regulators can be classified into two groups--defective parts and design problems. Among the 20 electromechanical regulators are temperature and environment controllers (accounting for the nine defective parts) and speed regulators associated with the crane operation (11 design problems).

8. Field Failure Rates

Calculation of field failure rates is limited to those nine populations defined in the preceding two subsections which have a sufficient number of failures and associated times to failure to make calculation feasible. Exhibit 7 summarizes this information for each of the three major groupings and includes individual times to failure, total accumulated time, and total number of failures for each component population.

Exhibit 8 shows the mean time to failure for each of the nine populations derived as the sum of all individual times to failure divided by the number of observed failure times. The FFR is then found by taking the reciprocal of the mean failure time and converting to units of failures per 1,000 hours.

EXHIBIT 7 - NUMBER OF FAILURES AND TIMES TO FAILURE[1] FOR THE THREE REGULATOR COMPONENT GROUPS

I. Components Defined by Part Numbers

	75M50165-13		75M08410-1,-1B		75M50305-1		75M04839-4,-1		75M11856	
	n_i	t_i	n_i	t_i	n_i	t_i	n_i	t_i	n_i	t_i
	1	90	1	15	1	15	2	7	1	19
	3	120	1	17	1	60	1	30	1	21
	2	180	1	66	1	240	2	210	1	29
	1	210	1	78	1	300			1	39
	1	270	1	99	1	870				
	1	300	1	125						
	3	360	1	128						
	1	420	1	170						
Σn_i	13		8		5		5		4	
$\Sigma n_i t_i$		3090		698		1485		464		108

II. Components Defined by Inlet Pressure Range

High Pressure		Medium Pressure		Low Pressure	
n_i	t_i	n_i	t_i	n_i	t_i
1	0	1	2	2	30
2	7	1	3	5	120
2	15	1	14	1	180
1	17	1	35	1	330
1	19	1	60	1	540
1	21	1	120	2	1080
1	29	1	210		

EXHIBIT 7 (Continued)

II. Components Defined by Inlet Pressure Range (Continued)

	High Pressure		Medium Pressure		Low Pressure	
	n_i	t_i	n_i	t_i	n_i	t_i
	2	30	2	270		
	1	39	1	330		
	2	60	4	360		
	1	66	1	420		
	1	78				
	1	90				
	1	99				
	3	120				
	1	125				
	1	128				
	1	170				
	4	180				
	3	210				
	1	240				
	1	270				
	2	300				
	3	360				
	1	420				
	1	540				
	1	720				
	1	870				
Σn_i	42		15		12	
$\Sigma n_i t_i$		7555		3174		3870

EXHIBIT 7 (Continued)

III. Electromechanical Regulators

	n_i	t_i
	1	0
	4	30
	1	90
	8	180
	1	210
	1	360
	2	540
	1	720
	1	1080
Σn_i	20	
$\Sigma n_i t_i$		5100

n_i = Number of failures

t_i = Times-to-failure

i Ranges from 1 to the total number of individual times-to-failure observed for each population

Σn_i = Total number of failures for each population

$\Sigma n_i t_i$ = Sum of the individual times-to-failure for each population

Note: (1) Times to failure are given in days.

EXHIBIT 8 - FFR ESTIMATES AND THEIR ASSOCIATED CONFIDENCE FACTORS

Regulator Groupings	Number of Failures	Associated Mean Failure Time (Days)	Estimated FFR (Per 1,000 Hours)	90 Percent Confidence Interval (Per 1,000 Hours)	
				Upper	Lower
Part Number					
75M50165-13	13	238	0.18	0.10	0.26
75M08410-1, -1B	8	87	0.48	0.24	0.78
75M50305-1	5	285	0.15	0.06	0.28
75M04839-4, -1	5	93	0.45	0.18	0.82
75M11856	4	648	1.54	0.53	2.99
Inlet Pressure Range					
$P \geq 3{,}000$ psi	42	180	0.23	0.18	0.29
750 psi $< P <$ 3,000 psi	15	212	0.20	0.12	0.29
$P \leq 750$ psi	12	322	0.13	0.07	0.20
Electromechanical					
Electromechanical	20	255	0.16	0.11	0.23

The mean FFR values given in Exhibit 8 are appropriate to the related population only; individual elements or groups of elements within the population might well have FFRs considerably different from the mean value presented. For example, all regulator populations shown in the grouping by part number form a part of the population of high-pressure regulators in the grouping by inlet pressure range. The five regulators in the former grouping have FFR estimates that vary by an order of magnitude, a fact which must be borne in mind if the average high-pressure regulator FFR estimate of 0.23 failures per 1,000 hours is to be used.

It should also be recognized that the FFR estimates presented are based on a rather small sample of regulator times to failure (compared to the number that would be available if all UCRs were completed) and hence may not be particularly stable. That is, those available might not be a random sample of failure times, but rather a sample with some inherent bias. The presence of bias is much more likely with the smaller sample sizes. It is the author's judgment, based on all available data, that the estimated FFRs for those populations of Exhibit 8 containing 12 or more samples are reasonably stable; additional data are not expected to significantly alter the values presented.

9. Confidence Factors

The failure rates computed in the preceding section indicate the order of magnitude of regulator failure rates under field conditions. It is important to note that no distributional assumption was made with respect to the times to failure or the FFRs.

In order to explore the potential variation of the FFRs in terms of confidence factors, some distributional assumption must be made. Using the Kolmogorov-Smirnov test, the hypothesis that the underlying distribution is exponential could not be rejected for any of the nine groups of regulators. There is no evidence that the wearout phenomenon sometimes associated with mechanical parts is present.

In view of the facts that the exponential distribution cannot be rejected for any of the populations and the data are insufficient to support any other distributional assumption, the exponential assumption is made for purposes of confidence interval determination for the estimated FFRs. This is considered to be the minimal assumption possible within the constraints of the data.

The confidence intervals for regulators are shown in Exhibit 8. Again, it should be emphasized that the confidence intervals are with respect to the mean FFR for a given population; individual FFRs within the given population could easily vary by an order of magnitude.

10. Resolution of FFR Factors

Section 7 pointed out that no evidence of the wearout phenomenon is evidenced by the data. Cycle information is not available for any of the regulators. Thus, neither of these two potential contributing factors is included here.

Investigation by date of problem occurrence in relationship to the associated vehicle or launch pad indicated no discernible factor that could be said to influence the FFR.

Exhibit 9 shows the original FFR for the five part types and three groupings of regulators and the contribution to those rates by the three categories defined in Exhibit 6--design, quality control, and contamination/corrosion. The percentages shown in Exhibit 6 are applied to all regulator groups (except electromechanical regulators) for the three groups of contributing factors. Design problems account for over 50 percent of the FFR of electromechanical regulators; no other contributing factor could be isolated for this group.

EXHIBIT 9 - CONTRIBUTION OF INFLUENCING FACTORS TO FFR ESTIMATES FOR REGULATORS

Regulator Grouping	Field-Failure-Rate Estimate Per 1,000 Hours: All Failures	Contribution of QC Failures	Contribution of Design Failures	Contribution of Contamination/ Corrosion	Adjusted FFR
Part Numbers					
75M50165-13	0.18	0.018	0.016	0.004	0.14
75M08410-1, -B	0.48	0.048	0.043	0.010	0.38
75M50305-1	0.15	0.015	0.014	0.003	0.12
75M04839-4, -1	0.45	0.045	0.040	0.009	0.36
75M11856	1.54	0.154	0.139	0.031	1.22
Inlet Pressure Range					
$P \geq 3,000$ psi	0.23	0.023	0.021	0.005	0.18
750 psi $< P <$ 3,000 psi	0.20	0.020	0.018	0.004	0.16
$P \leq 750$ psi	0.13	0.013	0.012	0.003	0.10
Electromechanical	0.16	--	0.088	--	0.072

RELIABILITY ASSESSMENT
OF
RELAYS

Date: 24 May 1972

Observed Field Failure Rate
In Failures Per Thousand Hours
Of Installed Component Time

Prior to 15 October 1969	0.09
After 15 October 1969	0.42

FAILURE MODES AND CAUSES CONTRIBUTING TO THE OBSERVED FIELD FAILURE RATE AS A PERCENT OF THE TOTAL

		Failure Cause			
		Normal Service	Quality Problem	Design Problem	Total
Prior to 15 October 1969	Contact Problem	6.7	-	-	6.7
	Higher Level Equipment Affected	33.1	0.4	1.5	35.0
	No Output	7.8	-	-	7.8
	Operation Problem	23.9	1.5	0.4	25.8
	Oscillating	1.9	0.4	0.4	2.7
	Short Circuit	3.7	0.4	-	4.1
	Undesired or Unspecified Operation	3.3		4.1	7.8
	Other	5.6	4.5	-	10.1
	Total	86.0	7.6	6.4	100
After 15 October 1969	Contact Problem	4.3	-	-	4.3
	Higher Level Equipment Affected	10.6	-	-	10.6
	No Output	-	-	-	-
	Operation Problem	29.7	-	-	29.7
	Oscillating	4.3	-	-	4.3
	Short Circuit	12.8	2.1	-	14.9
	Undesired or Unspecified Operation	17.0	-	-	17.0
	Other	12.8	4.3	2.1	19.2
	Total	91.5	6.4	2.1	100

Failure Classification (Percent)

Number of Relevant UCRs: 294 Currency:[(1)] 26 April 1971

[(1)]Date of latest UCR run included in the assessment.

DESIGN BACKGROUND DATA

1. Component Description

Relays are found in over 30 locations at KSC and represent components in over 25 functional systems. Relays have the major item code designation 645 for UCRs (unsatisfactory condition reports) written prior to 15 October 1969, and major item code 269 for UCRs written after 15 October 1969. Included in the reliability assessment are relay sockets and connectors, and relay driver units.

2. Data Base

The data base consists of 294 UCRs obtained through the use of the UCR major item code. There were 260 UCRs dated prior to 15 October 1969 and 34 UCRs dated subsequently.

3. Engineering Analysis

Analysis of the data base indicated six UCRs reported the same failure as other UCRs. These six failures occurred in relay drivers with the same failures documented on other UCRs under the part name "relays." For this analysis, only one failure is considered to have occurred. Thus, the total data base consists of 288 UCRs.

Exhibit 1 presents the number of relay UCRs occurring per calendar quarter. After the second quarter of 1969, the number of UCRs per quarter decreases sharply.

Exhibits 2 and 3 present the number of relay UCRs associated with various functional systems and originating at various locations.

4. Component Populations

There are two component populations: (1) UCRs written prior to 15 October 1969, and (2) UCRs written after 15 October 1969. The first population consists of 254 UCRs while the second contains 34 UCRs.

5. Component Times

There were 93 time entries for relay UCRs occurring prior to 15 October 1969. Exhibit 4 presents the cumulative distribution of these relay times-to-failure.

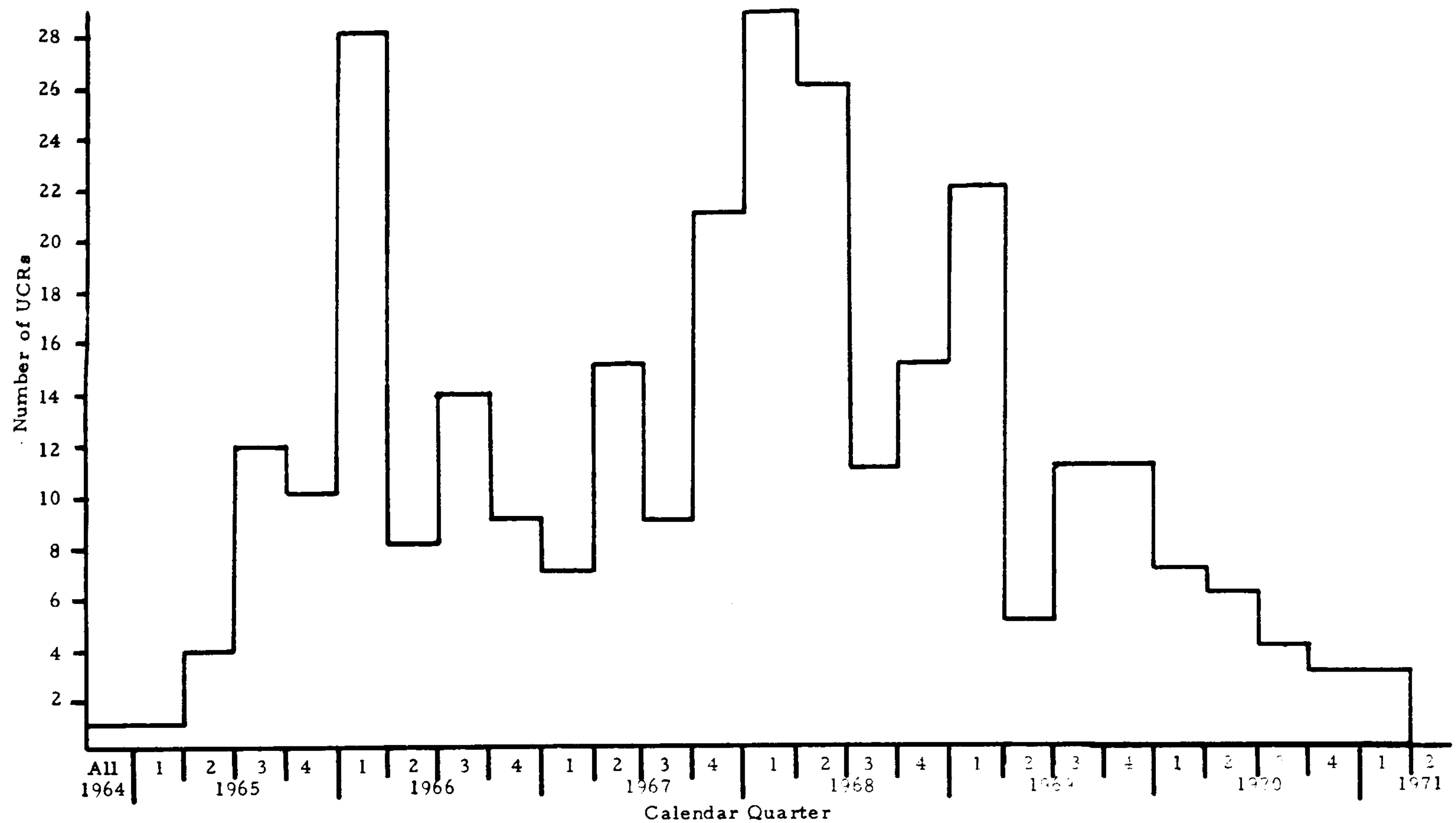

EXHIBIT 1 - NUMBER OF UCRS WITH RELAY FAILURES PER CALENDAR QUARTER

Functional System	Number of UCRs
Range Instrumentation	51
Electrical Networks	28
Environmental Control	26
Countdown Distribution	18
Timing Distribution	16
Camera Start	14
Control	12
Other (with 10 UCRs or less)	123

EXHIBIT 2 - NUMBER OF UCRS PER FUNCTIONAL SYSTEM

Launch Complex 39	172
Launch Complex 34	30
Launch Complex 37	17
O & C Bldg	17
Other (with 10 UCRs or less)	52

EXHIBIT 3 - NUMBER OF UCRS PER LOCATION

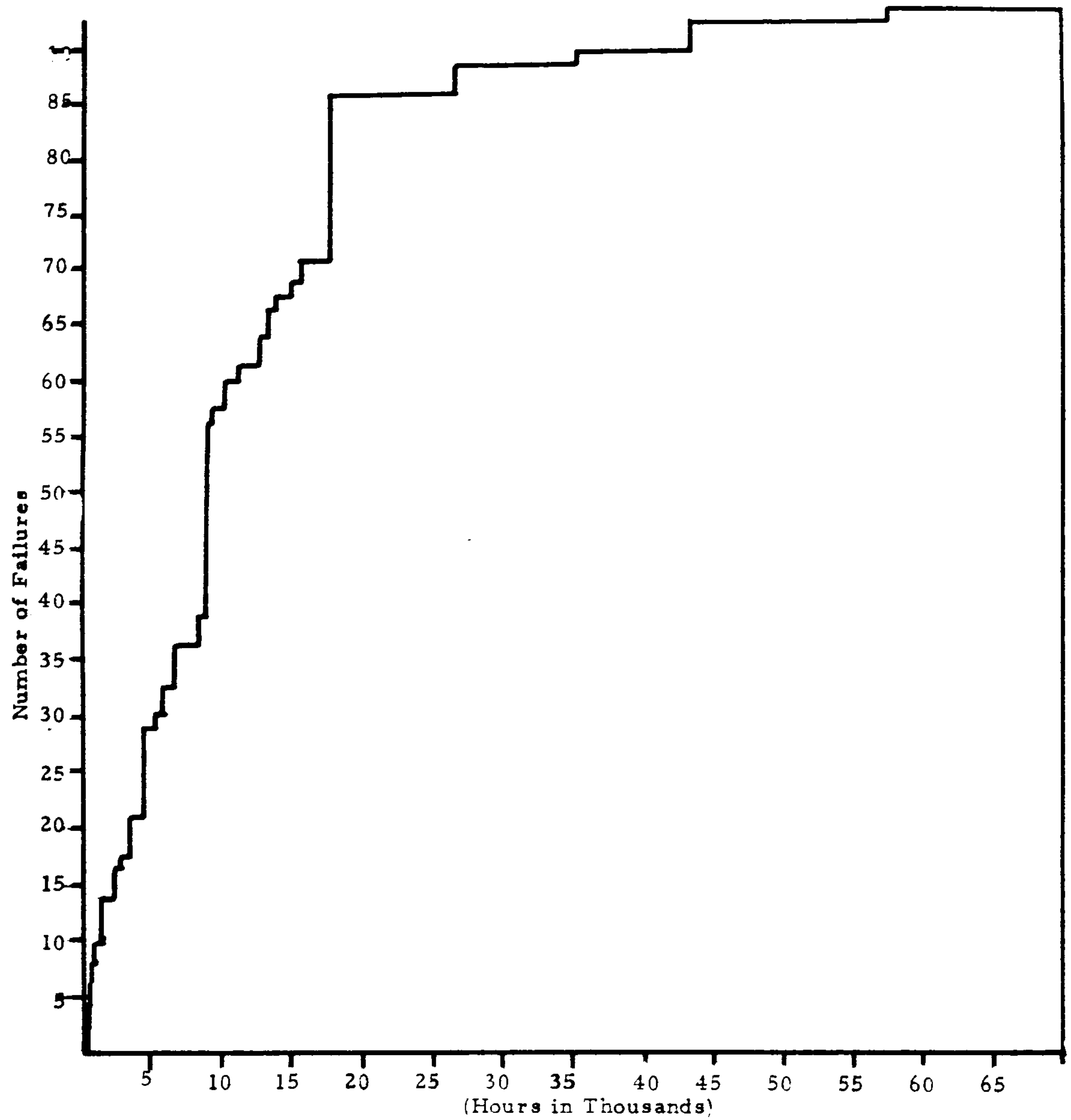

EXHIBIT 4 - CUMULATIVE DISTRIBUTION OF RELAY TIMES-TO-FAILURE FOR FAILURES OCCURRING PRIOR TO 15 OCTOBER 1969

For UCRs written after 15 October 1969, there were 10 time entries. Exhibit 5 presents the cumulative distribution of times-to-failure for this population.

6. Component Failures

Several UCRs report on multiple relay failures. As a result there were actually 270 failures occurring prior to 15 October 1969 and 47 occurring after that date.

7. Failure Classifications

Each relay failure was classified according to its cause of failure. The failure causes are:

- Normal Service - failure occurred as a result of normal field operation or for which insufficient information is available to assign it to any of the other two categories.
- Quality Problem - failure is a manufacturing problem such as corroded contacts on relay received from vendor.
- Design Problem - a failure in which the fault is inherent in and can be corrected by design action; such as incorrect voltage applied to operate relay.

Below are presented the failure causes for the two populations.

Failure Cause	No. of Failures	Percent
Normal Service	232	86
Quality Problem	21	8
Design Problem	17	6

(Failure causes for failures occurring prior to 15 October 1969)

Failure Cause	No. of Failures	Percent
Normal Service	43	92
Quality Problem	3	6
Design Problem	1	2

(Failure causes for failures occurring after 15 October 1969)

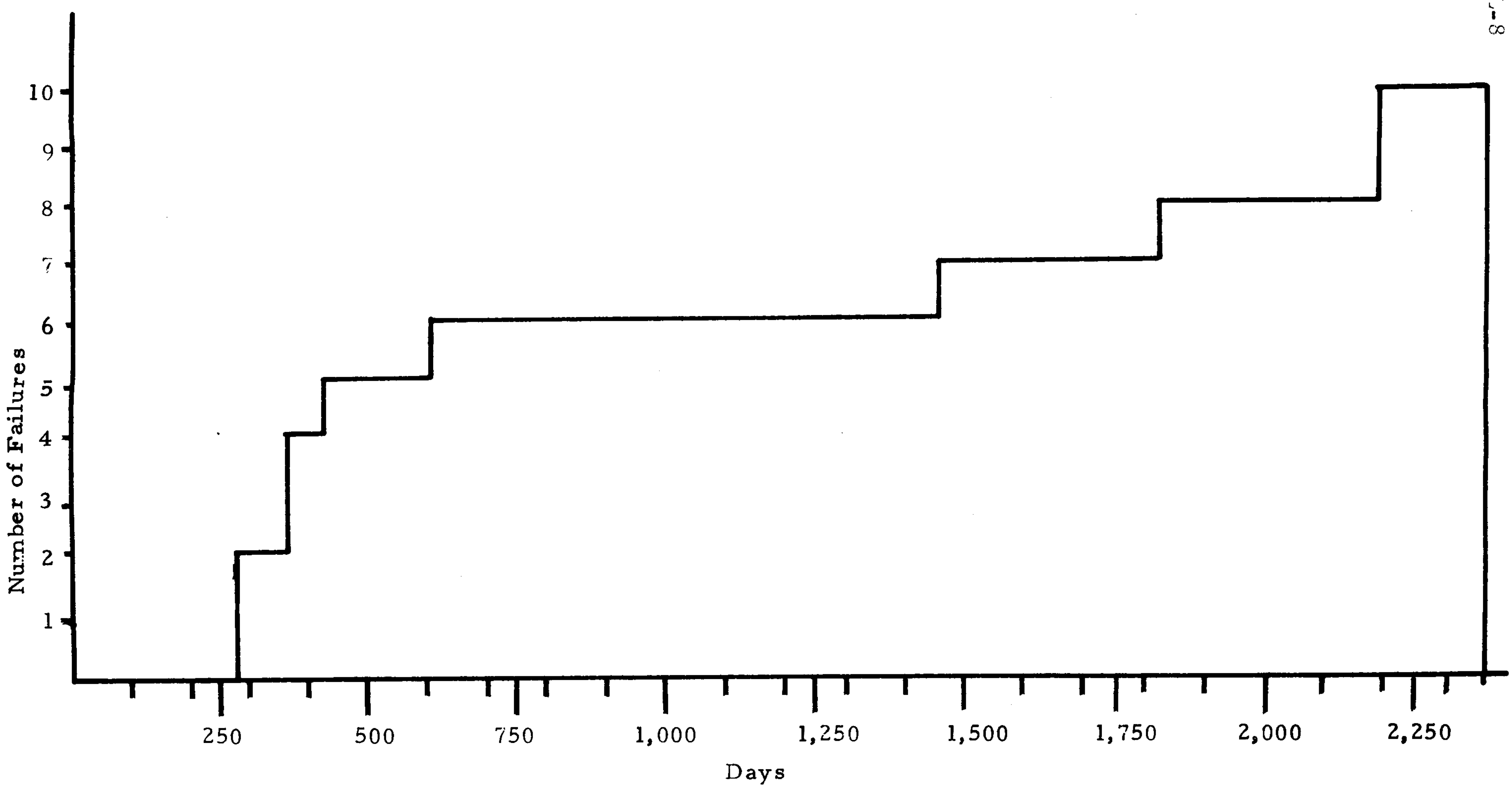

EXHIBIT 5 - CUMULATIVE DISTRIBUTION OF RELAY TIMES-TO-FAILURE FOR FAILURES OCCURRING AFTER 15 OCTOBER 1969

Each failure was further classified into the mode of the failure. These failure modes are:

- o Contact Problem - contacts not making, corroded contacts.
- o Higher Level Equipment Affected - higher level equipment fails to operate due to relay failure.
- o No Output - No voltage output of a circuit that includes a relay.
- o Operation Problem - relay fails to operate, operates too slow.
- o Oscillating - relay oscillating or causing oscillations.
- o Short Circuit - relay causes or has a short circuit; fuse blows.
- o Undesired or Unspecified Operation - relay operates at an undesired time; relay operates in an unspecified manner.
- o Other - all other failure modes.

Presented below are the failure modes for the two populations.

Failure Mode	No. of Failures	Percent
Contact Problem	18	6.7
Higher Level Equip. Affected	95	35.0
No Output	21	7.8
Operation Problem	69	25.8
Oscillating	7	2.7
Short Circuit	11	4.1
Undesired or Unspecified Operation	21	7.8
Other	28	10.1

(Failure Modes for Failures Prior to 15 October 1969)

Failure Mode	No. of Failures	Percent
Contact Problem	2	4.3
Higher Level Equip. Affected	5	10.6
No Output	-	-
Operation Problem	14	29.7
Oscillating	2	4.3
Short Circuit	7	14.9
Undesired or Unspecified Operation	8	17.0
Other	9	19.2

(Failure Modes for Failures After 15 October 1969)

The tables below present the number of parts that were reported as being replaced.

Part	Quantity
Coils	2
Contacts	8
Drivers	7
Relays	182
Sockets	3
Other	7

(Parts Replaced for Failures Occurring Prior to 15 October 1969)

Part	Quantity
Relays	34
Sockets	1

(Parts Replaced for Failures Occurring After 15 October 1969)

8. Field Failure Rate

Using the data of Exhibits 4 and 5 above, mean-times-to-failure and field failure rates were computed for each population. The FFRs are:

Time Period	FFR
Prior to 15 October 1969	0.09 Failures/1,000 hr.
After 15 October 1969	0.42 Failures/1,000 hr.

9. Confidence Factors

From Exhibits 4 and 5 it can be seen that the assumption of exponentially distributed times to failure is not unreasonable. Using this assumption the 90-percent confidence intervals on FFR are:

	Failures/1,000 Hours		
Time Period	Lower Limit	Mean	Upper Limit
Prior to 15 October 1969	0.075	0.09	0.11
After 15 October 1969	0.23	0.42	0.66

10. Resolution of FFR Factors

The field failure rate of the later population is higher by a factor of four when compared to the earlier population. Exhibit 4 shows that 1/4 of failures occurring prior to 15 October 1969, occurred after 13,000 hours (18 months). The data base for failures occurring after 15 October 1969, includes only an 18-month interval. Thus, a larger time span for the second population might tend to decrease the failure rate.

11. Repair Times

There were no repair times for failures occurring after 15 October 1969. There were 143 repair time entires for the first population. Summary repair time statistics include:

Minimum	Mean	Maximum
7 Min.	4.5 Hours	96 Hours

RELIABILITY ASSESSMENT
OF
RF CARRIER DEMODULATOR
(DSC-39-W)

Date: 24 May 1972

Observed Field Failure Rate In Failures Per Thousand Hours Of Installed Component Time		0.409
Observed Failure Times, In Hours		
Mean		2,440
Minimum	24	
Maximum	17,280	
Number of Observations	51	
Observed Repair Times, In Hours		
Mean		5.91
Minimum	0.17	
Maximum	17.0	
Number of Observations	113	

FAILURE MODES CONTRIBUTING TO THE OBSERVED FIELD FAILURE RATE AS A PERCENT OF THE TOTAL

Failure Mode	Component Problem	16.0
	Distorted Output	2.8
	Incorrect Output	18.1
	Inoperative	3.5
	Intermittent Output	2.8
	Mechanical Problem	0.7
	Noisy	18.7
	No Output	11.8
	Sync, Frequency Response	20.7
	Other	4.9
	Total	100.0

Failure Classification (Percent)

Number of Relevant UCRs: 167   Currency:[1] 26 April 1971

[1] Date of latest UCR run included in the assessment.

DESIGN BACKGROUND DATA

1. Component Description

The component population consists of all RF carrier demodulators, manufactured by AMELCO Incorporated, with part number DSC-39-W. All demodulators are located at launch complex 39 and represent a component within the television (OTV) functional system.

2. Data Base

The data base consists of 167 unsatisfactory condition reports (UCRs). Eighty-three of these were obtained by selecting all UCRs from the television functional system data base with the major item "demodulators, modulators," and then sorting by "demodulators." The remaining 84 UCRs were obtained by selecting UCRs from the television data base which indicated that a demodulator failed but were not written against the demodulator itself.

3. Engineering Analysis

Exhibit 1 presents the number of UCRs occurring per calendar quarter. Two peaks occur in the histogram, 36 UCRs in the first quarter of 1968 and 51 UCRs in the fourth quarter of 1968. For the first quarter of 1968, 78 percent of the UCRs occurred in March. Fifty-nine percent of the fourth quarter, 1968 UCRs occurred in November and 33 percent in December. Only one failure occurred after February 1969.

4. Component Populations

Only one component population was chosen for analysis--that of the RF Carrier Demodulator itself. All demodulators with part numbers DSC-39-W are located at launch complex 39.

5. Component Times

Eight UCRs had "Age" or "Time" entries. Forty-three additional time entries were determined by the use of the demodulator serial numbers. All UCRs were sorted by the serial numbers of the respective demodulators. From this information and replacement serial number information, the installation date and the failure date of a particular

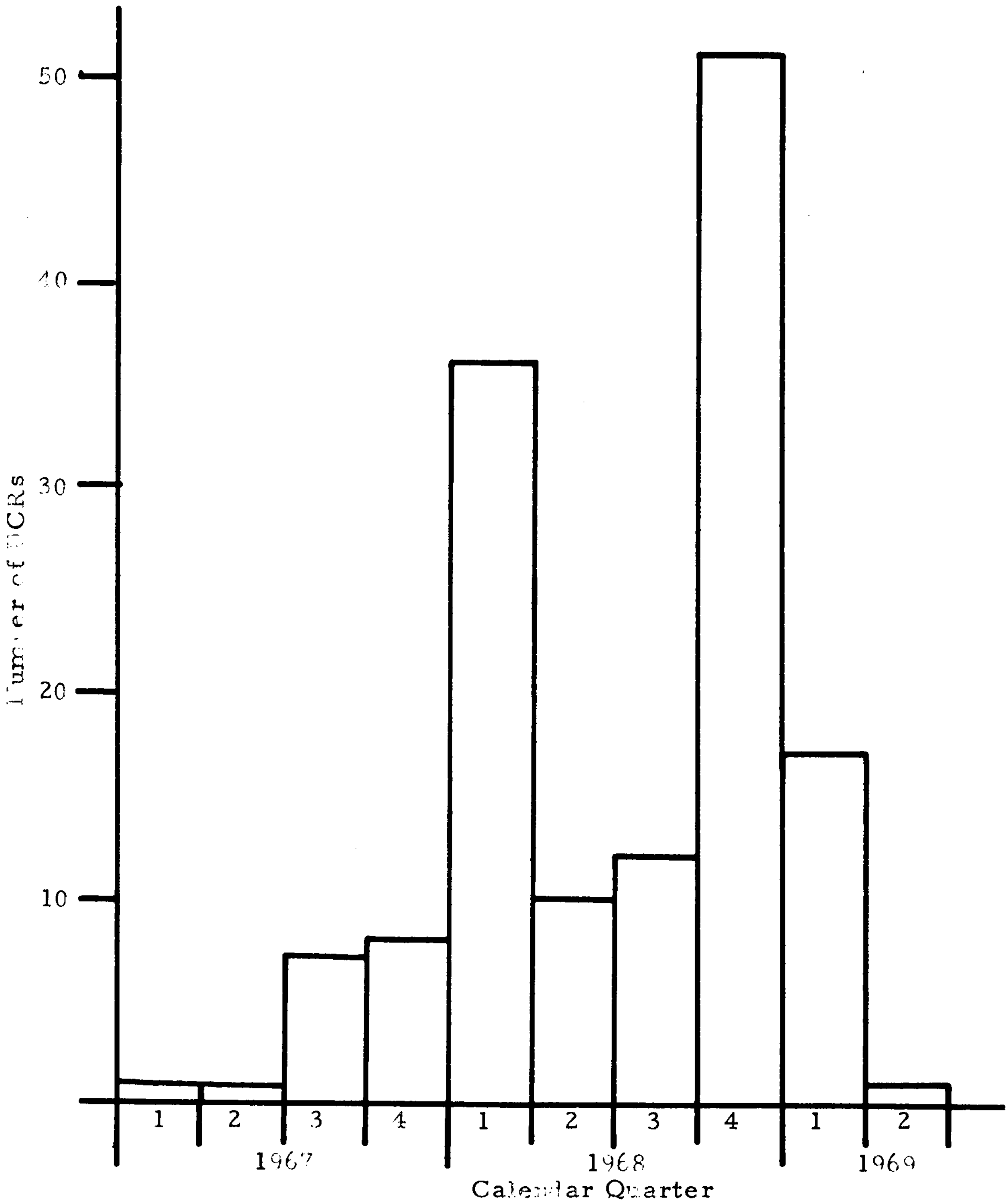

EXHIBIT 1 - NUMBER OF DEMODULATOR UCRS PER CALENDAR QUARTER

demodulator could be determined. The component time is then simply the difference between the two dates. Exhibit 2 presents the cumulative distribution of component times to failure.

6. Component Failures

There were 167 UCRs in the data base. However, 23 UCRs represent the same failure as reported on another UCR. This situation occurred when a demodulator printed circuit card or module was replaced and then repaired. One UCR was written against the demodulator and another written against the components that were replaced during repair. Thus, there are only 144 failures represented in the data base.

7. Failure Classifications

The predominant failure cause was normal operation; i.e., failures which arise as a result of normal field operation or for which insufficient information is available to determine otherwise. There was one failure that could have been corrected by design action.

The failure modes were:

- Component Problem - failure occurred due to a component, e.g., a transistor or a capacitor; this classification was used when a further explanation of the failure mode was not given in the UCR narrative.
- Distorted Output - output of a demodulator was distorted.
- Incorrect Output - output was incorrect, e.g., too high output voltage, too low output voltage, nonlinear output, etc.
- Inoperative - demodulator inoperative with no further information in the UCR narrative.
- Intermittent output - output intermittent or sporadic.
- Mechanical Problem - mechanical problem with demodulator unit such as bent connector pin.
- Noisy - output noisy.
- No Output - no output.
- Sync, Frequency Response - unit not in synchronization, or has poor or no frequency response.
- Other - all other failure modes.

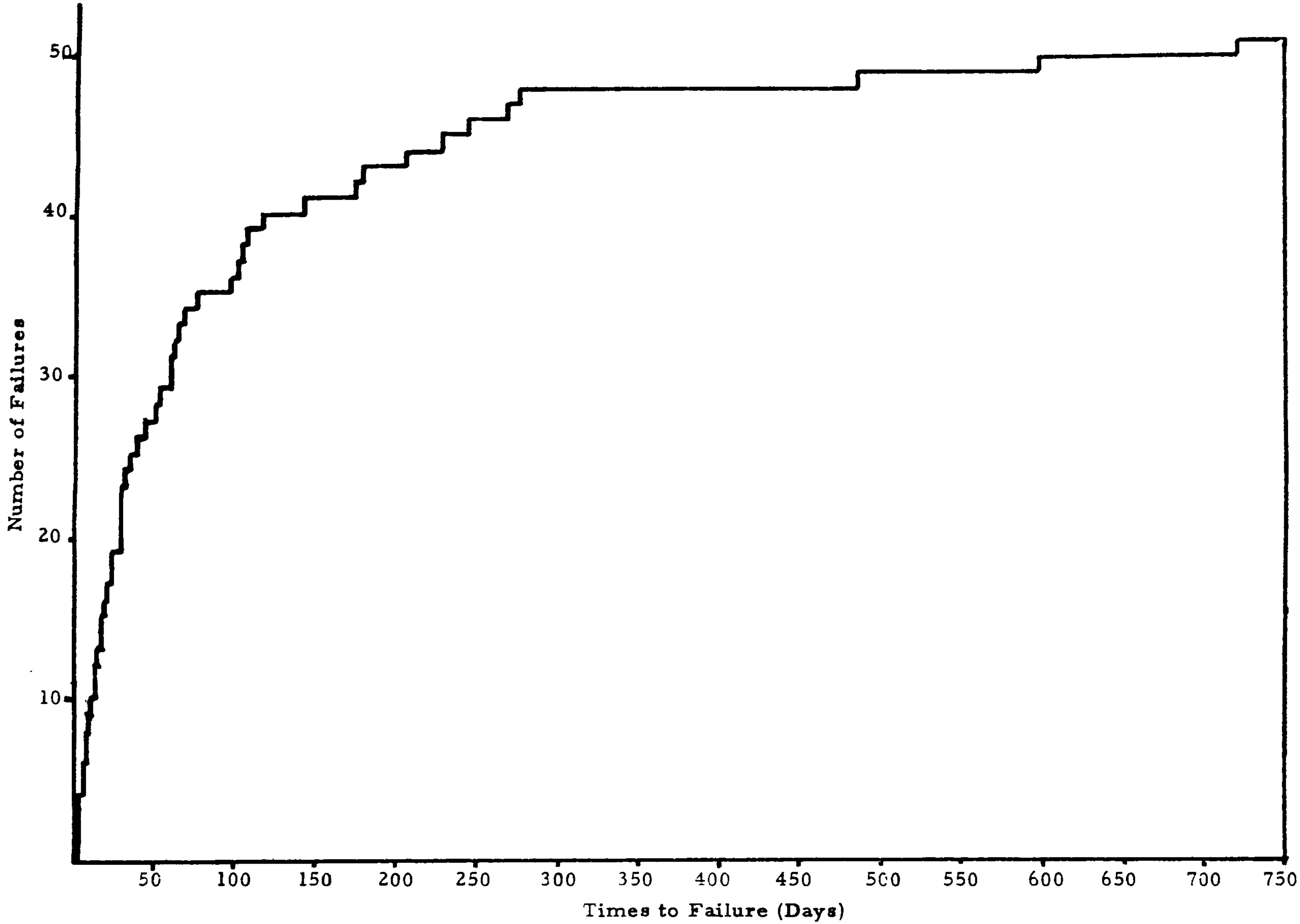

EXHIBIT 2 - CUMULATIVE DISTRIBUTION OF RF CARRIER DEMODULATOR TIMES-TO-FAILURE

Exhibit 3 presents the demodulator failure modes.

Failure Mode	No. of UCRs
Component Problem	23
Distorted Output	4
Incorrect Output	26
Inoperative	5
Intermittent Output	4
Mechanical Problem	1
Noisy	27
No Output	17
Sync, Frequency Response	30
Other	7
Total	144

EXHIBIT 3 - DEMODULATOR FAILURE MODES

Components (such as capacitors, transistors, etc.) were replaced on 85 UCRs. Exhibit 4 presents the number of UCRs mentioning a particular component failure.

Component	No. of UCRs
Capacitors	35
Diodes	1
Lamps	1
Resistors	5
Switches	4
Transistors	45
Wiring	1

EXHIBIT 4 - NUMBERS OF UCRS WITH REPLACEMENT OF A PARTICULAR COMPONENT

8. Field Failure Rates

Each of the 51 component times from Section 5 represents one time-to-failure (TTF); hence, the field failure rate is equal to 51 divided by the sum of the TTFs. The field failure rate is 0.409 failures/ 1,000 hours.

9. FFR Confidence Intervals

Assuming exponentially distributed times to failure, the 90-percent confidence interval on the FFR is:

- o Upper limit 0.506 failures/1,000 hours
- o Lower limit 0.318 failures/1,000 hours

10. Resolution of FFR Factors

Over 50-percent of the component times-to-failure represent failures occurring between November 1968 and February 1969. No reason for this rather unusual phenomenon is evident from the UCRs.

11. Repair Time

The number of UCRs having repair time information is 113. The minimum repair time is 10 minutes. The maximum repair time is 17 hours. The mean-time-to-repair is 5.91 hours.

RELIABILITY ASSESSMENT
OF
RF CARRIER MODULATOR
(MSC-39-W)

Date: 24 May 1972

Observed Field Failure Rate In Failures Per Thousand Hours Of Installed Component Time		0.831
Observed Failure Times, In Hours		
Mean		1,203
Minimum	24	
Maximum	5,160	
Number of Observations	55	
Observed Repair Times, In Hours		
Mean		4.13
Minimum	0.33	
Maximum	16.5	
Number of Observations	169	

FAILURE MODES CONTRIBUTING TO THE OBSERVED FIELD FAILURE RATE AS A PERCENT OF THE TOTAL

		Total
Failure Mode	Alignment, Adjustment	0.5
	Component Problem	16.7
	Distorted Output	14.5
	Incorrect Output	40.3
	Intermittent Output	1.6
	Noisy	8.1
	No Output	1.6
	Sync, Frequency Response	10.8
	Other	5.9
	Total	100.0

Failure Classification (Percent)

Number of Relevant UCRs: 206 Currency:(1) 26 April 1971

(1)Date of latest UCR run included in the assessment.

DESIGN BACKGROUND DATA

1. Component Description

This reliability assessment includes all RF carrier modulators manufactured by AMELCO, Incorporated with model (and KSC part) number MSC-39-W. The modulators are located at launch complex 39 and are contained within the television (OTV) functional system.

2. Data Base

The data base consists of 206 UCRs. Of these, 119 were obtained by retrieving all UCRs with the part number MSC-39-W. The remaining 87 UCRs were obtained by determining that the failure of a modulator occurred from information other than part numbers on UCRs from the television system file of UCRs.

3. Engineering Analysis

Exhibit 1 presents the number of UCRs per calendar quarter for the RF carrier modulators. Over 56 percent of all modulator UCRs were written in the fourth quarter of 1968, with the majority occurring in December 1968. Twenty-six UCRs were written in 1969. There were no UCRs after April 1969.

4. Component Populations

Since the data base is homogeneous with respect to location and function, the only component population chosen for analysis was the component itself, viz., RF carrier modulators.

5. Component Times

Seven UCRs had "Age" or "Time" entries. Component times were determined for another 48 carrier modulators by the use of serial numbers. UCRs were ordered by means of modulator serial numbers. Installation and failure dates were determined by tracing serial numbers using both serial number and replacement serial number information. The component times were then computed from the difference between the installation and failure dates. Exhibit 2 presents the cumulative times to failure for the RF carrier modulators.

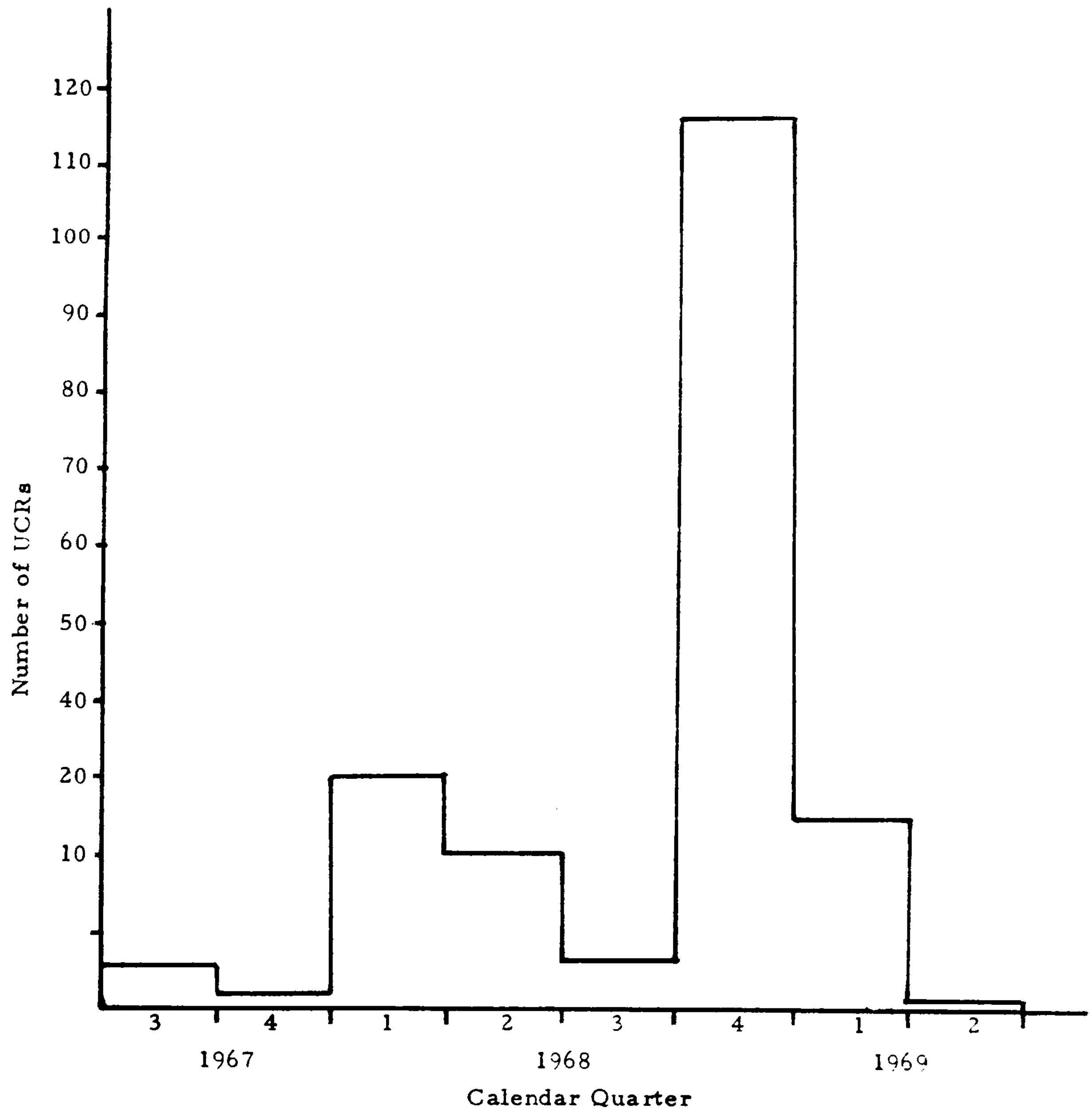

EXHIBIT 1 - NUMBER OF RF CARRIER MODULATOR FAILURES PER CALENDAR QUARTER

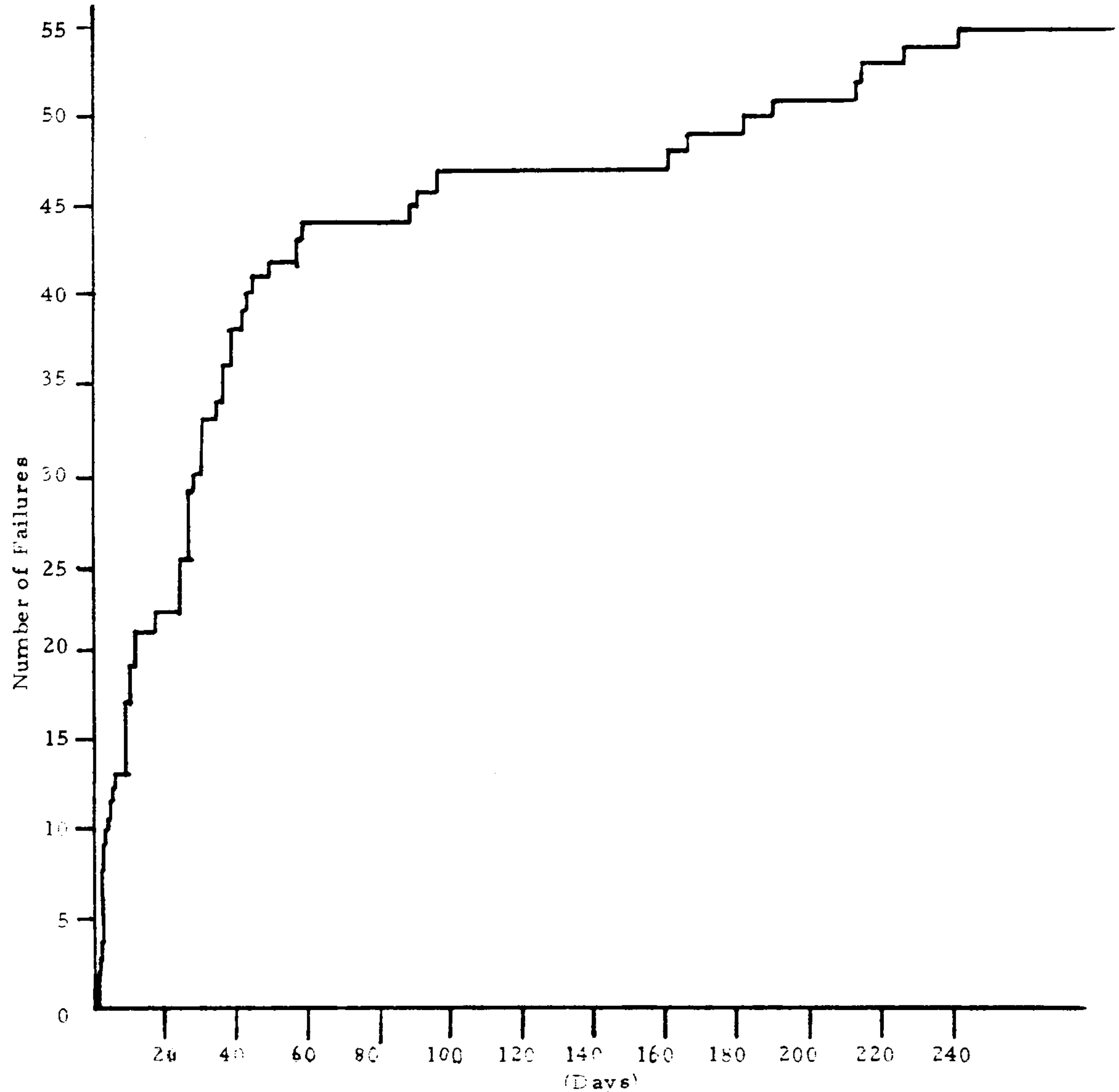

EXHIBIT 2 - CUMULATIVE DISTRIBUTION OF RF CARRIER MODULATOR TIMES-TO-FAILURE

6. Component Failures

Twenty UCRs could be classified as reporting failures that previously were reported. This situation arose when a modulator was replaced with another unit. A UCR was written to report this replacement and another UCR was written after the unit was repaired and parts such as resistors or transistors replaced. The second UCR was written with the part name of the part that was replaced. Eliminating these "second" UCRs from the failure total, there are 186 failures for RF carrier modulators.

7. Failure Classifications

The predominant cause of modulator failures was normal service, i. e., failures which arise as a result of normal field operation or for which insufficient information is available to classify it otherwise.

The failure modes are:

- Alignment, adjustment--output could not be aligned or adjusted; output is out of alignment or adjustment.
- Component problem--narrative of UCRs indicates that the failure occurred due to a component such as a transistor or capacitor; this classification was used when no further information existed to classify the failure in another failure mode.
- Distorted output--output is distorted.
- Incorrect output--output is incorrect such as an output voltage too high or too low or insufficient gain.
- Intermittent output--output is intermittent or sporadic.
- Noisy --output is noisy.
- No output--no output occurs from a modulator.
- Sync, frequency response--modulator exhibits poor or undesired frequency response; modulator is out of synchronization.

The table on the following page presents the modulator failure modes. Forty percent of the failures had incorrect output failure modes.

Failure Mode	No. of Failures
Alignment, Adjustment	1
Component Problem	31
Distorted Output	27
Incorrect Output	75
Intermittent Output	3
Noisy	15
No Output	3
Sync, Frequency Response	20
Other	11
Total	186

Eighty-one UCRs had individual components (such as capacitors and transistors replaced. The table below presents the number of times a component was reported as being replaced.

Component	No. of UCRs
Capacitor	15
Connector	1
Diode	2
Fuse	1
Inductor	1
Resistor	9
Switch	3
Transformer	1
Transistor	57
Wiring	4

8. Field Failure Rates

RF carrier modulator field failure rates were determined by dividing the number of component times by the total of the component times. The field failure rate is 0.831 failures/1,000 hours.

9. FFR Confidence Intervals

Assuming that times-to-failure are exponentially distributed, the 90-percent confidence interval is:

- Upper limit 1.022 failures/1,000 hours
- Lower limit 0.654 failures/1,000 hours

10. Resolution of FFR Factors

There is no evident indication of factors influencing the field failure rate for the RF Carrier Modulator (MSC-39-W). The failure mode analysis offers little to aid in the isolation of influencing factors. It should be noted that 76 percent of the failures having component times occurred between November 1968 and March 1969.

11. Repair Times

Repair time information was provided on 169 UCRs. The minimum repair time was 20 minutes. The maximum repair time was 16.5 hours. The mean-time-to-repair is 4.13 hours.

RELIABILITY ASSESSMENT
OF
RF INSTRUMENTATION

Date: 24 May 1972

Observed Field Failure Rate In Failures Per Thousand Hours Of Installed Component Time By Location		
Launch Complex 34		0.80
Launch Complex 37		1.02
Launch Complex 39		0.68
Other		0.23
Observed Repair Times, In Hours		
Mean		3.7
Minimum	0.18	
Maximum	32	
Number of Observations	27	

FAILURE CAUSES CONTRIBUTING TO
THE OBSERVED FIELD FAILURE RATE
AS A PERCENT OF THE TOTAL

Location	Failure Cause: Normal Service	Quality Problem	Design Problem	Total
LC-34	38.6	5.1	---	43.7
LC-37	10.2	2.6	---	12.8
LC-39	20.5	2.6	5.1	28.2
Other	5.1	5.1	5.1	15.3
Total	74.4	15.4	10.2	100

Failure Classification (Percent)

Number of Relevant UCRs: 39   Currency:(1) 26 April 1971

(1) Date of latest UCR run included in the assessment.

DESIGN BACKGROUND DATA

1. Component Description

The RF instrumentation system is comprised of all equipment located at launch complexes 34, 37, and 39 and other locations that are considered part of functional system code 23.

2. Data Base

The data base consists of 39 unsatisfactory condition reports (UCR's) obtained by retrieval of those UCR's bearing a functional system code of 23 (RF Instrumentation). Twenty-six UCR's had associated investigation and corrective action reports which are included in the data base.

3. Engineering Analysis

Exhibit 1 represents the number of UCR's written per calendar quarter. There were no UCR's for the RF Instrumentation System after September 28, 1968.

Calendar Quarter

	1965	1966				1967				1968		
Location	4	1	2	3	4	1	2	3	4	1	2	3
LC 34	3	6	4	-	-	2	2	-	-	-	-	-
LC 37	-	-	-	-	3	2	-	-	-	-	-	-
LC 39	-	-	-	-	1	-	4	1	1	-	2	2
Other	-	1	-	3	1	-	-	-	-	-	-	1
Total	3	7	4	3	5	4	6	1	1	-	2	3

EXHIBIT 1: Number of UCR's Written Per Calendar Quarter

The UCR's are written against major items which are at a lower level than the RF instrumentation system.

4. Component Populations

Component populations were chosen by launch complex so as to have functionally similar equipment for analysis. There were 17 UCR's occurring at launch complex 34, 5 UCR's for launch complex 37, 11 UCR's for launch complex 39, and 6 UCR's for other locations.

5. Installation Times

Installation times were found by determining the number of days between the first and last failures for a given location. The installation times are:

Location	Date of First and Last Failures	Installation Time (Days)
LC-34	11/02/65-04/08/68	886
LC 37	11/21/66-03/20/67	118
LC 39	11/28/66-09/25/68	668
Other	02/16/66-08/29/68	925

6. Number of Failures

Each unsatisfactory condition report had one failure, thus, there are 39 failures. It should be noted that several UCRs had failures of several piece parts (such as transistors, capacitors, gears, etc.) but only one failure is considered to have occurred against the RF instrumentation system itself.

7.0 Failure Classification

Failure causes were determined for each UCR. These data are presented in Exhibit 2. The failure causes explanations are:

Normal Service -- In this category are all those unsatisfactory conditions which arise as a result of normal field operation or for which insufficient information is available to assign it to any of the other categories.

Quality -- This implies a fault which is neither inherent in the design nor the result of normal (or abnormal) operation. It is generally a manufacturing problem such as a connector not tightened enough to give a good connection.

System Design -- A fault which is inherent in, or can be corrected by, the system design.

Location	Failure Cause: Normal Service	Failure Cause: Quality Problem	Failure Cause: Design Problem	Total
LC-34	9	2	-	17
LC 37	4	1	-	5
LC 39	8	2	2	11
Other	2	1	2	6
Total	23	6	4	39

EXHIBIT 2 - FAILURE CAUSES BY LOCATION

Failure modes are presented in Exhibit 3. The failure modes are:

- o Component Failure -- A "piece part" such as a capacitor or transistor was responsible for the failure. Used only when there is insufficient information available to otherwise classify the failure.
- o Design -- A failure which is inherent in, or can be corrected by, the system design.
- o Incorrect Output -- A failure in which the output of an electrical circuit is incorrect such as, too high or too low voltage, or incorrect waveform.
- o Inoperative -- Inoperative used when the failure mode cannot be more explicitly determined.
- o Intermittent -- Intermittent operation of an electrical circuit.

- o Mechanical -- Failure is mechanical in nature such as broken connector.
- o Noisy, Distorted -- Output is noisy or distorted.
- o No Output -- No output from an electrical circuit.
- o Short Circuit -- Electrical short circuit or unit blows fuses.

	Location				Total
	LC-34	LC-37	LC-39	Other	
Component Failure	2	-	-	-	2
Design	-	-	-	2	2
Incorrect Output	2	1	1	1	5
Inoperative	2	1	2	-	5
Intermittent	4	2	1	-	7
Mechanical	2	-	3	1	6
Noisy, Distorted	2	-	2	-	4
No Output	2	1	2	-	5
Short Circuit	1	-	-	2	3
Total	17	5	11	6	39

EXHIBIT 3 - FAILURE MODES BY LOCATION

8. Field Failure Rates

The field failure rate for the RF instrumentation system was found by dividing the number of failures by the installation time. The field failure rates are given by location as follows.

Location	Field Failure Rate (Failures/1000 Hours)
LC-34	0.80
LC-37	1.02
LC-39	0.685
Other	0.226

9. FFR Confidence Intervals

Ninety percent confidence intervals for RF Instrumentation components are given below.

	Field Failure Rate (Failures/1000 Hours)		
Location	Upper Limit	Mean	Lower Limit
LC-34	1.12	0.80	0.502
LC-37	3.23	1.02	0.695
LC-39	1.06	0.685	0.384
Other	0.473	0.226	0.117

10. Resolution of FFR

Normal service failures accounted for over seventy percent of all failures for launch complexes 34, 37 and 39. All failures occurred before October 1968.

11. Repair Time

Twenty-seven UCR's had repair time information. The minimum repair time is 10 minutes. The maximum repair time is 32 hours. The mean total repair time is 3.7 hours.

RELIABILITY ASSESSMENT
OF
RF LINE REPEATER AMPLIFIER
(ASC-39-W)

Date: 24 May 1972

Observed Field Failure Rate In Failures Per Thousand Hours Of Installed Component Time		0.537
Observed Failure Times, In Hours		
Mean		1,850
Minimum	24	
Maximum	5,100	
Number of Observations	9	
Observed Repair Times, In Hours		
Mean		3.48
Minimum	0.50	
Maximum	12.0	
Number of Observations	21	

FAILURE MODES CONTRIBUTING TO THE OBSERVED FIELD FAILURE RATE AS A PERCENT OF THE TOTAL

		Total
Failure Mode	Alignment, Adjustment	13.6
	Incorrect Output	54.6
	Inoperative	22.8
	No Output	4.5
	Other	4.5
	Total	100.0

Failure Classification (Percent)

Number of Relevant UCRs: 24 Currency:[(1)] 26 April 1971

(1) Date of latest UCR run included in the assessment.

DESIGN BACKGROUND DATA

1. Component Description

This reliability assessment includes all RF Line Repeater Amplifiers manufactured by AMELCO, Incorporated with model number ASC-39-W. These repeater amplifiers are located at launch complex 39. They are part of the Television (OTV) functional system.

2. Data Base

The data base consists of 13 UCRs obtained by retrieving all UCRs with part number ASC-39-W. An additional 11 UCRs were obtained by retrieving UCRs having a failure of an RF line repeater amp from the television system master file of UCRs. The latter method involved analysis of UCR information other than part number. Thus, the data base consists of 24 UCRs.

3. Engineering Analysis

Forty-six percent of the repeater amplifier failures occurred in the first quarter of 1969 as can be seen in Exhibit 1. There were no failures occurring after March 1969.

4. Component Populations

Only one component population is considered for analysis because of the similarity of all the components and the common location of the components.

5. Component Times

None of the UCRs had "Age" or "Time" entries. However, component times were determined for nine repeater amplifiers. The UCRs were first sorted by repeater amplifier serial numbers. Next, using the serial numbers and replacement serial numbers information, a component time was determined from the installation date and the failure date of a particular repeater amplifier. The cumulative distribution time for the RF line repeater amplifiers is given in Exhibit 2.

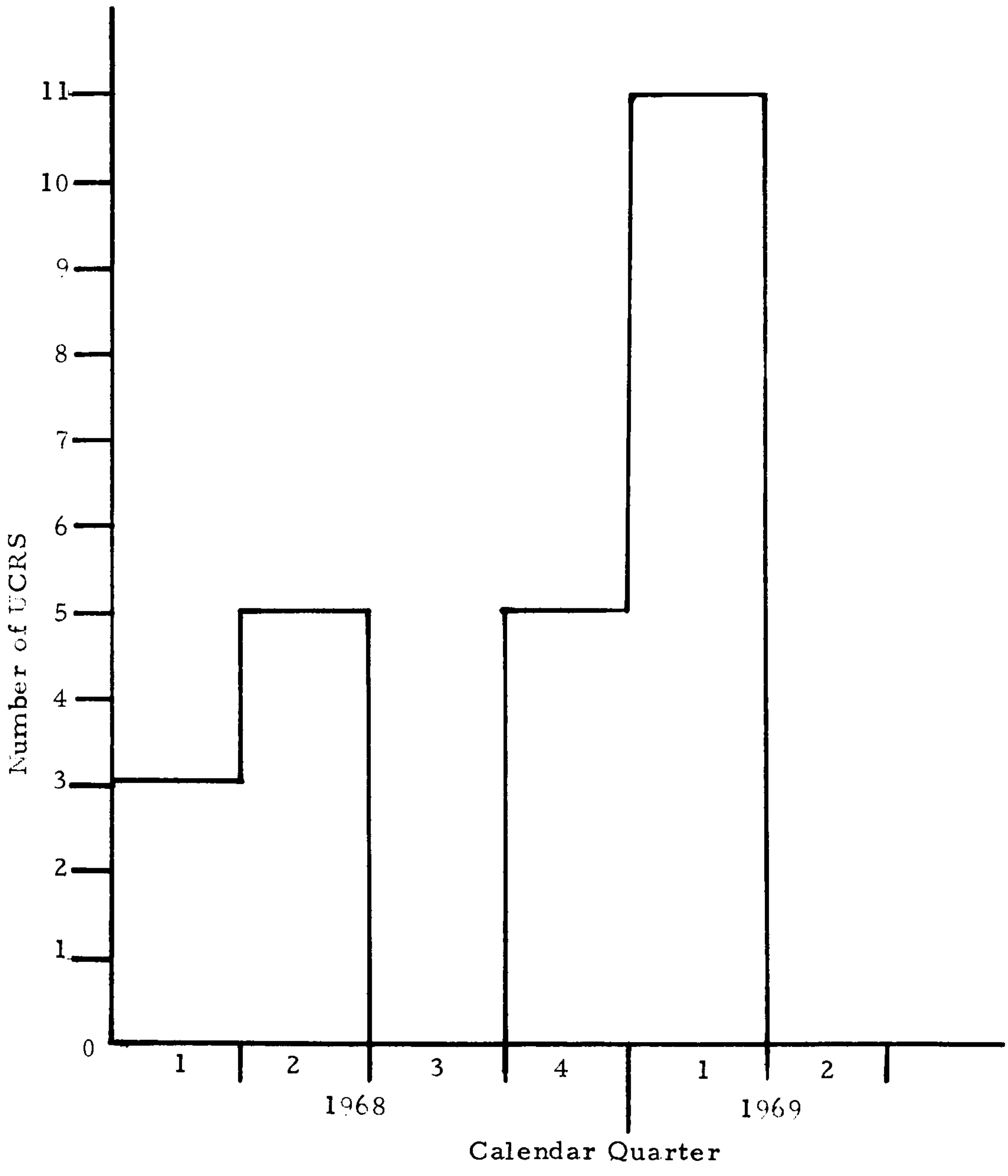

EXHIBIT 1 - NUMBER OF RF LINE REPEATER AMPLIFIER UCRS PER CALENDAR QUARTER

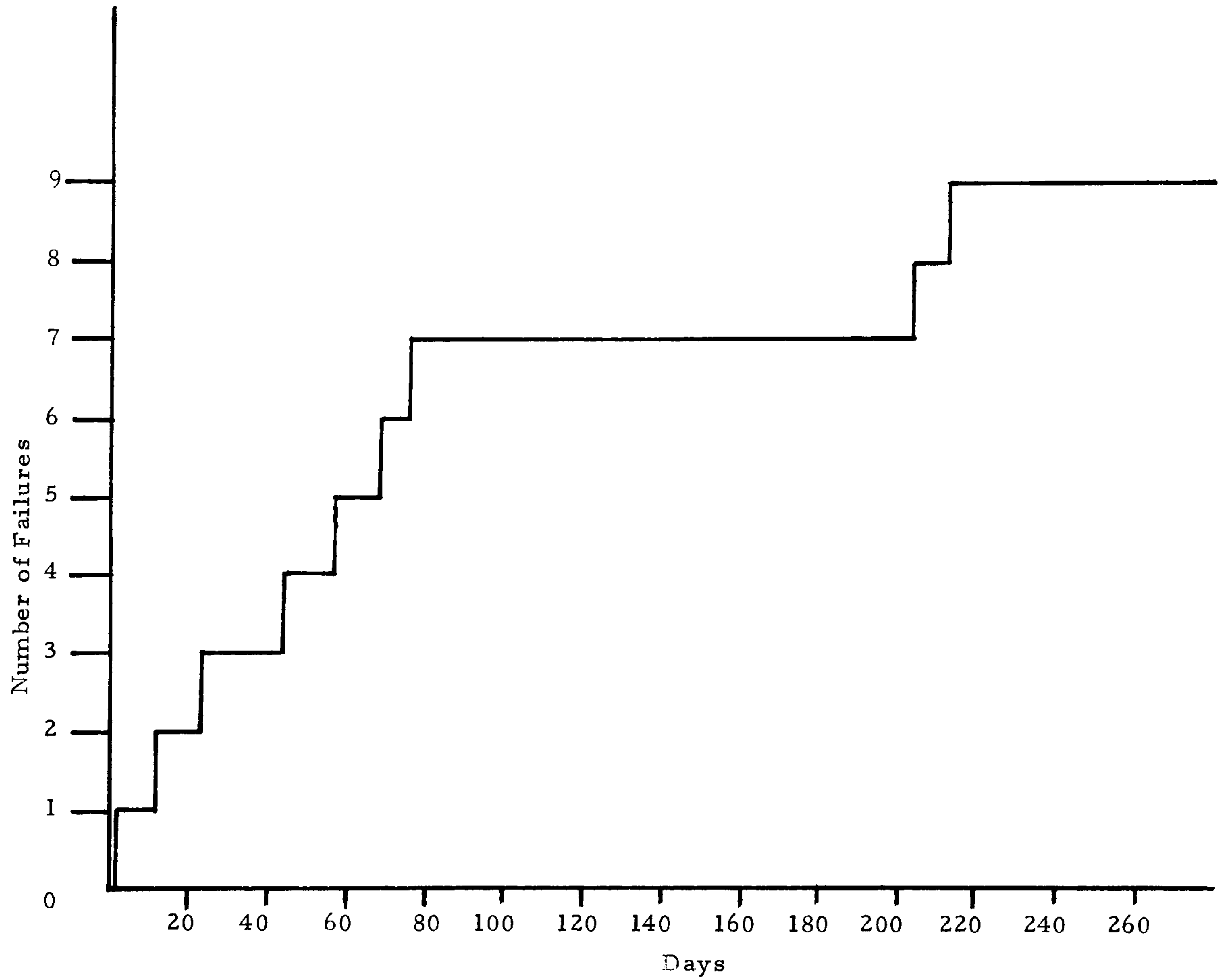

EXHIBIT 2 - CUMULATIVE DISTRIBUTION OF RF LINE REPEATER AMPLIFIER TIMES-TO-FAILURE

6. Component Failures

The number of reported failures is the same as the number of UCRs, except for two failures which are the same as two other failures on other UCRs. These repeated failures occurred when a repeater amplifier was replaced with another repeater amplifier. A UCR was written for the replacement itself, with another UCR written against the particular component (such as transistor, capacitor, etc.) that failed within the amplifier. There are, therefore, 22 failures in the data base.

7. Failure Classifications

All failures had causes classified as normal service; i.e., those failures which arise as a result of normal field operation or for which insufficient information is available to assign it to any other category.

The failure modes of the repeater amplifiers were:

- Alignment, adjustment--amplifier out of alignment or adjustment; amplifier could not be aligned or adjusted.
- Incorrect output--output incorrect such as too low output, too high output, low gain, etc.
- Inoperative--inoperative; this classification used when insufficient UCR narrative information precluded further classification.
- No output--no output from a repeater amplifier.
- Other--all other failure modes.

The repeater amplifier modes are presented below. The failure mode "incorrect output" presented 55 percent of all failures.

Failure Mode	No. of Failures
Alignment, Adjustment	3
Incorrect Output	12
Inoperative	5
No Output	1
Other	1
Total	22

The table below gives the number of times a particular component such as capacitor, transistor, etc. was reported as having been replaced.

Component	Number of UCRs
Capacitors	1
Diodes	1
Fuse Holders	1
Switches	1
Transistors	5

8. Field Failure Rates

The field failure rate for RF line repeater amplifiers was determined by dividing the number of component times (9) by the sum of the component times. The field failure rate is 0.537 failures/1,000 hours.

9. FFR Confidence Intervals

Assuming that times-to-failure are exponentially distributed the 90-percent confidence intervals are:

- Upper limit - 0.863 failures/1,000 hours
- Lower limit - 0.280 failures/1,000 hours

10. Resolution of FFR Factors

There is no evident indication of factors influencing the field failure rate for this particular amplifier. It should be noted, however, that over half of the failures for which component times could be derived occurred between November 1968 and March 1969.

11. Repair Time

Twenty-one failures had associated repair time information. The minimum repair time was 30 minutes. The maximum repair time was 12 hours. The mean-time-to-repair was 3.48 hours.

RELIABILITY ASSESSMENT
OF
SOLENOID VALVES

Date: 24 May 1972

Observed Field Failure Rate In Failures Per Thousand Hours Of Installed Component Time		0.118
Observed Failure Times, In Hours		
Mean		8,496
Minimum	4	
Maximum	60,480	
Number of Observations	76	
Observed Repair Times, In Hours		
Mean		4.05
Minimum	0.33	
Maximum	36	
Number of Observations	65	

FAILURE MODES AND CAUSES CONTRIBUTING TO
THE OBSERVED FIELD FAILURE RATE
AS A PERCENT OF THE TOTAL

		Failure Cause				
		Normal Service	Quality Problem	Design Problem	Operational Problem	Total
Failure Mode	Configuration Problems	0.8	6.8	0.5	0.5	8.6
	Contamination/Corrosion	8.1	0.5	1.0	-	9.6
	Defective Mechanical Part Part Malfunctions	3.4	2.1	-	0.3	5.8
	Electrical Malfunctions	30.8	0.5	1.0	0.3	32.6
	Failed to Actuate Properly	8.6	-	0.8	-	9.4
	Leakage Problems	32.3	0.8	0.3	-	33.4
	Other	-	0.3	-	0.3	0.6
	Total	84.0	11.0	3.6	1.4	100.0

Failure Classification (Percent)

Number of Relevant UCRs: 333 Currency:[(1)] 13 May 1971

[(1)]Date of latest UCR run included in the assessment.

DESIGN BACKGROUND DATA

1. Component Description

This reliability assessment consists of all electromechanical components known as solenoid valves. Solenoid valves were designated by major item code 786 on UCRs written prior to 15 October 1969, and by major item code 319 on UCRs written thereafter.

Solenoid valves are located throughout the Kennedy Space Center ground support equipment locations and are components of several functional systems.

2. Data Base

The data base consists of 333 UCRs. Of these 333 URCs, 305 UCRs were written prior to 15 October 1969, and were retrieved through major item code 786. The remaining 28 UCRs were retrieved through major item code 319.

3. Engineering Analysis

Exhibit 1 presents the number of UCRs occurring per calendar quarter for the solenoid valve population.

Exhibit 1 has a peak of 51 UCRs during the fourth quarter of 1967. From this point on, the number of UCRs occurring per calendar quarter decreases to two UCRs during the first quarter of 1971.

Only six solenoid valve part numbers have four or more UCRs. These six part numbers account for 26% of the data base as presented below.

Part Number	Number of UCRs
10425701	51
75M02986	12
75M04406	12
10425706	9
PA92304-5100	4
Other	245

Sixty-nine percent of all solenoid valve UCRs occurred at launch complex 39. The three mobile launchers account for 54 percent of all UCRs.

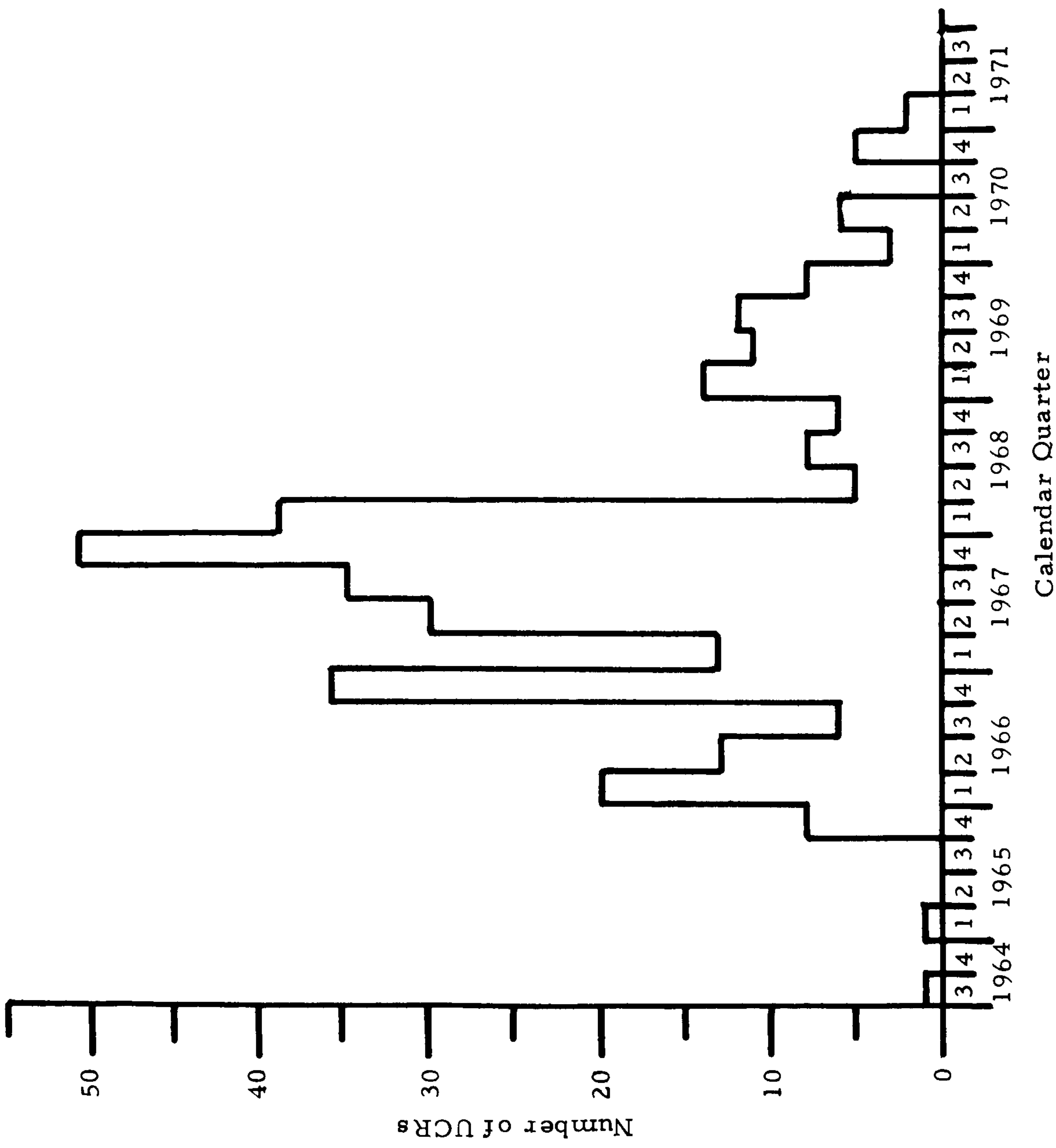

EXHIBIT 1 - NUMBER OF UCRs PER CALENDAR QUARTER FOR SOLENOID VALVES

Four functional systems account for 54% of the data base. These are: N_2 (132 UCRs), Hydraulic (56 UCRs), Pneumatic (27 UCRs), and Umbilical Swing Arms (22 UCRs).

4. Component Populations

There are a wide variety of solenoid valves located at every launch complex and in nearly every functional system. There is no evident and useful way to group the valves other than by part number. Hence, for this analysis only two population groupings are considered. The first consists of populations defined by part number--the size of each population being determined by the number of time-to-failure observations available. Only those solenoid valves which have four or more observed times to failure are considered suitable for the derivation of FFR estimates. The second population consists of solenoid valves in general; the size of this population includes all available time-to-failure observations including those in the first grouping. Identification of each of these populations and the sample size of time-to-failure observations for each must await the determination of component times and component failures.

5. Component Times

In-service time for each solenoid valve must either be given directly on the UCR as an age or time entry or be deducible from the replacement part serial numbers. Each available time observation is assumed to represent the in-service time of the major item immediately prior to the initiation of the UCR.

A detailed analysis of the entire solenoid valve data base to determine in-service times results in the following distribution of the number of observed in-service times versus number of valves, by part number (dash numbers were uniformly suppressed):

								Totals
Number of Observed In-Service Times	26	6	5	4	3	2	1	76
Number of Associated Valve Part Numbers	1	1	1	3	2	2	17	27

Only six solenoid valve part numbers have four or more observed in-service times, thus severely limiting the number of populations that can be defined by part number.

Of the 76 observed in-service times, 63 were given directly on the UCR as age entries, two were time entries, and the remaining 11 were deduced by subtracting the installation date from the date of occurrence of the UCR.

6. Component Failures

There were 382 failures reported in the solenoid valve data base. Seventy-six failures had component times-to-failure.

The 76 valves for which an in-service time observation was available were further analyzed to determine which of these observations terminated in major item failure.

Of the five part numbers with four or more times-to-failure available, all but one (P/N 10425701 with 25 failures) are rejected as being suitable populations for FFR calculations. This is because of the nature of the time-to-failure data. The difficulty is that, although each failure time is associated with one and only one valve failure, they do not appear to be random samples. That is, the failure dates and times-to-failure are entirely too similar to be completely independent events.

In fact, the entire sample of failure times for solenoid valves seems to be somewhat subject to this phenomenon, as can be seen from Exhibit 2. This exhibit shows all the observed times-to-failure and the frequency with which each occurs over the entire sample and for part number 10425701 only. Note the relatively heavy concentration of failure times at 60, 180, 360 and 720 days.

The reasons for this rather lumpy distribution of failure times can only be surmised. That they occur in multiples of 30 days is not surprising, since most UCR entries are in terms of months, and a conversion factor of 30 days per month was used in deriving Exhibit 2. The clustering effect at the equivalent of 2 years, 1 year, and 6 months may be related to maintenance policies, or they may just be good round

EXHIBIT 2 - DISTRIBUTIONS OF TIME TO FAILURE FOR SOLENOID VALVES

Time (Days)	Frequency of Failures: All Valves	P/N 10425701
2520	1	
1080	2	
900	1	
720	11	1
540	5	
450	1	1
440	1	
390	2	2
360	12	7
356	1	
314	1	
300	1	1
296	1	
210	2	1
180	8	2
150	3	1
120	2	
108	1	
91	1	1
90	4	
60	4	4
46	1	
37	1	
30	3	3
11	1	
10	1	
5	1	
4	1	1
0	2	
TOTAL	76	25

numbers used to indicate the order of magnitude of in-service time. The distribution of data for the single valve generally follows that for the entire sample but is considerably less pronounced.

Exhibit 3 shows the cumulative distribution of solenoid valve times-to-failure.

7. Failure Classification

A failure cause was determined for each of the 382 failures. The failure causes and the number of failures reported are:

- Normal Service (322 failures) - failures which arise as a result of normal field operation or for which insufficient information is available to assign it to any of the other three categories.
- Quality (42 failures) - implies a fault which is neither inherent in the design nor the result of normal (or abnormal) operation.
- Design (14 failures) - a fault which is inherent in, and can be corrected by, the contractor design.
- Operation and Maintenance (4 failures) - failures were caused or exacerbated by the misuse of the solenoid valve on the part of the operating or maintenance personnel.

In addition, the following failure modes were determined:

- Configuration Problems (33 failures) - improper assembly, part misapplication, or solenoid valve cannot operate to specifications.
- Contamination/Corrosion (37 failures) - solenoid valve was contaminated or corroded.
- Defective Mechanical Part Malfunctions (22 failures) - solenoid valve had damaged parts, excessive wear, perforated diaphragm or valve was sticking or chattering.
- Electrical Malfunctions (125 failures) - open or short circuit, switch malfunctions, valve gives wrong indication.

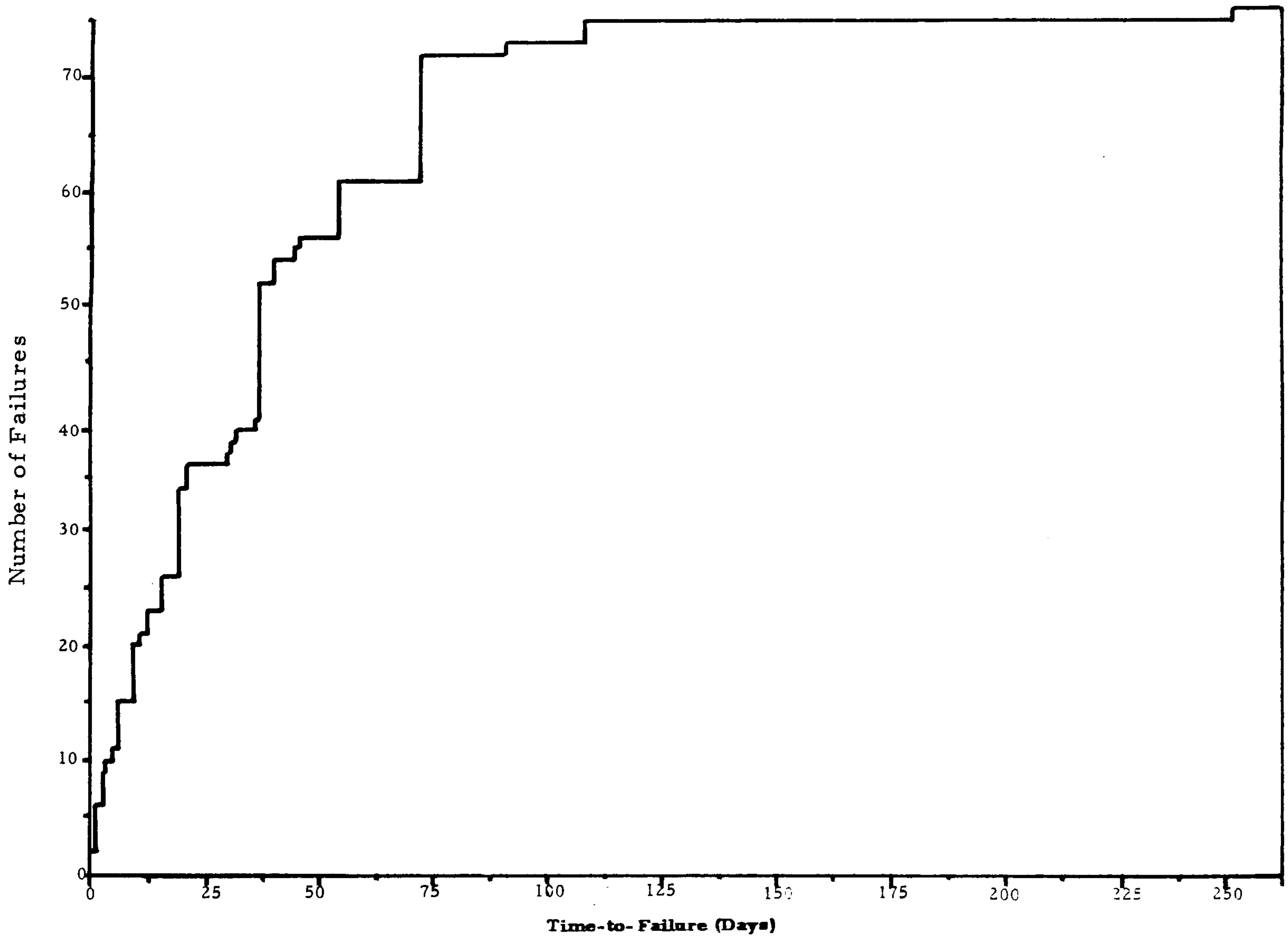

EXHIBIT 3 - CUMULATIVE DISTRIBUTION OF SOLENOID VALVE TIMES-TO-FAILURE

- Failed to Actuate Properly (36 failures) - valve did not actuate, or actuated too slow or too fast, or did not fully open or close.
- Leakage Problems (128 failures) - solenoid valve leaked either externally or internally.
- Other (2 failures) - all other failure modes.

8. Field Failure Rates

A field failure rate for solenoid valves was determined by dividing the sum of the individual times-to-failure into the number of failures. The field failure rate for the solenoid valve population is 0.118 failures/ 1000 hours.

For solenoid valve part number 10425701, the field failure rate is 0.19 failures per 1000 hours.

9. FFR Confidence Intervals

From Exhibit 3, it can be seen that the assumption of exponentially distributed solenoid valve times-to-failure is not an unreasonable assumption. Using this assumption, the 90% confidence interval is:

Upper Limit	0.141 failures/1000 hours
Lower Limit	0.097 failures/1000 hours

10. Resolution of FFR Factors

In section 8 it was noted that the FFR for part number 10425701 was 0.19 failures/1000 hours. This part number represents over 1/3 of the total population used to compute the overall solenoid valve FFR which was 0.08 failures/1000 hours less than the part number 10425701 population.

Also, from Exhibit 1, the number of reported failures has been decreasing. This may have an effect on the present FFR.

11. Repair Time

Sixty-five failures had repair time information. The mean-time-to-repair was 4.05 hours. The minimum time-to-repair was 0.33 hours. The maximum time was 36 hours. Exhibit 4 shows the cumulative distribution of solenoid valve times-to-repair.

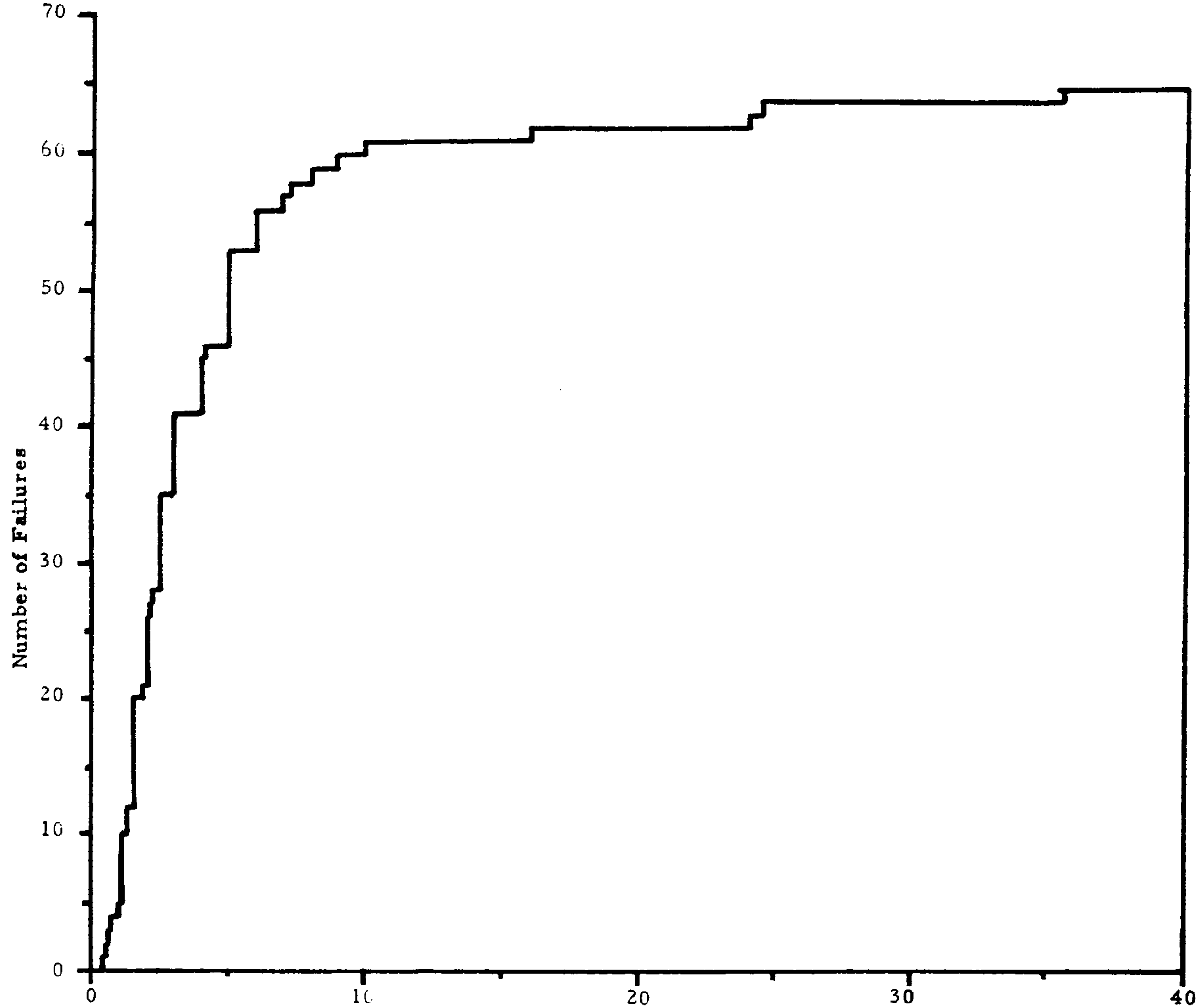

EXHIBIT 4 - CUMULATIVE DISTRIBUTION OF SOLENOID VALVE TIMES-TO-REPAIR

RELIABILITY ASSESSMENT
OF
TAIL SERVICE MASTS AT LAUNCH COMPLEX 39

Date: 24 May 1972

Observed Field Failure Rate
In Failures Per Thousand Hours
Of Installed Component Time

Prior to 15 October 1969	0.65
After 15 October 1969	0.11

Number of Relevant UCRs: 166 Currency:[1] May 1971

[1] Date of latest UCR run included in the assessment.

DESIGN BACKGROUND DATA

1. Component Description

The tail service masts considered here are those found at launch complex 39 where they are affixed, in sets of three, to the three mobile launchers. Their function is to support service lines to the S-IC stage and to provide a means for rapid retraction of the service lines from the S-IC stage during vehicle lift-off. The location and specific function of each of the tail service masts is as follows: TSM 1-2 (fuel line service and inert prefill), TSM 3-2 (environmental air conditioning service), and TSM 3-4 (liquid oxygen emergency drain).[1] The KSC part numbers for these three items are, respectively, 75M11776, 75M11775, and 75M11774.

2. Data Base

The entire data base for the tail service masts at launch complex 39 consists of 166 UCRs. Of these 141 were retrieved in September 1969 and analyzed in the TSM RAC published as part of the Phase I PRC study report.[2] Twelve additional UCRs generated under the old system (i.e., prior to 15 October 1969) were added to this analysis as were 13 UCRs from the new system (the occurrence date of one of these was actually in the time domain of the old system). UCRs from the old system were primarily collected by retrieving on the appropriate next assembly part numbers (given above) but were supplemented by seeking out various referenced reports. UCRs from the new system were collected by retrieving on functional system codes 750, 751, and 752 representing the tail service masts system--general, electrical and mechanical. Both retrievals were made in May 1971. Coverage is assumed

[1] Performance and Design Requirements for Saturn V/Apollo Launch Support Equipment, Launch Complex 39, Project Specification for, Specification No. RS12A046, John F. Kennedy Space Center, 9 September 1966.

[2] KSC Program for Investigating and Generating Field Failure Rates Phase II, PRC R-1432, Planning Research Corporation, 1 May 1970.

to be complete for the old system and nearly so for the first year of the new system. The two systems are not, however, considered to be entirely compatible[1] and hence are treated virtually in parallel in the following paragraphs.

3. Engineering Analysis

Preliminary consideration of the data base results in some interesting and sometimes contradictory, conclusions. The UCRs indicate that there are nine individual TSMs bearing serial numbers 1001 through 1009, and that these nine TSMs are utilized for launch support in sets of three. This can be clearly seen from Exhibit 1, where each short vertical line represents one unsatisfactory condition of a particular TSM at the date indicated. Launch dates and the mobile launcher utilized are also indicated for vehicles AS-501 through AS-509. Note that the TSM serial numbers and mobile launcher assignments are not entirely consistent with the assumption of a permanent correspondence between the two. The installation date of the new UCR system (15 October 1969) is indicated by a vertical dashed line as is the retrieval date (15 May 1971) for this assessment.

The preliminary analysis indicates quite strongly that the unsatisfactory conditions occurring prior to about April 1967 (on all TSMs) reflect an initial acceptance or checkout situation of some kind rather than an actual launch support role as is the case subsequent to that date. The end of the initial acceptance and checkout is also indicated by a vertical dashed line in Exhibit 1.

In general, the UCRs are quite complete although they are written against a major item; that is, at a lower level than the TSM, and

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[1] This incompatibility is reflected more in the large reduction in UCR frequency under the new system (a difference only partially explained by increased TSM reliability and reduced utilization rate) than in any inherent differences in the two systems (different UCR forms, for example). The reduction in UCR frequency began prior to implementation of the new system and continues; dividing the data into that generated under the old and new systems is then seen to be essentially arbitrary.

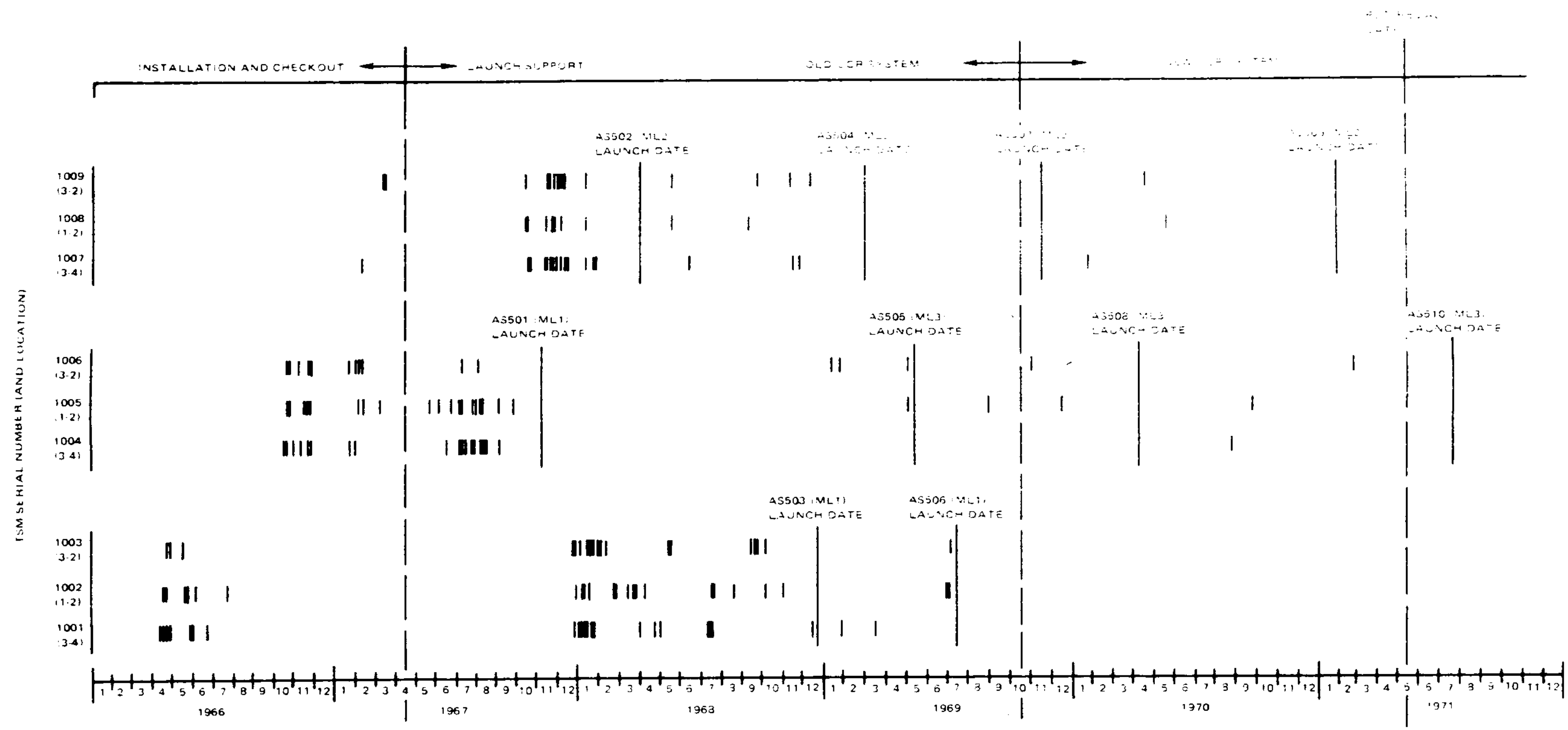

EXHIBIT 1 - TSM UNSATISFACTORY CONDITION OCCURRENCE DATES BY TSM SERIAL NUMBER

hence the impact of the reported condition on the TSM must be largely deduced. The significance of the large reduction in UCR frequency with time is somewhat obscured by the installation of the new UCR system. Exhibit 2 is a tabulation of the number of UCRs (and failures) for the three groups of TSMs by general time period and launch supported. The number of failures is slightly larger than the number of UCRs because of multiple failures reported on a single UCR.

4. Component Populations

The engineering analysis indicates that there are a large number of likely, or possible, tail service mast subpopulations. First, all the data is divided into the three time periods indicated in Exhibits 1 and 2. For each of these time periods the following populations may be considered: (1) all TSMs, i. e., 1 population consisting of 9 units, (2) each individual TSM, i. e., 9 populations containing 1 unit each, and (3) TSMs by location (3-2, 1-2, and 3-4), i. e., 3 populations with 3 units each. In addition each set of three TSMs used in support of one launch may be considered as a single population with three units. There are, therefore, 3 (1+9+3) + 10 = 49 potential populations to be assessed.

5. Component Times

There are no UCR time or age entries as such pertinent to the TSMs. From the UCR occurrence date, however, a partial time profile for each component above may be derived, much in the manner of Exhibit 1. The component times for the TSMs in support of a particular launch are derived by using the date of the first UCR prior to the given launch (and after the immediately preceding launch using the same TSMs) as a conservative approximation to its "date of installation" or start date. The date of launch is taken as the end date. For all other populations two estimates of component times are presented. The first is referred to as "maximum" time and is derived as follows for the three time periods: for the installation and checkout period the maximum estimate is the period from the date of the first recorded UCR (13 April 1966) to 15 April 1967. The latter date is a rather arbitrarily assumed end

Tail Service Mast Serial Numbers	Installation & Checkout	Launch Support			Totals
		Launch Number	Old UCR System	New UCR System	
1001 1002 1003 (ML-1)	22 (23)	AS-503 AS-506	39 (46) 5 (5)		66 (74)
1004 1005 1006 (ML-2)	20 (27)	AS-501 AS-505 AS-508 AS-510	19 (26) 3 (4) 1 (1)	 3 (3) 3 (3)	49 (64)
1007 1008 1009 (ML-3)	5 (5)	AS-502 AS-504 AS-507 AS-509	31 (32) 8 (9) 1 (1)	 2 (2) 4 (4)	51 (53)
Totals	47 (55)		107 (124)	12 (12)	166 (191)

EXHIBIT 2 - DISTRIBUTION OF TSM UCR'S (FAILURES)

point to the installation and checkout process. The second period ends with the installation of the new UCR system on 15 October 1969. The final period ends with the date of the most recent UCR (24 February 1971).

The second set of estimates are referred to as minimum times and are estimated by the elapsed time between the date of the first and last UCR in each of the given populations. The time so derived is assumed to apply to all units in the population. Exhibit 3 summarizes the component times for all 49 populations rounded to the nearest 100 hours. Maximum times are listed only once for each period. Minimum times are determined for each of the first 39 populations as are singular component times for the 10 launch related populations.

On the basis of component times six of the potential 49 populations may be eliminated from the analysis. These are TSMs 1001, 1002, and 1003 in the third time period and TSMs 1007, 1008, and 1009 in the initial or installation period.

6. Component Failures

In the course of the engineering analysis those UCRs which were judged not to represent a TSM failure (under the most stringent interpretation) were eliminated from the data base; multiple failures represented on a single UCR were separated in the preparation of Exhibit 2. The resultant number of failures for each of the 43 potential populations remaining after the component time analysis is given in Exhibit 4. Note that nearly all of the restricted populations for the new UCR system indicate fewer than four failures. Only the TSMs associated with AS-509 and TSM location 1-2 satisfy the four or more failure criteria for FFR calculation. Borrowing a UCR from the old system enables AS-508 to join this select group. Including AS-507 and excluding location 1-2 for reasons of inner group consistency results in four populations associated with the new UCR system. The population representing TSMs associated with launch AS-510 is excluded because of the reasonable expectation of its incurring additional UCRs not included in the data base.

	Time Period: 13 April 1966 – 15 April 1967		15 April 1967 – 15 October 1969		15 October 1969 – 24 February 1971	
	Installation		Old UCR System		New UCR System	
Population	Min.	Max.	Min.	Max.	Min.	Max.
All TSM's	8300	8800	19800	21100	11800	11900
TSM Serial						
No. 1001 (3-4)	1700		10700		-	
1002 (1-2)	2500		13100		-	
1003 (3-2)	600		13400		-	
1004 (3-4)	2500		1800		5200	
1005 (1-2)	3200		19800		6700	
1006 (3-2)	2600		16000		11400	
1007 (3-4)	-		15800		2700	
1008 (1-2)	-		15800		5000	
1009 (3-2)	100		15800		1400	
TSM Location						
3-4	7400		18700		7200	
1-2	7900		19800		8100	
3-2	8200		18200		11400	
TSM's in Support of Launch						
AS-501			4000			
AS-502			4000			
AS-503			8600			
AS-504			6900			
AS-505			3000			
AS-506			4000			
AS-507					2400	
AS-508					5400	
AS-509					8900	
AS-510					8100*	

* Launch date subsequent to date of UCR retrieval.

EXHIBIT 3 - COMPONENT TIMES FOR LAUNCH COMPLEX 39 TAIL SERVICE MASTS IN HOURS

Population	Time Period: 13 April 1966 – 15 April 1967 Installation	15 April 1967 – 15 October 1969 Old UCR System	15 October 1969 – 24 February 1971 New UCR System
All TSM's	55	124	12
TSM Serial			
No. 1001 (3-4)	10	17	*
1002 (1-2)	9	19	*
1003 (3-2)	4	15	*
1004 (3-4)	9	11	(1)**
1005 (1-2)	8	15	(2)
1006 (3-2)	10	5	(2)
1007 (3-4)	*	(18)**	(2)**
1008 (1-2)	*	(10)	(1)
1009 (3-2)	*	(13)	(1)
TSM Location			
3-4	20	(47)**	(3)***
1-2	17	(13)	(4)
3-2	18	(33)	(3)
TSM's in Support of Launch			
AS-501		26	
AS-502		32	
AS-503		46	
AS-504		9	
AS-505		4	
AS-506		5	
AS-507		1	2
AS-508		1	3
AS-509			4
AS-510			3

* These potential populations eliminated due to lack of component time data.
** One additional failure not attributable to a specific TSM within the group of three is known to have occurred.
*** Two additional failures not attributable to specific TSMs within the group of three is known to have occurred.

EXHIBIT 4 - DISTRIBUTION OF COMPONENT FAILURES FOR LAUNCH COMPLEX 39 TAIL SERVICE MAST POPULATIONS

For the old UCR system there are 19 populations including the first six Apollo-Saturn launches. No potential populations are excluded for lack of failure data.

All 10 populations in the initial or installation period with adequate component times also have four or more failures, hence, each represents an admissible population.

7. Failure Classifications

Virtually all of the installation period failures associated with TSMs 1001, 1002, and 1003 can be classified as TSM design failures with 2/3 of the UCRs actually being written against the TSM itself. For TSMs 1004 through 1009 there are only five design failures (about 3 percent of the total) and only one failure attributed to a TSM proper.

Of all TSM failures in the installation time period 42 percent are design problems; the remainder are best classified as normal service as are all the failures covered by the old and new UCR systems subsequent to 15 April 1967.

Over half the TSM failures were generated by the following six part types: regulators 75M11856 and 75M11859, transducers 75M11857 and 75M13108, and solenoid valve 75M11864.

On an overall basis, valves of all types contributed approximately 1/3 of the failures, regulators 1/6, transducers 1/8, hose assemblies 10 percent and all others about 25 percent. Those items which failed most frequently in the installation and earlier operational periods are not among those reported to have failed under the new UCR system. This suggests that the earlier problems are in fact being resolved. Exhibit 5 is a rather detailed classification of the TSM failures.

8. Field Failure Rates

The FFR's for those selected subpopulations with adequate time and failure data are shown in Exhibit 6. Only the maximum times from Exhibit 3 have been utilized as these are considered to be more representative of actual installation times.

TAIL SERVICE MASTS

FAILURE	1001 1002 1003	1004 1005 1006	1007 1008 1009
Installation:			
TSM Design Problems	14		
TSM Normal Service	1		
Arm Assembly	5		
Hose & Line Assemblies	2	7	
Valves, Solenoid		5	2
Valves, Other	1	4	
Hydraulic Cylinders		3	
Pressure Regulators		5	1
Pressure Switches			2
Miscellaneous		3	

	UCR System		UCR System		UCR System	
	Old	New	Old	New	Old	New
Operation:						
Pressure Transducers						
75M11857	5		5		5	
75M13108	8				1	
Pressure Regulators						
75M11859	6		4		2	
75M11856			7		5	
Others	2				2	
Valves						
Solenoid						
75M11936	1		3		7	
75M11864	6		1		2	
Others	9		1	1	4	1
Others	4		3	4	6	2
Hose & Line Assemblies	2		5		2	
Pressure Switches	2			1	2	
Hydraulic Cylinders						2
Miscellaneous	6		2		3	1

EXHIBIT 5 - CLASSIFICATION OF TSM FAILURES

Population	Installation (13 April 1966 – 15 April 1967)	Old UCR System (15 April 1967 – 15 October 1969)	New UCR System (15 October 1969 – 24 February 1971)
All TSM's	0.694	0.653	0.112
TSM Serial			
No. 1001 (3-4)	1.136	0.806	*
1002 (1-2)	1.023	0.900	*
1003 (3-2)	0.454	0.711	*
1004 (3-4)	1.023	0.521	*
1005 (1-2)	0.909	0.711	*
1006 (3-2)	1.136	0.237	*
1007 (3-4)	*	0.853	*
1008 (1-2)	*	0.474	*
1009 (3-2)	*	0.616	*
TSM Location			
3-4	0.756	0.742	*
1-2	0.644	0.679	*
3-2	0.682	0.521	*
TSM's in Support of Launch			
AS-501		2.167	
AS-502		2.667	
AS-503		1.783	
AS-504		0.435	
AS-505		0.444	
AS-506		0.417	
AS-507			0.417
AS-508			0.247
AS-509			0.150
AS-510			*

* Insufficient data from which to calculate an FFR.

EXHIBIT 6 - FFR'S FOR LAUNCH COMPLEX 39 TAIL SERVICE MASTS IN FAILURES PER 1,000 HOURS PER TSM

9. FFR Confidence Intervals

Assuming that the time to failure of TSMs is exponentially distributed, 90 percent confidence intervals for the estimates of population FFRs may be calculated using Equation (1).

$$\frac{X^2_{\alpha/2}(2r)}{2T} < FFR < \frac{X^2_{1-\alpha/2}(2r)}{2T} \quad (1)$$

These intervals are presented in Exhibit 7 for each population.

10. Resolution of FFR Factors

A number of factors appear to be influential or potentially so on the magnitude of TSM failure rates. A number of these will be investigated briefly in this subsection.

The TSM location does not appear to have a strong influence on field failure rate; however, the overall averages given below do indicate the general tendency.

TSM Location	FFR[1]
3-4	0.558
1-2	0.510
3-2	0.431

As can be seen from Exhibits 6 and 7 the decrease in FFR with launch vehicle being supported is both persistent and dramatic indicating that the reliability of this component is increasing steadily with time.

The differences in individual TSMs does not appear to be significant or consistent.

While the difference between the new UCR system and the old UCR system is highly significant it appears to be due more to a continued reduction in UCR frequency over both systems rather than to any characteristics unique to the new system.

[1] All values in failures per TSM per 1,000 hours.

	Upper Confidence Limit	FFR	Lower Confidence Limit
Installation			
All TSM's	0.854	0.694	0.546
No. 1001	1.784	1.136	0.619
1002	1.642	1.023	0.534
1003	0.881	0.454	0.155
1004	1.642	1.023	0.534
1005	1.494	0.909	0.452
1006	1.784	1.136	0.619
Location:			
3-4	1.057	0.756	0.502
1-2	0.920	0.644	0.411
3-2	0.966	0.682	0.441
Operation (Old UCR System)			
All TSM's	0.752	0.653	0.559
No. 1001	1.152	0.806	0.514
1002	1.265	0.900	0.590
1003	1.038	0.711	0.438
1004	0.803	0.521	0.291
1005	1.038	0.711	0.438
1006	0.434	0.237	0.093
1007	1.208	0.853	0.552
1008	0.744	0.474	0.258
1009	0.922	0.616	0.365
Location:			
3-4	0.929	0.742	0.573
1-2	0.858	0.679	0.518
3-2	0.679	0.521	0.382
Operation (New UCR System): All TSM's	0.170	0.112	0.064
All TSM's in Support of Launch			
AS-501	2.908	2.167	1.517
AS-502	3.488	2.667	1.942
AS-503	2.236	1.783	1.374
AS-504	0.698	0.435	0.227
AS-505	0.861	0.444	0.152
AS-506	0.762	0.417	0.164
AS-507	0.875	0.417	0.114
AS-508	0.478	0.247	0.084
AS-509	0.290	0.150	0.051

EXHIBIT 7 - CONFIDENCE INTERVALS FOR LAUNCH COMPLEX 39 TSM'S IN FAILURES PER 1,000 HOURS PER TSM

RELIABILITY ASSESSMENT
OF
TELEVISION SYSTEM (OTV)

Date: 24 May 1972

Observed Field Failure Rate In Failures Per Thousand Hours Of Installed Component Time		91.9
Observed Repair Times, In Hours		
Mean		8.27
Mean	0.07	
Maximum	582	
Number of Observations	2,031	

FAILURE MODES CONTRIBUTING TO THE OBSERVED FIELD FAILURE RATE AS A PERCENT OF THE TOTAL

		Location				
		LC-34	LC-37	LC-39	Other	All
Failure Mode	Alignment, Adjustment	0.3	-	5.8	0.2	6.3
	Blast Damage	0.1	-	0.5	-	0.6
	Camera Remote Control Problem	0.6	0.2	0.9	0.3	2.0
	Component Problem	0.5	0.3	4.3	1.1	6.2
	Design, Modification, Overhaul	0.8	0.6	0.8	0.3	2.5
	Focus, Distorted Output	1.3	1.1	2.9	1.1	6.4
	Incorrect Output	0.8	0.6	7.5	1.8	10.7
	Inoperative	1.3	1.0	3.7	2.4	8.4
	Intermittent	0.9	0.5	1.3	0.5	3.2
	Mechanical Problem	0.8	0.4	2.2	0.3	3.7
	Noisy	1.4	0.8	4.1	1.7	8.0
	No Output	0.8	1.3	11.4	2.3	15.8
	No Video, Poor Video	1.5	1.1	2.8	1.6	7.0
	Short Circuit	0.6	0.4	2.0	1.2	4.2
	Sync, Frequency Response	0.9	0.6	3.6	0.7	5.8
	Video, Horizontal or Vertical	1.4	1.1	2.7	1.6	6.8
	Other	0.3	-	1.5	0.6	2.4
	Total	14.3	10.0	58.0	17.7	100.0

Number of Relevant UCRs: 3,350 Currency:(1) April 1971

(1) Date of latest UCR run included in the assessment.

DESIGN BACKGROUND DATA

1. Component Description[1]

The television system includes all equipment used to visually monitor operations in support of:

- o Launch vehicle and spacecraft prelaunch activities or other hazardous operations that cause an area to be uninhabitable.
- o Administration such as public information activities and the launch information exchange facility.
- o General surveillance for security.
- o Detection of dangerous hydrogen flame activity.

The equipment is located at launch complexes 34, 37, 39, and in the industrial area as follows:

Launch complex 39 equipment (9TV001A) is located in the pad terminal connection room 204 (PTCR), the mobile service structure room 102, and the launch control center (LCC) room 1P1. The remote viewing cameras are located in strategic places on the mobile launcher (ML), the mobile service structure (MSS), and other areas within the complex, such as the VAB, the launch pad, and various field locations surrounding the pad.

Launch complexes 34 and 37 (4TV001A/7TV001A) control and switching equipment is located on the first floor of the control center . The monitors are located in the firing room and operations management room on the second floor. Cameras are located on the pad and surrounding areas, in the automatic ground control station (AGCS) computer room, and in the launch control center.

Central instrumentation facility (CIF) equipment (2TV001A) is located in a limited number of rooms on each of the three floors of the building and the antenna facility to monitor the launch complex 39 area, the Bell Telephone system, and the launch information exchange facility.

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[1] Summarized from reference material.

Spacecraft and industrial area equipment (ITV001A) is located in the operations and checkout building, auditorium and training facility, Kennedy Space Center headquarters building, hypergolic test areas 1 and 2, cryogenics areas 1 and 2, and environmental system test facility.

A simplified system block diagram is shown in Exhibit 1.

A typical camera/monitor configuration is shown in the block diagram of Exhibit 2.

The camera is mounted to view the desired area and is connected via cable to a camera control unit. A local/remote switch provides for choice of local control of the camera for maintenance purposes, or remote control for operation of the camera functions at a distance of up to 3,000 feet.

Video information is sent via rf cable to the receiver equipment where it is demodulated and presented on a monitor. Patch panels and switching provide flexibility in choice of cameras and monitors. Remote control of the pan, zoom, and tilt cameras is accomplished from the remote control panel in the launch control center communications control room.

Audio communications capability is provided from each camera to the camera control unit. Also, two-way communications is possible between the camera audio communication circuit and the remote control panel. This is not connected into the operational intercommunications system (OIS).

Synchronizing pulses are generated by a master sync generator and distributed to all areas of the complex. A slave sync generator in each area provides synchronizing pulses to each camera monitor chain in the respective area. The master generator and each slave generator are provided with a standby unit that is automatically switched into the circuit when a failure is detected.

At launch complex 39, a fault alarm system provides visual and aural cues at an alarm panel in the launch control center communications control room when abnormal conditions are present in the areas monitored.

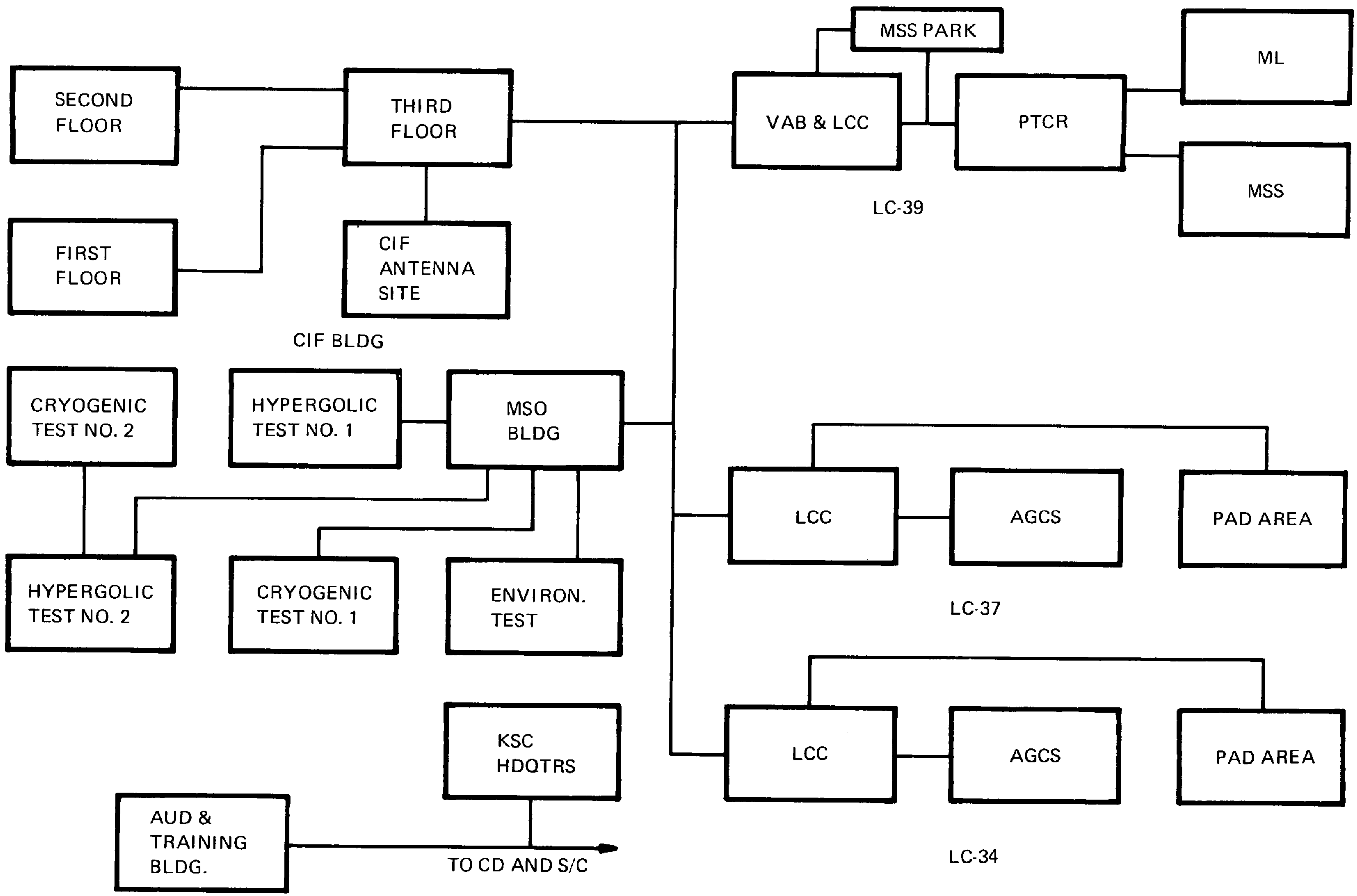


EXHIBIT 1 - BLOCK DIAGRAM OF TELEVISION SYSTEM EQUIPMENT LOCATIONS

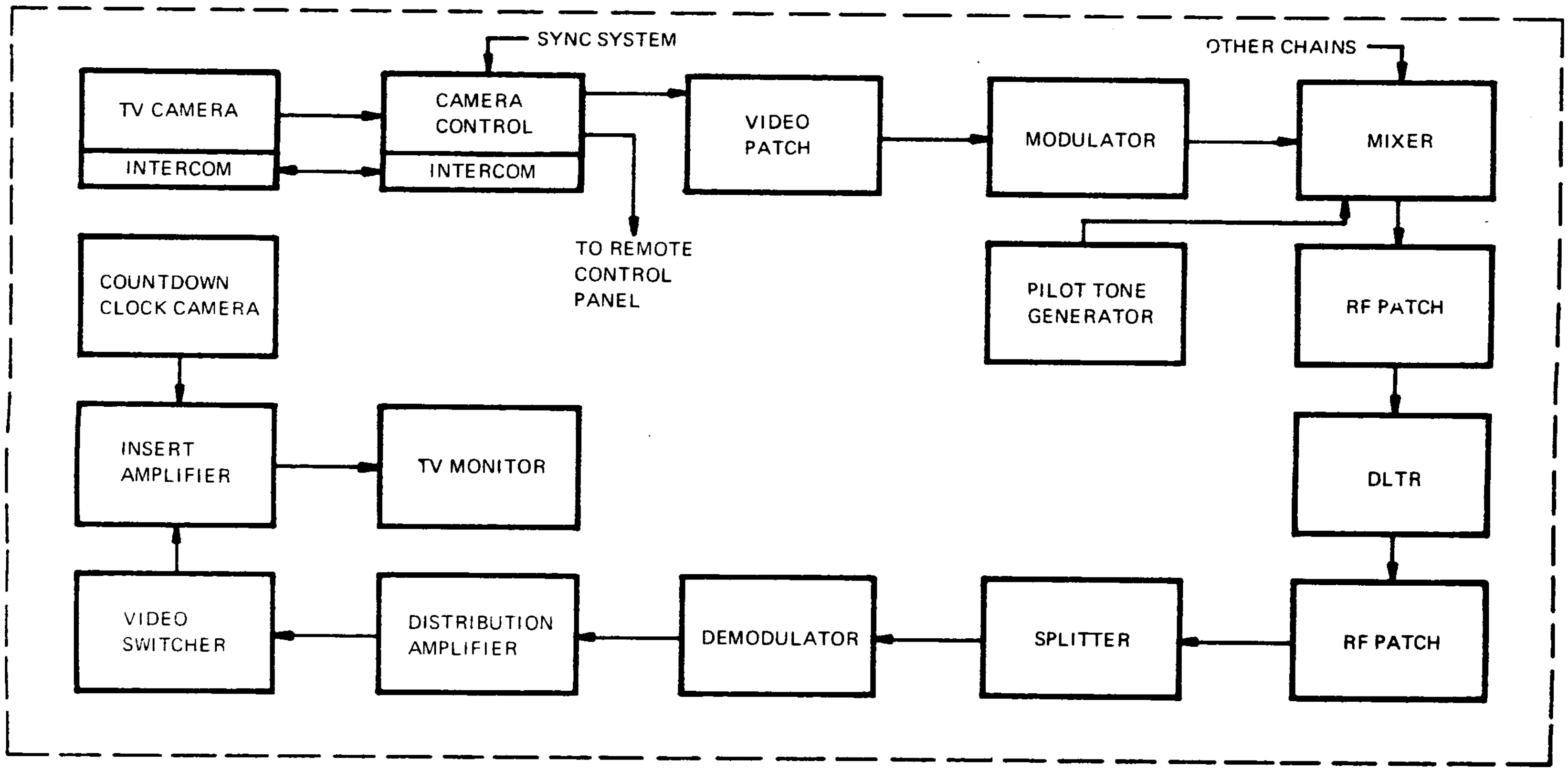


EXHIBIT 2 - TYPICAL CAMERA/MONITOR CONFIGURATION

Unsatisfactory condition reports written prior to 15 October 1969 for failures occurring within the television system are referenced by functional system code 34 and those written after 15 October 1969 are referenced by functional system code 790.

2. Data Base

The data base consists of 3,348 UCRs written prior to 15 October 1969 and two UCRs written after this date. The 3,348 UCRs were obtained by retrieving all UCRs having a functional system code of 34 from the "old" (i.e., UCRs written prior to October 1969) UCR master file. The remaining two UCRs were obtained by retrieving all UCRs having a functional system code of 790 from the "new" UCR master file.[1] Nearly 300 UCRs had corresponding investigation and corrective action reports (ICARs). These ICARs are also included in the data base.

3. Engineering Analysis

A sort by location of failure was made on the UCRs. The results of this sort are presented below. Approximately 60 percent of the failures occurred at launch complex 39.

Launch Complex	Number of UCRs	Percent of Total
34	468	14.0
37	319	9.5
39	2,006	59.9
All other locations	557	16.6
	3,350	

[1]These UCRs were actually written prior to 15 October 1969 and hence, are included in the data base. No other UCRs were retrieved since this responsibility now rests with INS QAL.

For each launch complex a plot of the number of UCRs per calendar quarter was made. These plots are presented in Exhibits 3 through 6. Only nine UCRs have failure occurrence dates later than the first quarter of 1969.

4. Component Populations

Four component populations were chosen, each representing one launch complex. This was done so that the overall television system failure rate could be considered by launch complex, i. e., by functional subsystem. The launch complexes are: 34, 37, 39, and all remaining locations grouped under the heading "other."

5. Installation Times

Component installation times were found by computing the number of days between the date of the first failure and the date of the last failure from the component UCRs. The installation times are presented below.

Location	Time Period	Days
LC-34	8/24/65 - 10/10/68	1,144
LC-37	1/7/66 - 5/17/68	861
LC-39	12/3/65 - 5/28/69	1,292
Other	9/8/65 - 3/11/69	1,280
All	8/24/65 - 5/28/69	1,373

6. Component Failures

Though a single UCR might report several part or module failures (e.g., three transistors, two capacitors, two printed circuit cards, etc.), only one failure has occurred against the television system itself--the failure of some functional part in the television system. However, in the television system, there are 318 cases in which two UCRs represent only one failure. The situation arises when a module of a television system component is replaced with another module. Two UCRs

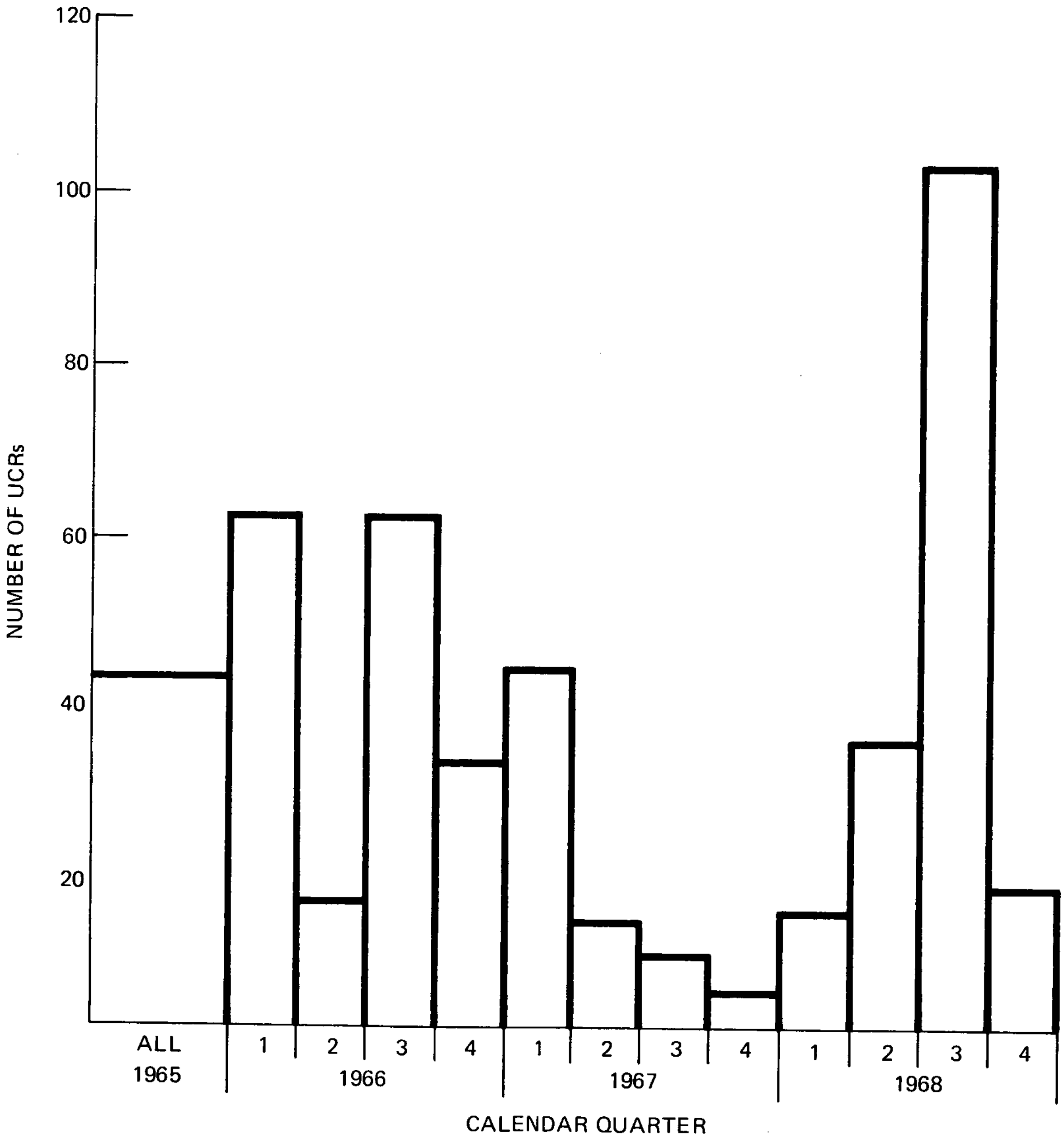


EXHIBIT 3 - NUMBER OF UCRS PER CALENDAR QUARTER FOR LAUNCH COMPLEX 34

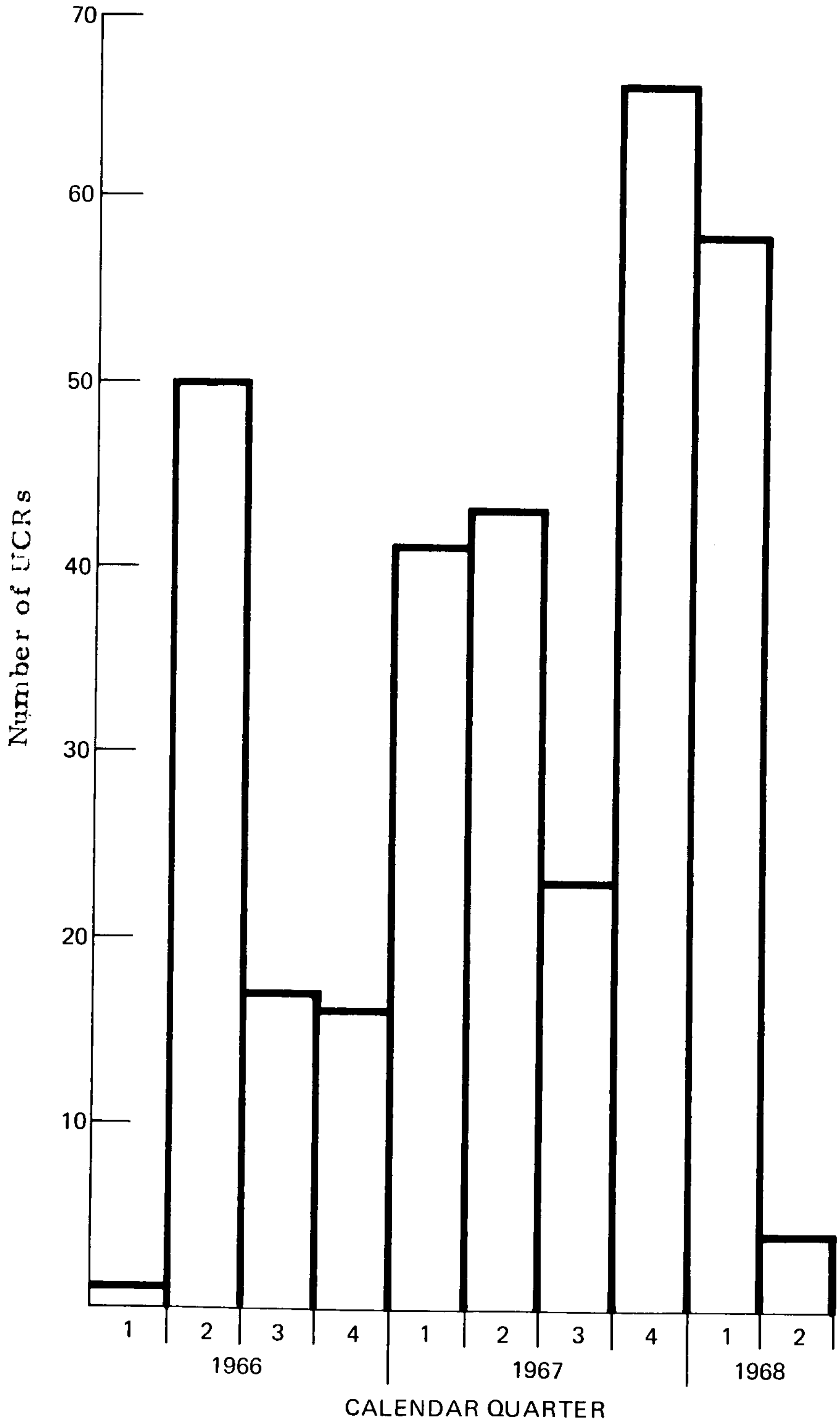


EXHIBIT 4 - UCRS PER CALENDAR QUARTER FOR LAUNCH COMPLEX 37

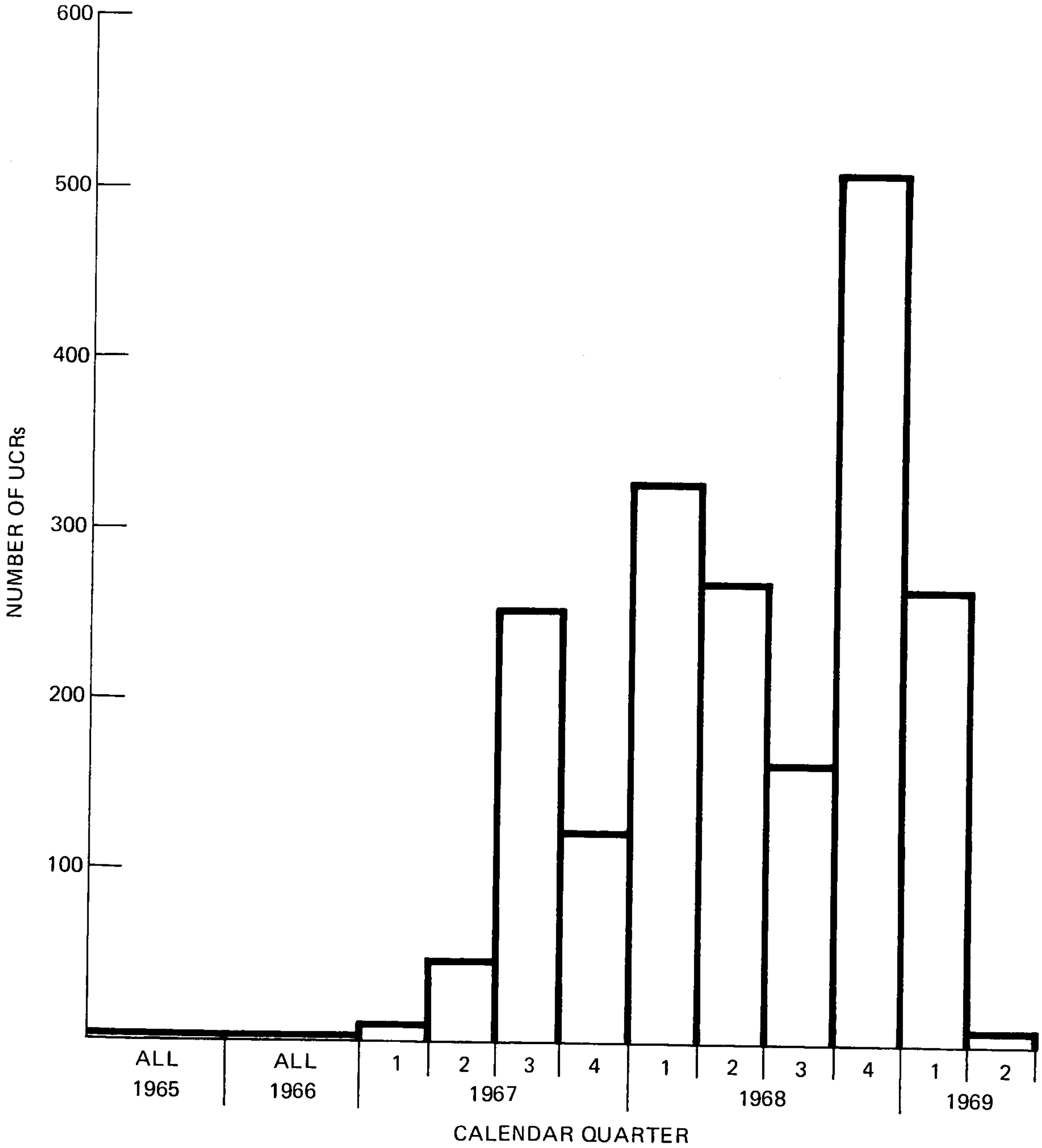


EXHIBIT 5 - UCRS PER CALENDAR QUARTER FOR LAUNCH COMPLEX 39

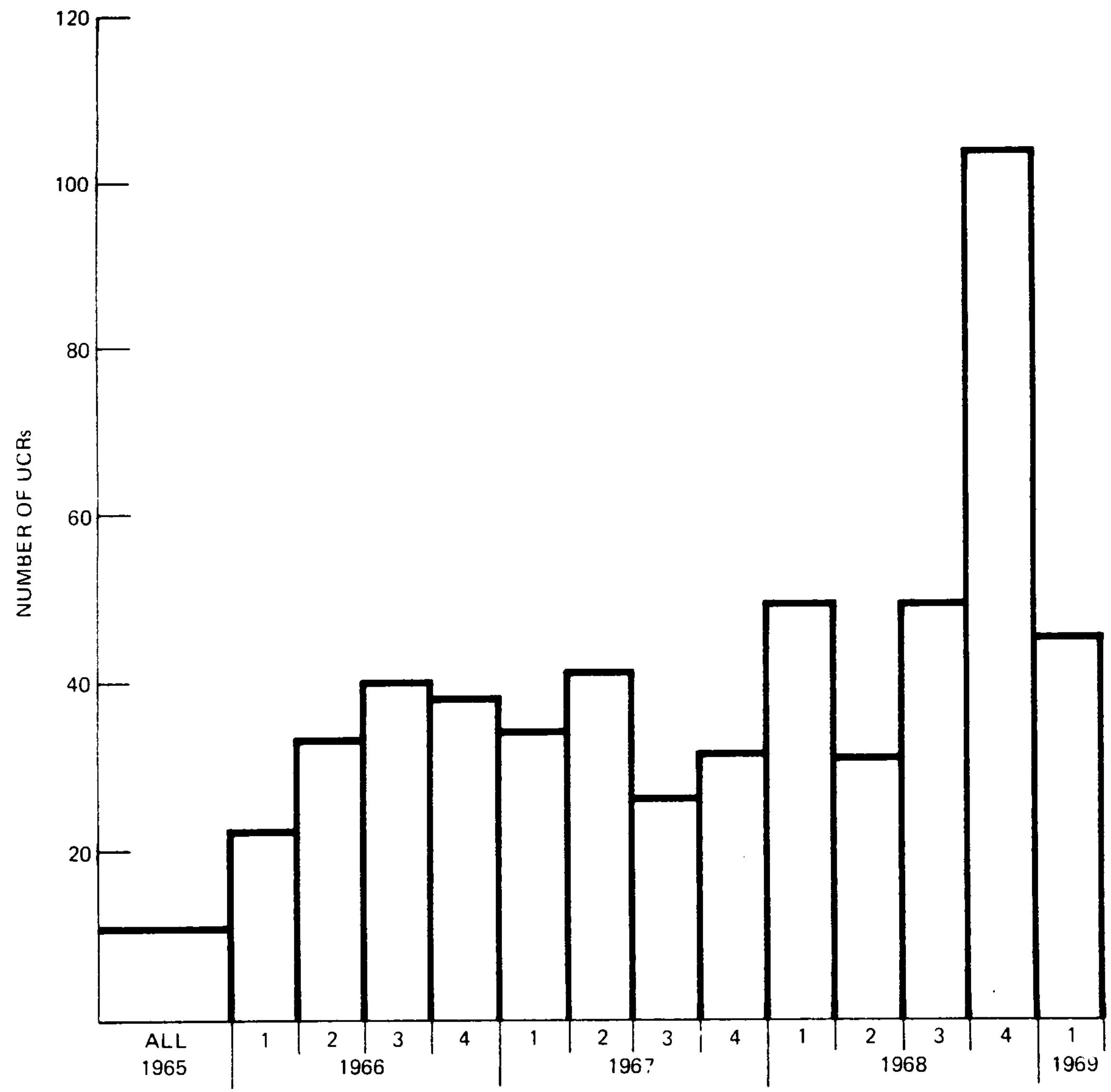


EXHIBIT 6 - NUMBER OF UCRS PER CALENDAR QUARTER FOR LOCATIONS OTHER THAN LAUNCH COMPLEXES 34, 37, AND 39

were written: one against the module failure and another UCR against the piece part (capacitor, potentiometer, resistor, etc.) that failed within the module. Thus, the number of failures is equal to the number of UCRs, 3,350, minus the number of repeated failures, 318. The number of failures per location is presented below.

Location	Number of Failures
LC-34	433
LC-37	304
LC-39	1,755
Other	540
All	3,032

7. Failure Classification

Over 96 percent of the UCRs had failures that could be classified as "normal service,"[1] design problem failures occurred on 2.3 percent of the UCRs and the remaining UCRs had quality and operation and maintenance failure causes.

For each location, the UCRs could be further divided into five component types:

- Amplifiers
- Cameras and camera associated equipment
- Modulators/demodulators
- Monitors
- Miscellaneous

Exhibit 7 presents the number of failures for each location and component type. Amplifiers, cameras, and camera associated equipment account for 61 percent of all failures in the television system.

[1] "Normal service" applies to all conditions which arose as the result of normal field operation or for which insufficient information is available to assign it to other categories.

Launch Complex	Amplifiers	Cameras and Associated Camera Equipment	Modulator/ Demodulator	Monitor	Other	Total
	Subpopulation					
34	153	183	-	89	8	433
37	100	136	-	63	5	304
39	598	418	331	343	65	1755
Other	146	125	-	240	29	540
TOTAL	997	862	331	735	107	3032

EXHIBIT 7 - NUMBER OF FAILURES PER LAUNCH COMPLEX AND TELEVISION SYSTEM COMPONENTS

It should be noted that modulator/demodulator failures occurred only in launch complex 39. It is not known for other locations if there were any modulator/demodulator failures or if these components were included under another component name.

All failures were classified by the reported modes of failure. These failure modes and their descriptions are:

- Alignment, adjustment - needed alignment or adjustment; could not be aligned or adjusted.
- Blast damage - damaged as a result of launch blast.
- Camera remote control problem - failures in remote control of cameras, e.g., no pan, no tilt, no zoom, sluggish response, etc.
- Component - failure of a piece part in an equipment; used only when no other failure mode was evident on the UCR except for a failed piece part.

- Design, modification, overhaul - failure is a problem that should be or should have been corrected by design action; or parts replaced under a modification or overhaul action.
- Focus, distorted output - video image is not clear; distorted picture; output has incorrect waveform.
- Incorrect output - output too high or too low.
- Inoperative - component inoperative; used when no further failure mode description is available.
- Intermittent - component output intermittent.
- Mechanical problem - covers any failures that are mechanical such as any fractures, cracked cases, missing mounting fixtures, gears broken, etc.
- Noisy - component output is noisy or causes noise to exist in other components.
- No output - component has no output; does not include video output.
- No video, poor video - no, or poor video display.
- Short circuit - short circuit.
- Sync, frequency response - component out of sync, no sync; component exhibits poor, or no frequency response.
- Video horizontal or vertical - failure results in vertical or horizontal circuit problems.
- Other - all other failure modes.

Exhibits 8 through 11 present the number of failures by location for these failure modes. Each location has a different distribution of failures by failure modes.

Over 70 percent of the UCRs had failures that required the replacement of piece parts such as transistors, capacitors, motors, vidicons, etc. The number of UCRs per location reporting the replacement of piece parts is as follows:

Failure Mode	Amplifiers	Cameras and Camera-Associated Equipment	Modulators/ Demodulators	Monitors	Miscellaneous	Total
	Components					Total
Alignment, Adjustment	1.2	1.1	3.3	4.2	0.1	9.9
Blast Damage	-	1.5	-	-	-	1.5
Camera Remote Control	-	0.9	-	-	-	0.9
Component	4.3	3.1	0.1	-	0.1	7.6
Design, Modification, Overhaul	0.3	1.0	-	-	0.1	1.4
Focus, Distorted Output	-	1.4	1.9	1.7	-	5.0
Incorrect Output	6.5	1.9	4.1	0.1	0.3	12.9
Inoperative	1.7	2.0	0.5	1.1	0.9	6.2
Intermittent	0.9	0.6	0.5	0.1	0.1	2.2
Mechanical	0.9	1.7	0.2	0.1	1.0	3.9
Noisy	1.9	2.1	2.4	0.6	0.2	7.2
No Output	11.9	1.4	2.3	3.8	0.3	19.7
No Video, Poor Video	-	2.2	-	2.7	-	4.9
Short Circuit	0.9	1.6	0.1	0.7	0.2	3.5
Sync, Frequency Response	1.9	0.6	3.4	0.3	-	6.2
Video, Horizontal or Vertical	-	0.7	-	3.8	-	4.5
Other	1.7	-	0.3	0.2	0.3	2.5
Total	34.1	23.8	19.1	19.4	3.6	100

EXHIBIT 8 - COMPONENT FAILURE MODES FOR LAUNCH COMPLEX 39 (PERCENT)

Failure Mode	Components: Amplifiers	Components: Cameras & Camera-Associated Equipment	Components: Monitors	Components: Miscellaneous	Total
Alignment, Adjustment	-	0.3	-	-	0.3
Blast Damage	-	-	-	-	-
Camera Remote Control	-	2.0	-	-	2.0
Component	-	3.0	-	0.3	3.3
Design, Modification, Overhaul	1.0	4.9	0.3	-	6.2
Focus, Distorted Output	4.3	3.9	2.6	-	10.8
Incorrect Output	3.9	1.6	-	-	5.5
Inoperative	3.6	4.3	1.6	0.7	10.2
Intermittent	3.3	2.0	-	-	5.3
Mechanical	0.3	2.6	0.3	0.3	3.5
Noisy	3.9	3.6	0.7	-	8.2
No Output	5.3	3.9	3.3	0.3	12.8
No Video, Poor Video	3.3	4.9	2.6	-	10.8
Short Circuit	0.6	1.0	2.6	-	4.2
Sync, Frequency Response	3.3	1.0	1.3	-	5.6
Video, Horizontal or Vertical	-	5.9	5.4	-	11.3
Other	-	-	-	-	-
Total	32.8	44.9	20.7	1.6	100

EXHIBIT 9 - COMPONENT FAILURE MODES FOR LAUNCH COMPLEX 37 (PERCENT)

Failure Mode	Component: Amplifiers	Component: Cameras & Camera-Associated Equipment	Component: Monitors	Component: Miscellaneous	Total
Alignment, Adjustment	2.1	0.2	-	-	2.3
Blast Damage	-	0.9	-	-	0.9
Camera Remote Control	-	4.4	-	-	4.4
Component	0.5	2.8	0.5	-	3.8
Design, Modification, Overhaul	2.8	1.6	0.7	0.5	5.6
Focus, Distorted Output	2.5	4.8	1.8	-	9.1
Incorrect Output	3.5	0.5	1.8	-	5.8
Inoperative	4.8	2.5	1.6	0.5	9.4
Intermittent	3.5	1.8	0.7	-	6.0
Mechanical	-	4.6	0.2	0.5	5.3
Noisy	4.6	3.7	1.2	-	9.5
No Output	2.1	1.4	1.6	0.5	5.6
No Video, Poor Video	3.7	4.8	1.8	-	10.3
Short Circuit	1.4	0.5	2.1	-	4.0
Sync, Frequency Response	3.2	1.2	1.8	-	6.2
Video, Horizontal or Vertical	0.5	5.3	3.7	-	9.5
Other	0.2	1.2	0.9	-	2.3
Total	35.4	42.2	20.4	2.0	100

EXHIBIT 10 - COMPONENT FAILURE MODES FOR LAUNCH COMPLEX 34 (PERCENT)

Failure Modes	Components: Amplifiers	Components: Cameras and Camera-Associated Equipment	Components: Monitors	Components: Miscellaneous	Total
Alignment	-	-	1.1	-	1.1
Blast Damage	-	-	-	-	-
Camera Remote Control	-	1.7	-	-	1.7
Component	1.5	1.5	3.3	-	6.3
Design, Modification, Overhaul	-	0.7	0.4	0.4	1.5
Focus, Distorted Output	2.2	1.9	1.5	0.7	6.3
Incorrect Output	4.1	0.4	4.4	1.5	10.4
Inoperative	4.4	3.9	4.4	0.7	13.4
Intermittent	0.4	1.1	1.5	-	3.0
Mechanical	0.2	0.6	0.7	0.4	1.9
Noisy	5.2	2.2	1.5	0.6	9.5
No Output	5.4	1.3	5.4	0.6	12.7
No Video, Poor Video	1.1	3.7	4.4	-	9.2
Short Circuit	0.2	0.6	5.9	-	6.7
Sync, Frequency Response	1.3	0.7	1.7	0.4	4.1
Video, Horizontal or Vertical	0.7	1.5	6.3	-	8.5
Other	0.7	1.5	1.3	0.2	3.7
Total	27.4	23.3	43.8	5.5	100

EXHIBIT 11 - COMPONENT FAILURE MODES FOR OTHER LOCATIONS (PERCENT)

Location	Number of UCRs With Piece Part Failures	Percent of Total
LC-34	382	82
LC-37	251	78
LC-39	1,348	67
Other	432	78
All	2,413	70

Exhibit 12 presents the number of UCRs indicating replacement of particular piece parts. (It does not give the total number of piece parts replaced.)

8. Field Failure Rates

Field failure rates for the television system populations were computed by dividing the total number of failures by the total installation time. The resulting failure rates are presented below.

Location	Field Failure Rate (Failures/1,000 Hours)
LC-34	15.8
LC-37	14.7
LC-39	56.7
Other	17.5
All	91.9

9. FFR Confidence Intervals

It was assumed that each location had an exponential distribution of times to failure. Based on this assumption the 90-percent confidence intervals were computed and are presented as follows:

Piece Parts	Location				Total
	LC-34	LC-37	LC-39	Other	
Capacitor	134	88	521	168	911
CRT	10	6	62	19	97
Connector	3	2	5	1	11
Diode	24	31	64	28	147
Faceplate	6	1	21	-	28
Fuse	17	13	53	10	93
Inductor	7	5	6	7	25
Lamp	6	1	97	3	107
Lens	3	1	33	1	38
Module	21	7	35	4	67
Motor	12	9	7	12	40
O Ring	10	1	7	-	18
Photocell	-	-	58	-	58
Relay	2	-	6	-	8
Resistor	50	29	74	43	196
SCR	2	-	6	-	8
Switch	3	7	6	1	17
Transformer	10	9	16	17	52
Transistor	104	80	402	98	684
Tube	44	34	40	12	216
Vidicon	28	12	53	12	105
Wiring	17	12	26	4	59
Yoke	3	1	9	5	18
Miscellaneous	17	15	72	4	108

EXHIBIT 12 - NUMBER OF UCRS INDICATING REPLACEMENT OF PIECE PARTS

Location	Failure Rate (Failures/1,000 Hours) Upper Limit	Mean	Lower Limit
LC-34	17.0	15.8	14.5
LC-37	16.1	14.7	13.4
LC-39	58.8	56.7	54.4
Other	18.8	17.5	16.3
All	94.3	91.9	89.4

10. Resolution of FFR Factors

The FFR for launch complex 39 was more than three times that of the other locations. Fifty-eight percent of all failures at launch complex 39 were attributed to amplifier and cameras and camera-associated equipment. These two component types represented 78 percent of the field failure rate on launch complex 34, 78 percent on launch complex 37, and 50 percent for all other locations.

The table below presents the individual contribution to the field failure rate for five component types.

Subpopulation	LC-34	LC-37	LC-39	Other
Amplifiers	5.6	4.8	19.3	4.9
Cameras & Camera Associated Equipment	6.7	6.7	13.5	4.1
Modulators/ Demodulators	-	-	10.7	-
Monitors	3.2	3.0	11.1	7.8
Miscellaneous	0.3	0.2	2.1	0.9
Total	15.8	14.7	56.7	17.5

11. Repair Times

Repair time data were provided on 65 percent of the UCRs. These data provide the results presented (in hours) in the following table. The mean repair time for launch complex 39 is approximately one-half that of the other locations.

The maximum total time-to-repair is largely due more to waiting for repair parts, than to actual repair of the equipment.

Location	Minimum	Mean	Maximum	Number of Observations	Percent of UCRs
LC-34	6 min.	11.61	501	357	82
LC-37	5 min.	10.96	432	257	85
LC-39	4 min.	6.56	120.25	976	56
Other	5 min.	9.99	582.2	341	63
All	4 min.	8.27	582.2	2,031	67

RELIABILITY ASSESSMENT
OF
WATER SYSTEM

Date: 24 May 1972

Observed Field Failure Rate
In Failures Per Thousand Hours
Of Installed Component Time

Prior to 15 October 1969	10.1
After 15 October 1969	2.80

FAILURE MODES AND CAUSES CONTRIBUTING TO THE OBSERVED FIELD FAILURE RATE AS A PERCENT OF THE TOTAL

Failure Cause

Failure Type		Normal Operation	Design Problem	Quality Problem	Operational Problem	Total
	Mechanical	26	25	12	4	67
	Piping	3	6	4	2.5	15.5
	Pumps & Engines	2	4	2	0.5	8.5
	Valves	18	9	4	1	32
	Miscellaneous	3	6	2	-	11
	Electrical	12	13	3	5	33
	Pumps & Engines	2	2	1	2	7
	Switches	4	3	-	1	8
	Wiring	1	6	1	2	10
	Miscellaneous	5	2	1	-	8
	Total	38	38	15	9	100.0

Failure Classification (Percent)

Number of Relevant UCRs: 335 Currency:[1] May 1971

[1] Date of latest UCR run included in the assessment.

DESIGN BACKGROUND DATA

1. Component Description

The water system includes all equipment used to supply water for use at launch complexes 34, 37, and 39 and associated areas except that used for the potable water supply. Thus, all unsatisfactory condition reports (UCRs) written against functional systems 10 and 68 (industrial water system and water quench system) before 15 October 1969 and all UCRs written against functional systems 840, 841, 842 and 843 (firex water system, industrial water system, water control system and pump station water) after 15 October 1969 are included in the assessment.

The water system is designed to provide water for use in testing, fire control, and cooling at launch.

2. Data Base

The water system data base consists of 335 unsatisfactory condition reports. Three hundred and three of these were written prior to 15 October 1969 and 32 afterwards. The time period covered by these data is from May 1965 to January 1971. Approximately 75 percent of the UCRs have associated investigation and corrective action reports (ICARs); these are also included in the data base.

3. Engineering Analysis

The number of UCRs written per calendar quarter are shown in Exhibit 1. From the first quarter of 1968, the number of UCRs has steadily decreased. A further drop in UCR frequency occurs after installation of the new UCR system (15 October 1969).

Exhibit 2 presents the number of UCRs written by associated functional system and launch complex. Eighty percent of the UCRs occurred at launch complex 39, 11 percent at launch complex 37 and 5 percent at launch complex 34.

Ninety percent of the UCRs were written against functional systems 10 and 68 while only 10 percent of the failures were written against functional systems 840 through 843. (Functional systems 10 and 68 represent UCRs written before 15 October 1969 and functional systems

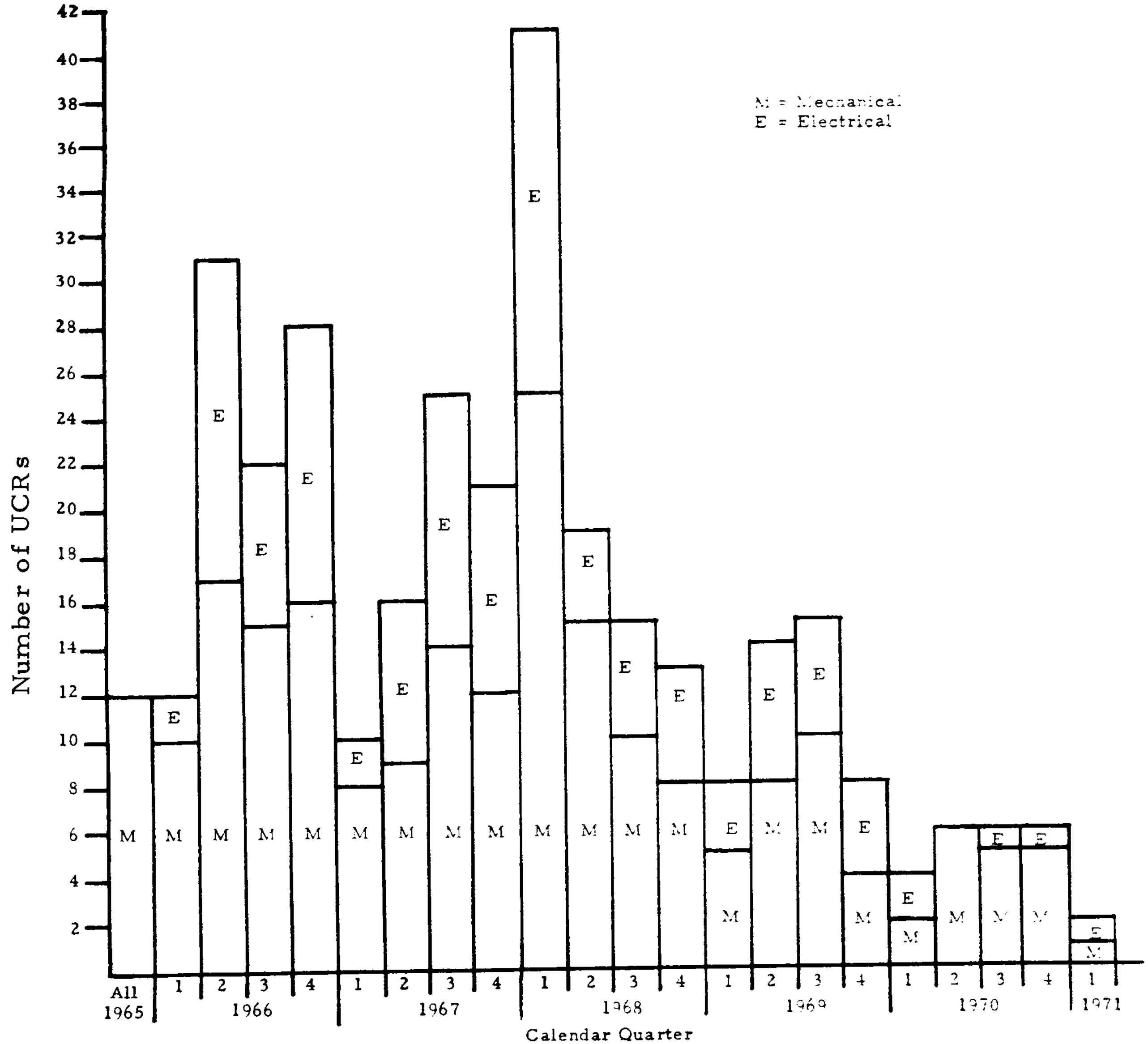


EXHIBIT 1 - NUMBER OF WATER SYSTEM UCRS VERSUS CALENDAR QUARTER

EXHIBIT 2 - WATER SYSTEM UCRs BY LOCATION AND FUNCTIONAL SYSTEM

	Functional System						
Location	10	68	840	841	842	843	Total
LC-34	17	19					36
LC-37	1	14					15
MSS	2	8		3			13
ML-1	6	3					9
ML-2	4	1			5		10
LC-39 A	33	18		3	9	1	64
LC-39 B	10	14			3		27
LC-39	25	111		5	5		146
Other	4	5	1	3	2		15
Total	102	193	1	14	24	1	335

Functional System

10	Water Quench
68	Industrial Water
840	Control System Water
841	Firex Water
842	Industrial Water
843	Pump Station Water

840-843 after that date. Also, 58 of the 102 UCRs written against the water quench system were considered as part of the industrial water system based on information contained in the UCR (i. e., UCRs from functional systems 840-843).

Seven of the "new" UCRs had occurrence dates prior to 15 October 1969. These UCRs are included in the data base for "old" UCRs (i. e., functional systems 10 and 68).

4. Component Populations

The water system data base may be divided into two subpopulations: (1) those UCRs considered to be from the "old" UCR system; and (2) those UCRs from the "new" UCR system. The first subpopulation consists of 295 UCRs originally from the "old" system plus 8 UCRs from the "new" system (303 total). The "new" subpopulation comprises 40 UCRs minus 8 that should be in population 1 (32 total).

5. Component Time

No UCR age or time entries refer specifically to the water system. The UCR entries are written against the particular component that failed and not against the water system. The component time, therefore, was assumed to extend from the date of the first UCR in 1966[1] (17 January) to 15 October 1969. This time is 1, 367 days. The component time for the new UCR system is 476 days, from 15 October 1969 to the occurrence date of the most recent UCR 3 February 1971.

6. Component Failures

There were 331 failures on 303 UCRs for the old system and 32 failures on 32 UCRs for the new system. Twelve failures on the old UCR system occurred previous to 1966. These are not included in failure rate calculations because of lack of water system data at that time. Thus, there are 319 failures associated with the first population and 32 with the second.

[1]UCRs occurring in 1965 were not included because this time period represents the start of the UCR system and water system data from 1965 may not be complete.

7. Failure Classifications

The water system failures may be classified as electrical or mechanical. They may be further classified by failed part type; e.g., valves, piping, switches, etc. Exhibit 3 presents the number of UCRs and failures by these classifications.

Exhibit 4 assigns failure causes to each of the failure classifications. The explanations for failure causes are:

- Normal operation - Includes all failures which arise as a result of normal field operation or for which insufficient information is available to assign it to any other category.
- System design - A fault which is inherent in, and can be corrected by, the water system design.
- Quality - Implies a fault which is neither inherent in the design nor the result of normal (or abnormal) operation. It is generally a manufacturing problem such as missing valve parts or no initial lubrication.
- Design due to corrosion - A fault which is inherent in, and can be corrected by, the system design in respect to a corrosive environment.
- Operation and maintenance - Implies that the failure was caused or exacerbated by the misuse of water system components on the part of operating or maintenance personnel.
- Construction error - Implies a failure of the water system due to errors in construction. This category is used for the electrical system for errors in wiring due to construction personnel or construction drawing errors.

The predominant failure causes are normal operation and system design problems which account for over 65 percent of all reported failures. Exhibit 5 shows that electrical failures caused by design problems virtually disappeared after the fourth quarter of 1968; mechanical failures caused by design problems continue at a rate of nearly one per month.

EXHIBIT 3 - NUMBER OF WATER SYSTEM ELECTRICAL AND MECHANICAL FAILURES

	Old UCR System		New UCR System	
	UCRs	Failures	UCRs	Failures
Piping	49	55	2	2
Pumps & Engines	25	28	1	1
Valves	97	105	10	10
Miscellaneous, Mechanical	28	28	9	9
Total, Mechanical	199	216	22	22
Pumps & Engines	18	21	3	3
Switches, Electrical	26	27	2	2
Wiring	34	35	-	-
Miscellaneous, Electrical	26	32	5	5
Total, Electrical	104	115	10	10

	Normal Operation	System Design	Quality	Design Due to Corrosion	Operation and Maintenance	Construction Error	Total
Old System							
Mechanical							
Piping	15	19	6	2	8	5	55
Pumps & Engines	10	12	1	4		1	28
Valves	60	29	5	8	2	1	105
Miscellaneous	6	15	3	2	2		28
Electrical							
Pumps & Engines	8	6	3		2	2	21
Switches	13	8	1	1		4	27
Wiring	3	21	1		5	5	35
Miscellaneous	19	7	3		2	1	32
TOTAL	134	117	23	17	21	19	331
New System							
Mechanical							
Piping		1				1	2
Pumps & Engines				1			1
Valves	7	2	1				10
Miscellaneous	5	4					9
Electrical							
Pumps & Engines		2			1		3
Switches	1	1					2
Wiring							0
Miscellaneous	5						5
TOTAL	18	10	1	1	1	1	32

EXHIBIT 4 - FAILURE CLASSIFICATIONS (NUMBER OF FAILURES)

	Quarter																					
	1966				1967				1968				1969				1970				1971	
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	Total
Electrical	1	8	2	6	1	3	7	3	6	4	1	-	-	-	-	1	1	-	-	1	-	45
Mechanical	1	10	4	4	6	1	7	2	12	4	9	4	2	2	3	2	-	4	3	-	-	80

EXHIBIT 5 - NUMBER OF FAILURES DUE TO SYSTEM DESIGN

Failure modes are further detailed in Exhibit 6. The explanations for the failure modes are:

- o Adjustment problem - output of electrical components could not be adjusted or is out of adjustment.
- o Corrosion - corrosion of components causing failures.
- o Design deficiency - failure which is inherent in, and can be corrected by system design.
- o False indication - electrical failure caused by a component failing to give the correct indication of some part of the system's operating status.
- o Installation error-- failure of system due to errors in system installation; primarily electrical wiring errors.
- o Internal component failure - failure of a component in a higher level of water system equipment; used only when further resolution of failure mode cannot be determined.
- o Leakage - mechanical equipment is leaking either liquid or gas.
- o Open - open electrical circuit.
- o Operational problem - equipment cannot be operated or is difficult to operate.
- o Other - mechanical failures not classified elsewhere.
- o Output incorrect - output from an electrical component is incorrect, e.g., too high or too low voltage.
- o Short - shorted electrical circuit; blown fuse.
- o Support failure - failure of supports of water system components, e.g., supports buckled or fractured.
- o Tolerance - mechanical components out of tolerance.

8. Field Failure Rates

Field failure rates were computed by dividing the number of failures for the old and new UCR systems by their respective component times. For the old system the field failure rate is 10.09 failures per 1,000 hours. The new system has a field failure rate of 2.80 failures per 1,000 hours or approximately 1/3 that of the old system.

a. Electrical Failures

Failure Mode	Old UCR: Pumps & Engines	Old UCR: Switches	Old UCR: Wiring	Old UCR: Miscellaneous	Old UCR: TOTAL	New UCR: Pumps & Engines	New UCR: Switches	New UCR: Wiring	New UCR: Miscellaneous	New UCR: TOTAL
Adjustment Problem	2			3	5				2	2
Corrosion		5	3		8					
Design Deficiency	3	6	6	3	18	2	1			3
False Indication				3	3				2	2
Installation Error	3	2	14	1	20					
Internal Component Failure	9	4	9	9	31	1	1		1	3
Open	1	1	1		3					
Operational Problem	2	9			11					
Output Incorrect				8	8					
Short	1		2	5	8					
TOTAL	21	27	35	32	115	3	2	0	5	10

b. Mechanical Failures

Failure Mode	Old UCR: Piping	Old UCR: Pumps & Engines	Old UCR: Valves	Old UCR: Miscellaneous	Old UCR: TOTAL	New UCR: Piping	New UCR: Pumps & Engines	New UCR: Valves	New UCR: Miscellaneous	New UCR: TOTAL
Corrosion, Contamination	10	3	23	4	40		1	1	1	3
Design Deficiency	8	3	15	9	35	1		3	1	5
Internal Component Failure	15	11	24	3	54			2	2	4
Leakage	17	10	25	2	54				2	2
Operational Problem	2	1	9	4	16	1		3	3	7
Other	2	-	4	5	11					
Support Failure	-	-	3	-	3					
Tolerance	-	-	2	1	3			1		1
TOTAL	55	28	105	28	216	2	1	10	9	22

EXHIBIT 6 - FAILURE MODES

9. FFR Confidence Intervals

For the old UCR system, assuming an exponential distribution of failure times, the FFR confidence intervals (per 1,000 hours) are:

Upper	11.40
Lower	8.83

For the new UCR system under the same assumption the FFR confidence intervals (per 1,000 hours) are:

Upper	3.66
Lower	2.04

10. Resolution of FFR Factors

There are approximately twice as many mechanically related failures as there are electrical failures. Normal service accounts for 40 percent of all old UCR failures and 56 percent of all new UCR failures. Failures caused by system design problems represented 35 percent of all old UCR failures and 31 percent of all new UCR failures. An FFR breakdown by source is given in Exhibit 7.

EXHIBIT 7 - FFRs (PER 1,000 HOURS) FOR SUBCLASSIFICATIONS

	Old UCR System	New UCR System
Mechanical		
Piping	1.68	0.18
Pumps & Engines	0.85	0.09
Valves	3.20	0.87
Miscellaneous	0.85	0.78
Total	6.58	1.92
Electrical		
Pumps & Engines	0.64	0.26
Switches	0.82	0.18
Wiring	1.08	--
Miscellaneous	0.97	0.44
Total	3.51	0.88

III. BASELINE UCR DATA

This section gathers in one place those reliability elements most commonly sought for selected portions of the ground support equipment under KSC design cognizance. These elements include field failure rates and associated confidence factors, classification of the failures as to cause and mode, and finally, certain repair time statistics. This section includes data from UCRs written prior to 15 October 1969. These data are called baseline data but only because they are so much more numerous than data subsequent to 15 October 1969. Reliability elements from the latter data are deferred to Section IV.

The reliability elements are collected into a number of exhibits each of which will be discussed shortly. At this point, however, it is strongly urged that any nontrivial use of the data of this section, or the next one, be made only after reasonable familiarity is gained with the appropriate RAC of Section II. Each RAC (reliability assessment of a component) contains all information gained from the UCR system with respect to the component's reliability. The FFR or a particular classification might be qualified in a way that can only be reported in the RAC itself.

A. Field Failure Rates and Confidence Factors

Exhibit 2 presents all baseline FFRs generated to date on the various elements of the KSC ground support equipment. The exhibit is divided into three major sections. The first represents FFRs for piece parts, the second FFRs for subsystems, and the third for systems. In this handbook the distinction between these three levels of equipment is not hard and fast. Piece parts are generally small, relatively high population items found in many if not all functional systems. A subsystem is generally a collection of piece parts that is still an integrally functioning unit. A system is generally a collection of subsystems and is often not particularly well defined in terms of constituent hardware. The examples included under each heading in Exhibit 2

EXHIBIT 2 - BASELINE FIELD FAILURE RATES FOR JOHN F. KENNEDY SPACE CENTER GROUND SUPPORT EQUIPMENT

Component		FFR(1)	Confidence Factor(2)
A.	Piece Parts		
1.	Batteries	0.108	9
2.	Cable Assemblies		
	Mechanical	0.059	14
	Electrical	0.125	80
3.	Capacitors	0.072	122
4.	Circuit Breakers	0.062	93
5.	Connectors	0.134	25
6.	Pressure Switches	0.10	50
7.	Regulators		
	Part No. 75M50165-13	0.18	13
	Part No. 75M08410-1, -1B	0.48	8
	Part No. 75M50305-1	0.15	5
	Part No. 75M04839-4, -1	0.45	5
	Part No. 75M11856	1.54	4
	With Inlet Pressure >3,000 psi	0.23	42
	With Inlet Pressure <750 psi	0.13	12
	Intermediate Inlet Pressures	0.20	15
	Electromechanical Regulators	0.16	20
8.	Relays	0.09	93
9.	Solenoid Valves	0.19	76

Notes: (1) Field failure rate (FFR) is given in failures per unit per 1,000 hours.

(2) Number of failures upon which the FFR is based. To convert to a statistical 90-percent confidence interval see the text (Section III. A) and Exhibit 3.

EXHIBIT 2 (Continued)

Component	FFR(1)	Confidence Factor(2)
B. Subsystems		
1. Amplifiers		
Composite	0.150	215
Television Functional System		
Switching Amplifier (3207, A1-A5)	0.167	29
Switching Output Amplifier (B05390D)	1.63	9
Insert Amplifier 3207-A12	0.285	14
Video Dist. Amplifier D5864A, DA61PA	0.226	8
Pulse Dist. Amplifier 5841A, 3202	0.149	4
A6C/DA: AG7394A	0.346	9
OIS-RF Functional System		
Audio IF Amplifier 758-0081-001	0.199	40
OIS-Audio Functional System		
Headset PCB: 24620496	0.307	11
AIA PC Card: C0-0046	0.284	9
Mike PCB: 24620492	0.176	6
Measuring Functional System		
Blue or Red Amplifier 173930	0.115	
Amplifier 723397-1	0.0709	10
Amplifier 356355-1	0.0579	7
Amplifier 356410-7	0.0512	7
Range Instrumentation Functional System		
Multiplexer Amplifier 20010, 20011	0.129	38

Notes: (1) Field failure rate (FFR) is given in failures per unit per 1,000 hours.

(2) Number of failures upon which the FFR is based. To convert to a statistical 90-percent confidence interval see the text (Section III. A) and Exhibit 3.

EXHIBIT 2 (Continued)

	Component	FFR (1)	Confidence Factor (2)
2.	Compressors	0.117	38
3.	Holddown Arms		
	Launch Complex 39	0.348	19
	Launch Complex 37	0.416	6
	Launch Complex 34	0.712	6
4.	Pump Assemblies	0.129	44
5.	RF Carrier Demodulator (DSC-39-W)	0.409	51
6.	RF Carrier Modulator (MSC-39-W)	0.831	55
7.	RF Line Repeater Amplifier (ASC-39-W)	0.537	9
8.	Tail Service Masts at Launch Complex 39		
	Composite	0.653	124
	Serial No. 1001 (Location 3-4)	0.806	17
	Serial No. 1002 (Location 1-2)	0.900	19
	Serial No. 1003 (Location 3-2)	0.711	15
	Serial No. 1004 (Location 3-4)	0.521	11
	Serial No. 1005 (Location 1-2)	0.711	15
	Serial No. 1006 (Location 3-2)	0.237	5
	Serial No. 1007 (Location 3-4)	0.853	18
	Serial No. 1008 (Location 1-2)	0.474	10
	Serial No. 1009 (Location 3-2)	0.616	13
	TSMs at Location 3-4	0.742	47
	TSMs at Location 1-2	0.679	13

Notes: (1) Field failure rate (FFR) is given in failures per unit per 1,000 hours.
(2) Number of failures upon which the FFR is based. To convert to a statistical 90-percent confidence interval see the text (Section III. A) and Exhibit 3.

EXHIBIT 2 (Continued)

Component	FFR(1)	Confidence Factor(2)
TSMs at Location 3-2	0.521	33
TSMs in Support of Launch AS 501	2.167	26
TSMs in Support of Launch AS 502	2.667	32
TSMs in Support of Launch AS 503	1.783	46
TSMs in Support of Launch AS 504	0.435	9
TSMs in Support of Launch AS 505	0.484	4
TSMs in Support of Launch AS 506	0.417	5
C. Systems		
1. RF Instrumentation		
At Launch Complex 39	0.68	11
At Launch Complex 37	1.02	5
At Launch Complex 34	0.80	17
At Other Locations	0.23	6
2. Television System (OTV)		
At Launch Complex 39 -- Composite	86.7	1,755
Amplifiers	19.3	598
Cameras and Associated Equipment	13.5	418
Modulators/Demodulators	10.7	331
Monitors	11.1	343
Miscellaneous	2.1	65

Notes: (1) Field failure rate (FFR) is given in failures per unit per 1,000 hours.

(2) Number of failures upon which the FFR is based. To convert to a statistical 90-percent confidence interval see the text (Section III. A) and Exhibit 3.

EXHIBIT 2 (Continued)

Component	FFR[1]	Confidence Factor[2]
At Launch Complex 37-- Composite	14.7	304
Amplifiers	4.8	100
Cameras and Associated Equipment	6.7	136
Monitors	3.2	63
Miscellaneous	0.3	5
At Launch Complex 34-- Composite	15.8	433
Amplifiers	5.6	153
Cameras and Associated Equipment	6.7	183
Monitors	3.2	89
Miscellaneous	0.3	8
At Other Locations-- Composite	17.5	540
Amplifiers	4.7	146
Cameras and Associated Equipment	4.1	125
Monitors	7.8	240
Miscellaneous	0.9	29
3. Water System	10.1	319

Notes: (1) Field failure rate (FFR) is given in failures per unit per 1,000 hours.
(2) Number of failures upon which the FFR is based. To convert to a statistical 90-percent confidence interval see the text (Section III. A) and Exhibit 3.

serve better to identify these elements than any simple definition. They are listed separately because of their slightly different treatment in the RACs. Any equipment grouping to which an FFR is attached or upon which the RAC methodology is performed is called a component.

All FFRs are derived by dividing the number of component failures by total accumulated component time and are reported in units of failures per thousand hours. For piece parts and some subsystems component time is given directly on the UCR. For other subsystems and for all systems component time must be estimated or deduced. The specific procedure in either case is contained in the appropriate RAC. The number of failures are determined by an analysis of all pertinent UCRs; again, this process is documented in the RACs.

The confidence factor is simply the number of failures upon which the corresponding FFR is based. Using the number of failures as the confidence factor has two advantages. First, a single number can be used which is directly indicative of statistical confidence and at least indirectly indicative of engineering confidence. That is, the higher the number of failures the more accurate the indicated FFR. Secondly, this number together with Exhibit 3 and the FFR can be used to determine the 90-percent confidence interval on the estimated FFR. The abscissa of Exhibit 3 is entered at the value corresponding to the number of failures and multiplying factors to be applied to the FFR are read on the ordinate which will give the upper and lower limits of the 90-percent confidence interval. For example, batteries have an indicated FFR of 0.108 failures per thousand hours based on nine failures. Entering the abscissa of Exhibit 3 at nine, the smaller multiplying factor is found to be approximately 0.53 and the upper factor 1.61. The 90-percent confidence interval is then (0.53) (0.108) to (1.61) (0.108) failures per thousand hours. Performing the indicated multiplication gives the values 0.057 to 0.174 failures per thousand hours.

B. Failure Causes

Exhibit 4 assigns one of five failure causes to each component or subdivision thereof. These failure causes are defined in Section VI. C.

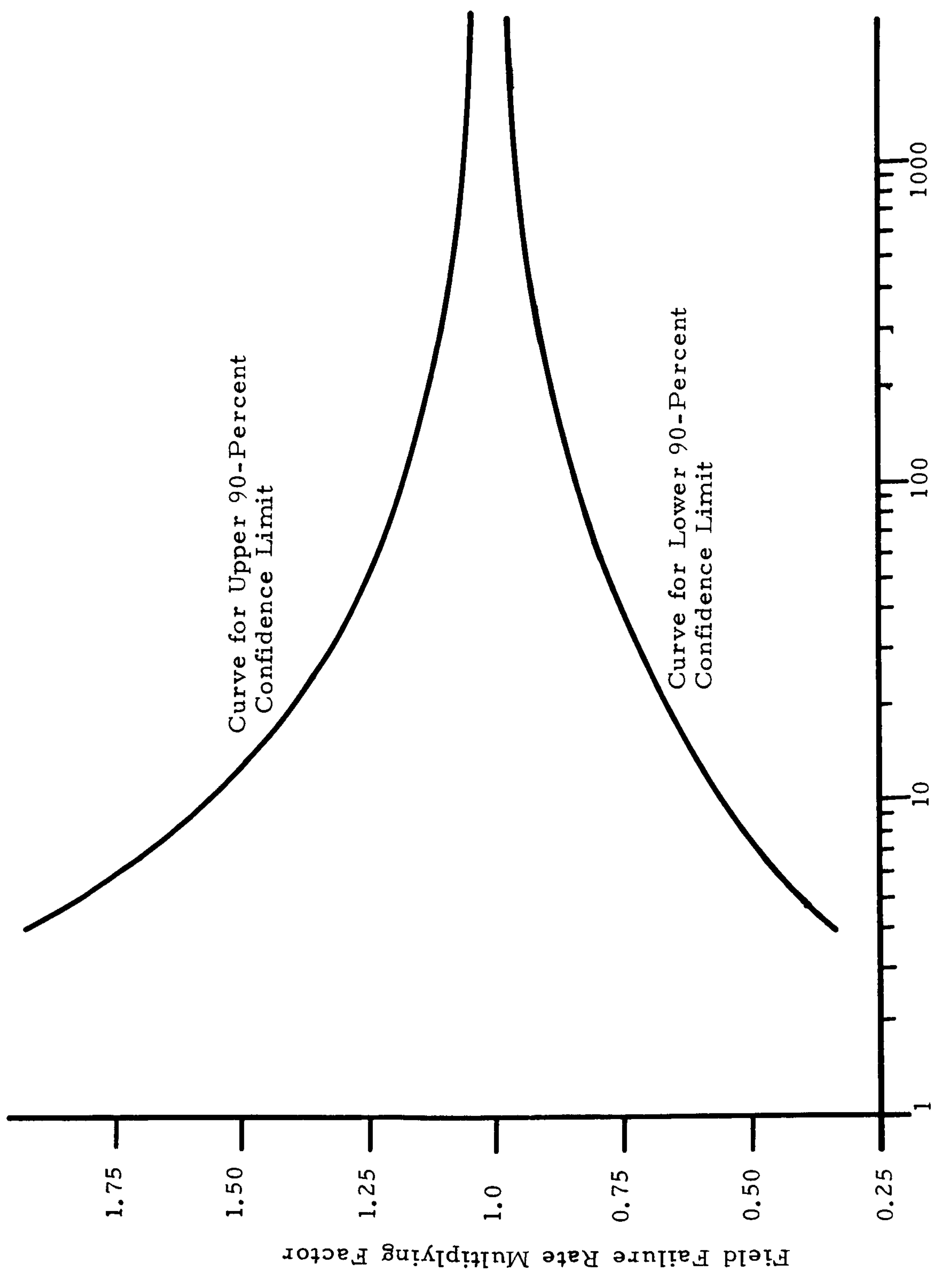


EXHIBIT 3 - GRAPH FOR DETERMINING 90-PERCENT CONFIDENCE LIMITS ON THE FIELD FAILURE RATE

EXHIBIT 4 - BASELINE FAILURE CAUSES FOR JOHN F. KENNEDY SPACE CENTER GROUND SUPPORT EQUIPMENT

A. Piece Parts

	Component	Failure Cause (Percent)[1] Normal Service	Design Problem	Quality Problem	Operational Problem	Preventive Maintenance	Other
1.	Batteries	56	26	18			
2.	Cable Assemblies						
	Electrical	23	30	37	10		
	Mechanical	18	64	9	9		
3.	Capacitors	72	22	1		5	
4.	Circuit Breakers	76	11	10	3		
5.	Connectors	58	9	14	17	2	
6.	Pressure Switches	40	42	16	2		
7.	Regulators (Composite)	64	12	9		13	2
	Inlet Pressure >3,000 psi	78	3	17		2	
	Inlet Pressure <750 psi	33	14			45	9
	Intermediate Pressure Range	64	10	9		13	5
8.	Relays	86	6	8			
9.	Solenoid Valves	84	4	11	2		

Note: (1) May not sum to 100 because of rounding.

EXHIBIT 4 (Continued)

B. Subsystems

	Component	Failure Cause (Percent)[1] Normal Service	Design Problem	Quality Problem	Operational Problem	Preventive Maintenance	Other
1.	Amplifiers	97		1	1	1	
2.	Compressors	79	11	5	4		
3.	Pump Assemblies	63	28	6	3		
4.	RF Carrier Demodulator (DSC-39-W)	99	1				
5.	RF Carrier Modulator (MSC-39-W)	100					
6.	RF Line Repeater Amplifier (ASC-39-W)	100					
7.	Tail Service Masts at Launch Complex 39	84	16				

Note: (1) May not sum to 100 because of rounding.

EXHIBIT 4 (Continued)

C. Systems

	Component	Failure Cause (Percent)[1] Normal Service	Design Problem	Quality Problem	Operational Problem	Preventive Maintenance	Other
1.	RF Instrumentation	75	10	15			
2.	Television (OTV) System	96	2	1	1		
3.	Water System	40	40	7	6		6

Note: (1) May not sum to 100 because of rounding.

Briefly, normal service denotes a failure for which there is no obvious cause, design problem denotes a failure which could have been prevented or can be corrected by either changing the design of the component itself or of the system of which it is a part, quality problem usually denotes a manufacturing defect, operational problem implies abuse on the part of operations or maintenance personnel, and preventive maintenance indicates a repair action induced by the recognition of an incipient failure. A final category of "other" is reserved for those failures which are not readily forced into one of the other categories. More specific information on these failures can be had by consulting the RAC.

C. Failure Modes

Exhibit 5 is an array of the failure modes for the various components which were assessed. Very little compaction of the failure mode categories has been attempted since the space saved by compaction is trivial in comparison with the information lost. Additional information and more detailed breakouts of failure modes are, however, sometimes contained in the RACs.

D. Repair Time Statistics

Exhibit 6 briefly summarizes all data with respect to repair time that is contained in the RACs. The RACs often contain an empirical distribution of repair time versus frequency which might be more desirable in some cases. The median repair time, for example, is easily determined from these curves and due to their skewed nature may be more representative of typical repair times than the mean given here. The number of repair time observations is given as a rough indication of the reliability of the other statistics.

EXHIBIT 5 - BASELINE FAILURE MODES FOR JOHN F. KENNEDY SPACE CENTER GROUND SUPPORT EQUIPMENT

A. Piece Parts

Failure Mode (Percent)(1)	Batteries	Cable Assemblies, Electrical	Cable Assemblies, Mechanical	Capacitors	Circuit Breakers	Connectors	Pressure Switches	Regulators, Composite	Relays	Solenoid Valves
Broken		9	27							
Cable Problem	15									
Component Part Problem										6
Configurational Problem										9
Connection Problem		16			6	27				
Construction Problem					9					
Contact Problem									7	
Corrosion					7					
Corrosion, Contamination								2		10
Damaged Cable		16	27							
Damaged Connector						30				
Damaged Pins						23				
Defective Insulation		21								
Electrical Problem										33
Erratic, Intermittent							9			
Everything Else								23		
Fails to Operate							13			
Foreign Material								7		
Improper Actuation										9
Improper Response					23					
Incorrect Regulation								6		
Inoperative					5	12				
Leakage				14				28		33
No Output									8	
No Regulation								4		
Open Circuit				6	4					
Operational Problem									69	
Oscillating									3	
Other	33	18	46	12	6	12	15		10	1
Out of Tolerance							35			
Past Problem	11									
Physically Damaged				20						
Pressure Not Maintained								18		
Removed for Preventive Maintenance								13		
Short Circuit		20		7	14				4	
Unknown-Unsatisfactory Condition or Operation				41	21		15			
Wearout	41									
Wiring Problem					5					
Won't Deactivate							14			

(1) May not sum to 100 because of rounding.

EXHIBIT 5 (Continued)

B. Subsystems

Failure Mode (Percent)[1]	Amplifiers	Compressors	Pump Assemblies	RF Carrier Demodulator (DSC-39-W)	RF Carrier Modulator (MSC-39-W)	RF Line Repeater Amplifier (ASC-39-W)	Tail Service Mast at Launch Complex 39
Alignment, Adjustment					1	14	
Bearing Problem			9				
Component Part Problem		18		16	16		88
Corrosion, Contamination		9	10				
Cracked or Broken Parts		19	17				
Defective or Worn Parts		13	15				
Design Deficiency		9	9				
Design Modification, Overhaul				3	14		
Electrical Problems		5	9				
Incorrect Gain	9						
Incorrect Output	10			18	40	54	
Inoperative	6	13	6	4		23	
Intermittent Output	3			3	2		
Leakage		6					
Mechanical Problem				1			
Noisy	15			19	8		
No Output	20			12	2	5	
Not to Specification		4					
Operational Problem	22						
Other	10	5	7	5	6	4	12
Seal Problem			18				
Sync; Frequency Response				21	11		
Unknown-Unsatisfactory Condition or Operation	5						

(1) May not sum to 100 because of rounding.

EXHIBIT 5 (Continued)

C. Systems

Failure Mode (Percent)[1]	RF Instrumentation	Television (OTV) System	Water System
Adjustment Problem			2
Blast Damage		1	
Camera Remote Control		2	
Component Failure	5	6	26
Corrosion, Contamination			14
Design Deficiency	5		16
Design, Modification, Overhaul		3	
False Indication			1
Focus, Distorted Output		6	
Incorrect Output	13	11	
Inoperative	13	8	
Installation Error			6
Intermittent	18	3	
Leakage			16
Mechanical Problem	15	4	
Noisy		8	
Noisy, Distorted	10		
No Output	13	16	
No Video, Poor Video		7	
Open Circuit			1
Operational Problem			8
Other		2	3
Output Incorrect			2
Short Circuit	8	4	2
Sync; Frequency Response		6	
Support Failure			1
Tolerance			1
Video, Horizontal or Vertical		7	

(1) May not sum to 100 because of rounding.

EXHIBIT 6 - REPAIR TIME DATA FOR JOHN F. KENNEDY SPACE CENTER GROUND SUPPORT EQUIPMENT

Component	Repair Time (Hours)			Number of Observations
	Minimum	Mean	Maximum	
A. Piece Parts				
Batteries	0	1.5	6	12
Cable Assemblies				
Electrical	0	3.0	106	210
Mechanical	4.0	8.0	14	3
Capacitors				
In TV Functional System	0.08	14.0	700	202
All Other Locations	0.05	4.3	77	203
Circuit Breakers	0.02	5.5	120	77
Connectors	0	3.3	36	100
Pressure Switches	0.33	6.7	50	36
Relays	0.12	4.5	96	143
Solenoid Valves	0.33	4.0	36	65
B. Subsystems				
Amplifiers				
Composite	0.03	2.6	170	1,896
In Functional System:				
Television	0.05	6.1	50	532
OIS-RF	0.07	0.52	9.0	529
OIS-Audio	0.10	1.6	16	446
Data Transmission	0.03	0.48	2.5	154
Measuring	0.08	0.10	0.82	43
Range Instrumentation	0.08	4.3	170	98
PA and Paging	0.25	6.8	39	81
Telemetry	0.17	0.47	0.60	13
Compressors	1.0	48	264	21
Holddown Arms	1.0	22.3	100	7

EXHIBIT 6 (Continued)

Component	Repair Time (Hours)			Number of Observations
	Minimum	Mean	Maximum	
Pump Assemblies	1.0	7.7	24	12
RF Carrier Demodulator (DSC-39-W)	0.17	5.9	17	113
RF Carrier Modulator (MSC-39-W)	0.33	4.1	16	169
RF Line Repeater Amplifier (ASC-39-W)	0.50	3.5	12	21
C. Systems				
RF Instrumentation	0.17	3.7	32	27
Television (OTV) System				
At Launch Complex 39	0.067	6.6	120	976
At Launch Complex 37	0.083	11	430	257
At Launch Complex 34	0.10	12	500	357
At Other Locations	0.083	10	580	341

IV. ADDITIONAL UCR DATA

Exhibits 7, 8, and 9 exactly parallel Exhibits 2, 4, and 5 of the previous section. The only difference is that these exhibits reflect data from UCRs written subsequent to 15 October 1969; i.e., under the new UCR system. The new system generally contains relatively few UCRs for any component. For this reason, and perhaps for others, results from the two systems often differ significantly. The results from the new system are presented for whatever influence they might have on the baseline data; they are presented separately to form the nucleus for an improved and dynamic data base which will eventually supplant that of Section III entirely.

These data should be periodically updated and if done so frequently enough would provide a ready means to monitor the field reliability of any components of interest. Updating procedures and formats, however, do not form a part of this issue of the handbook.

Due to the sparsity of data from the new system available as inputs to this issue of the handbook there are no entries for many of the components listed in Section III. There are no repair time data whatever since no provision is made for its collection in the new UCR system.

EXHIBIT 7 - ADDITIONAL FIELD FAILURE RATES FOR JOHN F. KENNEDY SPACE CENTER GROUND SUPPORT EQUIPMENT

	Component	FFR(1)	Confidence Factor(2)
A.	Piece Parts		
	Circuit Breakers	1.07	15
	Connectors	1.98	6
	Relays	0.42	10
B.	Subsystems		
	Tail Service Masts (Composite)	0.112	12
	TSMs in Support of Launch AS 507	0.417	3
	TSMs in Support of Launch AS 508	0.247	4
	TSMs in Support of Launch AS 509	0.150	4
C.	Systems		
	Water System	2.80	32

Notes: (1) Field failure rate (FFR) is given in failures per unit per 1,000 hours.
(2) Number of failures upon which the FFR is based. To convert to a statistical 90-percent confidence interval see the text (Section III. A) and Exhibit 3.

EXHIBIT 8 - ADDITIONAL FAILURE CAUSES FOR JOHN F. KENNEDY SPACE CENTER GROUND SUPPORT EQUIPMENT

Component	Failure Cause (Percent)[1]				
	Normal Service	Design Problem	Quality Problem	Operational Problem	Other
A. Piece Parts					
Relays	92	2	6		
B. Subsystems					
Tail Service Masts (Composite)	100				
C. Systems					
Water System	56	34	3	3	3

Note: (1) Totals may not add to 100 percent due to rounding.

EXHIBIT 9 - ADDITIONAL FAILURE MODES FOR JOHN F. KENNEDY SPACE CENTER GROUND SUPPORT EQUIPMENT COMPONENTS

A. Piece Parts

Failure Modes (Percent)[1]	Relays	
Contact Problem	4	
Operational Problem	57	
Oscillating	4	
Other	19	
Short Circuit	15	

Note: (1) Totals may not add to 100 percent due to rounding.

EXHIBIT 9 (Continued)

B. Subsystems

Failure Modes (Percent)[1]	Tail Service Masts (Composite)	
Component Part Problem	100	

Note: (1) Totals may not add to 100 percent due to rounding.

EXHIBIT 9 (Continued)

C. Systems

Failure Modes (Percent)[1]	Water System	
Adjustment Problem	6	
Corrosion, Contamination	9	
Design Deficiency	25	
False Indication	6	
Internal Component Failure	22	
Leakage	6	
Operational Problem	22	
Tolerance Problem	3	

Note: (1) Totals may not add to 100 percent due to rounding.

V. SUPPLEMENTARY DATA

It is recognized that the data of the preceding two sections is only a beginning effort in the compilation of needed data in various reliability engineering efforts at KSC. Even so it is strongly recommended that the data herein be used in lieu of that from any other source if there are, in fact, data available and perusal of the associated RAC indicates that it is relevant.

However, when such is not the case as will be true for the indefinite future for many components, recourse must be had to another source. It is the intent of this section to offer some guidelines and suggestions with respect to the utilization of such sources and for recording the results of such utilization.

A primary source of reliability data such as that provided by the UCR system should be handled in a manner entirely analogous to that provided by the RACs. Secondary sources such as MIL-HDBK-217A should be used in accordance with their instructions; particular care should be given to selecting a rate that is appropriate for the intended application. Multiple sources should be consulted and the results compared with each other. When a best rate from all available secondary sources is isolated it may be further modified to bring it more in line with the general ratio of failure rates in the chosen source and this handbook. If, for example, the FFRs for piece parts of Section III are always about three times higher than failure rates from the selected source it may be desirable to increase the best secondary source failure rate estimate by a factor of three prior to use.

In any event the entire process should be very carefully documented and submitted to Code DD-SED-21 for incorporation in subsequent issues of this handbook. The failure rate and source (or sources) must be identified together with the values of <u>all</u> parameters needed to pinpoint the failure rate such as part type, temperature, electrical stress, application environment K-factor, etc. If not obvious the reason for selecting each deciding parameter should also be included. The end item (functional system, launch complex, etc.) into which the unit, for which the failure rate is needed, is, or is being, installed should also be identified. An indication of the analyst's confidence in the accuracy of the result either quantitative or qualitative would also be very helpful to those using these results in the future. It is intended that these results be compiled in a table similar to the following:

Component	Failure Rate (Failures/hour)	Utilization	Reference
C_1	λ_1	U_1	R_1
C_2	λ_2	U_2	R_2
⋮	⋮	⋮	⋮
Integrated Circuit	12×10^{-6}	Amplifiers in the OTV at Launch Complex 39	k
⋮	⋮	⋮	⋮
C_n	λ_n	U_n	R_n

Component will have the same meaning as used in Section II. The failure rate will no longer have the connotation of field failure rate in the sense that it is derived from field data, it should however be applicable to field (or intended) utilization. The utilization will briefly describe the higher level equipment of which the component is to be a part. The reference is to a paragraph or subsection of this report which explains how, in detail, the failure rate was derived.

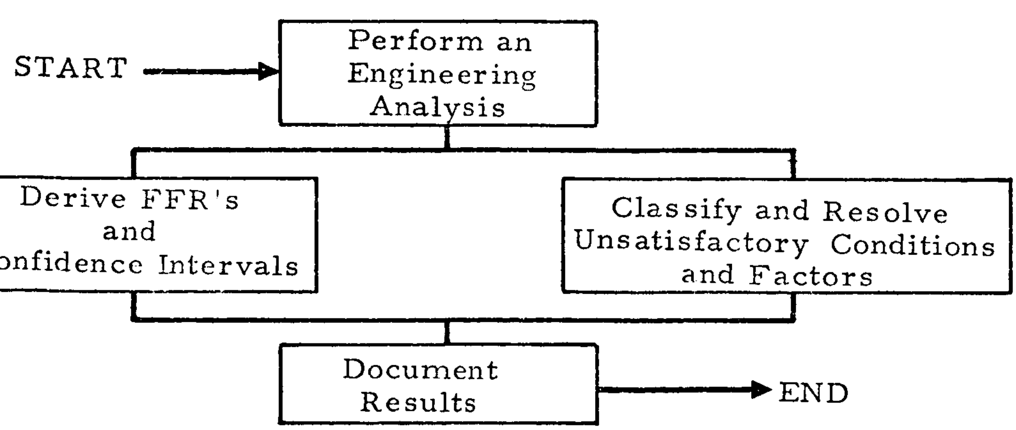
VI. METHODOLOGY FOR THE RELIABILITY ASSESSMENT OF COMPONENTS

A. General

A simplified flow diagram of the methodology is shown in Exhibit 10. The indicated approach is quite general and logical, even though the implementation of each step is rather open to interpretation. In extremely simplified terms, one selects a component to analyze, gathers the pertinent data, examines the data for its relevance and most prominent characteristics, and then selects from the data base those elements which permit the calculation of field failure rates (FFRs) including confidence statements and/or factors that influence the magnitude of the FFRs. Documenting the process ends the methodology application.

Although the flow diagram of Exhibit 10 is felt to be quite indicative of the developed methodology, it may appear to give more emphasis to the calculation of field failure rates (FFRs) and less emphasis to the classification of failures and resolution of FFR factors than is proper due simply to the greater number of blocks associated with the FFR calculations.

A better understanding of the overall process and the relative weights of the individual elements might be obtained by considering the following highly simplified flow chart.



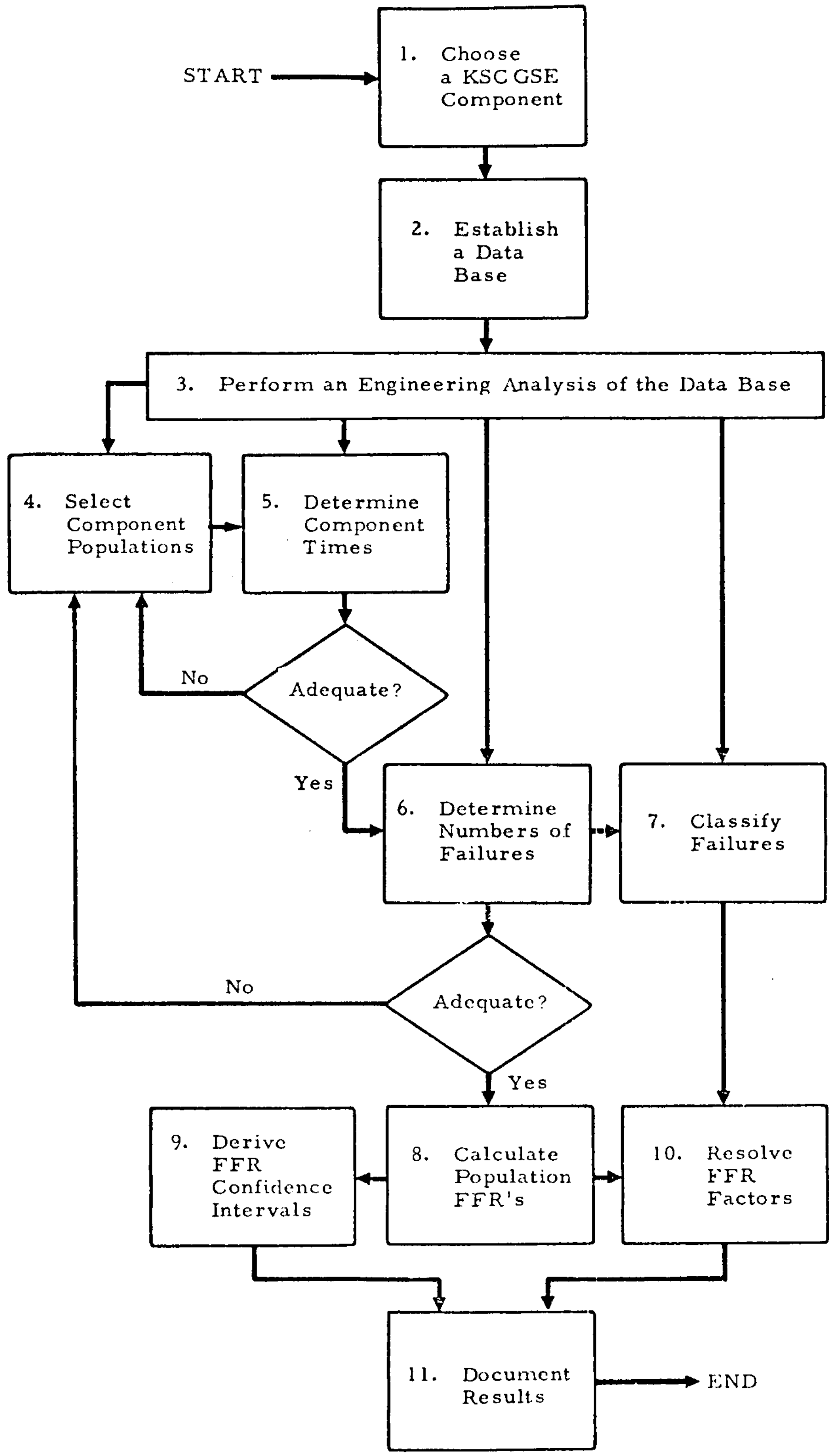


EXHIBIT 10 - METHODOLOGY FOR ASSESSING COMPONENT RELIABILITY

The grist for the methodology mill is provided solely by the UCR (Unsatisfactory Condition Report) system. There are, currently, two UCR systems: an old one and a new one. The new system was installed on 15 October 1969 and completely supersedes the old system which was in effect prior to that date. The two systems are not entirely commensurate. It is therefore recommended that data from the two systems not be combined into a single data base. Rather, separate applications of the methodology should be considered for each component of interest, one using all the data from the old system, the other using a current retrieval of data from the new system.

A highly useful adjunct to the UCR is the ICAR (Investigation and Corrective Action Report). While not strictly necessary, data from the ICAR often clarify the information carried on the UCR. Furthermore, the ICAR bears the same report number as the UCR, thus somewhat facilitating its retrieval in the old system, even though they are stored in a separate file. In the new system the ICAR's are stored and printed out with the corresponding UCR.

No system configuration or other descriptive hardware data are necessary for application of the methodology. Such data could, however, greatly enhance the reliability assessment of components. Even where such data are only partially available for a given component it might be profitably utilized in the assessment. Thus, although the methodology contains no explicit steps for incorporating the total number of a given component installed at the Cape or component categorization by performance characteristics (i.e., pressure ranges of regulators, etc.), these data should be considered in the assessment to the extent possible when they are available.

The critical outputs of the methodology are (1) field failure rate estimates, (2) an indication of the credibility and variability of the estimates, and (3) a delineation of the proportional contribution of each influencing factor on the component field failure rate. The quality of the results will vary directly with the quantity of data available and with the diligence and creativity used to apply the methodology.

The methodology permits, in fact requires, that a rather high degree of engineering knowhow be exhibited by the person who performs the reliability assessment. However, it has been shown by past experience that the exercise of personal judgment at the expense of any of the steps indicated in Exhibit 10 is highly detrimental to the end results of the methodology. Steps may be added but should not be taken away. Since each contributes a necessary facet to the overall assessment.

The basic steps in the methodology and their implementation are discussed at length in the following subsections. Each block of Exhibit 10 is discussed in a separate subsection, and one additional subsection covers the treatment of repair time data. Repair time is not an integral part of the component reliability assessment, but is an interesting addition to it. The reliability assessment of a component (RAC) is primarily a treatment of UCR data to establish a field failure rate (or rates) and to discover the factors which influence the magnitude of the component failure rate(s).

B. Definitions

This section is included to clarify the meaning of often used terms in the application of the methodology.

1. Component. A matrix of parts, assemblies, or subassemblies, typically self-contained, that functions in a defined manner relative to the overall equipment operation. This definition has been interpreted to include everything from piece-parts (e.g., capacitors) to functional systems (e.g., holddown arms).
2. Component Field Failure. The inability of a component to perform its defined function regardless of cause.
3. Component Time. The accumulated time of the component from date of installation (DOI) to date of failure (DOF) regardless of operational status during the period, e.g., for a given component the DOI = 12-31-66 and DOF = 3-7-67; therefore, the component time is 66 days or 1,584 hours. Since DOI is rarely known it is either estimated as the date

of first failure for large components with multiple failures or is ignored completely and component time derived by adding the age (or time) entries from the available sample of UCRs for a given component population.

4. Component Population. The complete inventory of components installed for operation that are structurally and functionally alike and stressed in a similar manner.

5. Confidence Factor (CF). The probability that the FFR of any given component is within acceptable engineering limits.

6. Confidence Interval. A confidence interval is calculated for each estimated FFR. This interval is defined on the range of the failure rate and is mathematically derived such that the probability is 90 percent that the "true" but unknown FFR is bounded by the interval.

7. Field Failure Rate (FFR). The ratio of the number of component field failures to their total component time for any given component population.

8. GSE. That equipment which can be classified into one of the following:

   a. Active GSE. That equipment which is a part of the vehicle system or interfaces with the vehicle system and is actively utilized during operations and/or testing, e.g., swing arms, service equipment, and test equipment.

   b. Passive GSE. That equipment which supports the launch vehicle system but is inactive during preflight operation and/or testing, e.g., flame deflector and some checkout and monitoring equipment.

   c. Support GSE. That equipment which is not directly connected to the vehicle but is essential to launch operations, e.g., launch complex communications, nondata type television, range-type instrumentation, and service structure.

9. Mean Time Between Failure. (MTBF). MTBF is another measure of failure frequency and is essentially the reciprocal of FFR. MTBF is primarily used in the reliability assessment of KSC GSE components to indicate the mean time between failures of the same component.

10. Mean Time to Failure (MTTF). This measure is highly similar to MTBF and is sometimes used interchangeably. It is more appropriate to use MTTF to indicate the mean of a sample of individual times to failure which are not all recorded against the same individual component.

11. Mean Time to Repair (MTTR). This statistic is often reported on the summary sheet of the previously assessed components and usually represents the mean value of a number of independent estimates of total downtime for a given component population. Since, however, the UCRs from the old system report both time to repair and time to locate the context of the individual assessment should make the meaning clear.

12. Problem Classification. Through considerable use the following classification of problems as reported on the UCRs has been found quite useful. The five categories do not overlap and taken together they cover all UCRs.

    a. Design Problem. A fault which is inherent in and can be corrected by the component design.

    b. Normal Service. In this category are placed all those unsatisfactory conditions that arise as a result of normal field operation or for which insufficient information is available to assign it to any of the other categories.

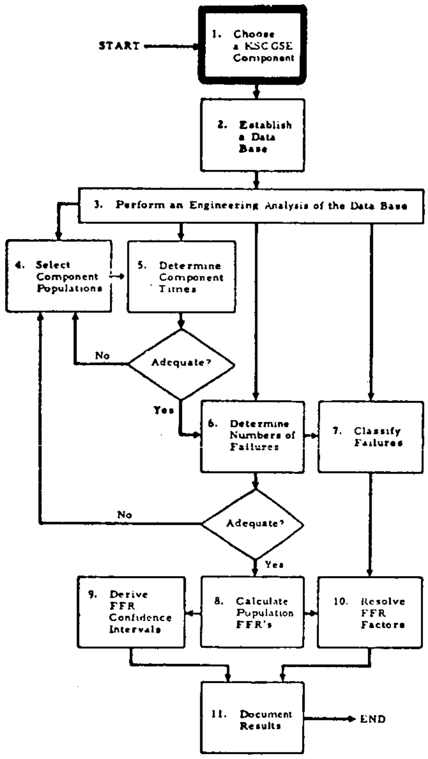
    c. Operational Problem. UCRs in this category imply that the unsatisfactory condition was caused or exacerbated by the misuse of the component on the part of operating or maintenance personnel.

    d. Preventive Maintenance. UCRs are placed in this category if they report conditions that are not currently unsatisfactory in any operational sense but could become so in the future.

e. Quality Problem. Implies a fault that is neither inherent in the design nor the result of normal (or abnormal) operation. It is often a manufacturing defect.

C. Step-By-Step Procedures

1. Choose a KSC GSE Component



The selection of a component or component type is probably the least difficult step in the methodology. Some care must be exercised, however, in component definition. Especially to be avoided are vague and overly general definitions, such as "valves" when the real interest is restricted to solenoid valves, or "tail service masts" when only those masts at launch complex 39 are of direct concern.

In choosing a component it is necessary to provide descriptors which are sufficiently detailed to distinguish the component from all other GSE, but which are not so precise that they exclude elements intended to be covered by the definition.

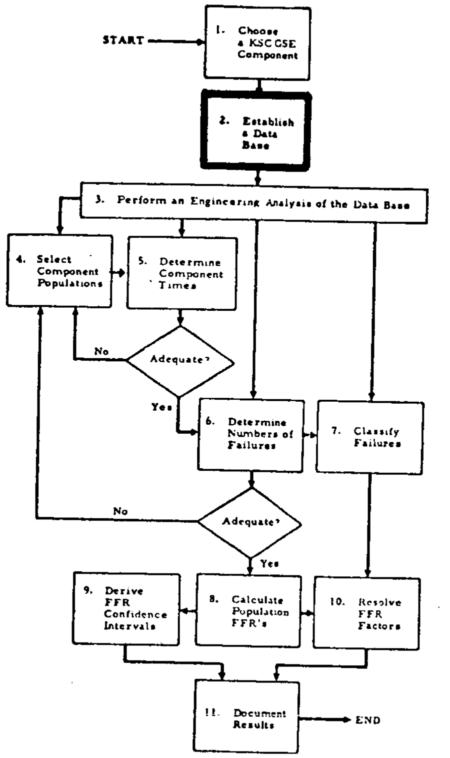
Wherever possible, the component definition should be one which can be easily expressed in terms that conform to elements of the UCR data bank. Obvious examples are those coded as major items or functional systems. Solenoid valves are coded as major item 786 in the old UCR system and tail service masts are reported under functional systems 750, 751, and 752 in the new UCR system.

An initial selection is often provided by a particular interest in a conjectured problem area. It often occurs, however, that study of the resultant data base indicates a component description either more or less restrictive than originally anticipated. In this case, either the data base or the original component description must be modified. For example, in the component "cable assemblies" previously assessed by PRC it was originally anticipated that these would be of the electrical variety only; however, the data base included a number of UCR's applicable to strictly mechanical cable assemblies which, since time and failure data were available, were carried under a broadened definition of this component.

The output of this step in the methodology is generally a simple descriptive paragraph. Typical is the following one for tail service masts at launch complex 39:

> "The tail service masts found at launch complex 39 are affixed, in sets of three, to the mobile launchers. Their function is to support service lines to the S-IC stage and to provide a means for rapid retraction of the service lines from the S-IC stage during vehicle lift-off. The location and specific function of each of the tail service masts is as follows: TSM 1-2 (fuel line service and inert pre-fill), TSM 3-2 (environmental air conditioning service), and TSM 3-4 (liquid oxygen emergency drain). The KSC part numbers for these three items are, respectively, 75M11776, 75M11775, and 75M11774."

2. Establish a Data Base



For each component selected, the pertinent data base will necessarily consist of two parts: (1) the complete printout of all UCRs written against the component in the old system, and (2) similar data generated under the new system. The first part will contain all pertinent UCRs written prior to 15 October 1969 whereas the second part will contain the subsequent UCRs that have been entered in the system as of the date of the computer retrieval. These data bases are established by assembling computer printouts of each UCR written against the chosen component. Two retrievals must be made; one from the old system and one from the new system.

In both cases the retrieval process is relatively straightforward but some care must be taken to assure that all the applicable UCRs are retrieved and that the number of irrelevant UCRs are kept to a minimum. To retrieve solenoid valve UCRs it is only necessary to request all UCRs written against major item 786 in the old system and major item 319 in the new system. For tail service masts at launch complex 39 the retrieval from the old system is against the next assembly part number for the three tail service masts. In the new system the retrieval is made against the three functional system numbers 750, 751, and 752. From this retrieval all UCRs not from launch complex 39 must be rejected either by excluding them from the retrieval process or manually sorting them out afterwards.

At this point it is necessary to further refine the computer printout, to eliminate UCRs with obvious coding errors, to reconcile inconsistencies in internal coding and to assess the completeness of the data run. If it is obvious that some pertinent UCRs have inadvertently been omitted, they should be requested and incorporated in the data base in a manner similar to that outlined above. At this point the analytical portion of the methodology may begin.

This can be a very tedious step in the methodology because of the necessity for dealing with often great quantities of data before any simplifying procedures can be determined to ease the task. As a result, it is tempting to reject huge blocks or categories of UCRs as not being relevant to the reliability assessment of the component under consideration. It is, however, a poor UCR indeed that carries no information and, if a large number of such UCRs occur for a given component, that fact itself may have strong reliability implications. Therefore, it is strongly urged that UCRs be eliminated from the data base only on the grounds that they do not fit the component description or that they are complete duplications of other UCRs included in the data base.

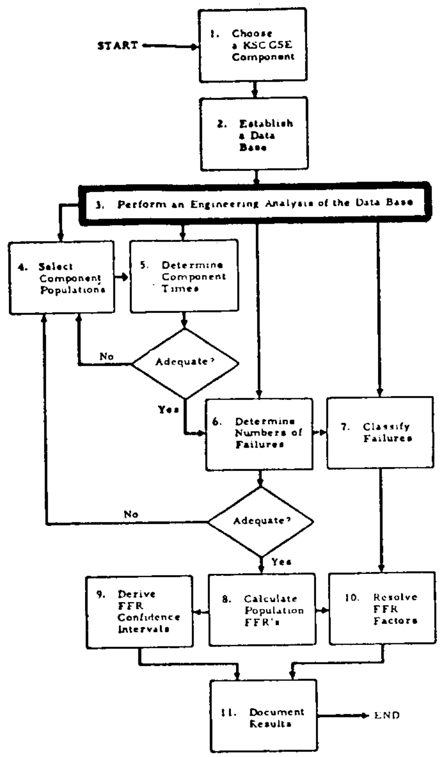
This step in the methodology results in a number of UCRs (and perhaps ICAR's, etc.) to be used in the assessment. The number of UCRs, the date of the most recent data retrieval and a judgment as to the adequacy of the coverage provided should be indicated in the final documentation of this step. The data base documentation for tail service masts for the Phase II study period[1] is quoted in full as follows:

> "The tail service mast data base consists of approximately 150 unsatisfactory condition reports and were collected by retrieving on the appropriate next assembly part numbers from the computerized data bank. A number of retrievals

[1]The complete report is the first citation in the bibliography of subsection VI.D.

were made, the most recent being on 16 June 1969. In addition, xerox copies of all TSM UCRs in the data file were made in late September 1969. Selected ICAR's were also collected at that time. Finally, some TSM UCRs were located by means of the reference report entry on the earlier UCR runs and these were requested specifically by UCR number. This data base is, therefore, considered to be quite complete, at least through early 1969."

3. Perform an Engineering Analysis of the Data Base



As can be seen from Exhibit 10, this step in the methodology is extremely important to all subsequent steps. Typical activities in the engineering analysis are difficult to specify precisely. The crux of this step is familiarization with the data base and its peculiarities. The end result should be a reasonably adequate historical profile of the component as revealed on the UCRs together with whatever other backup information can be brought to bear.

Particular attention is focused on determining if the data on a selected component can be divided into meaningful subsets. For example, solenoid valves may be divided according to the fluid controlled by them, or the specific location on the mobile launches of the tail service masts may be useful as a subset criteria.

The time period represented by the data base and selected subsets thereof is a second area of prime concern. The dates of the first and last UCRs in each data subset should be noted as well as their relative occurrence rate or density. Correlation of UCR occurrence with launch date is sometimes instructive. Extended periods of abnormally high or low UCR occurrence rates should be noted.

The unsatisfactory conditions reported in the data base (particularly in the narrative section of the UCRs) should first be carefully examined to establish the degree of credibility that can be placed in the data base. This may vary with component type, launch complex, and so forth. The data base for tail service masts might well have a higher degree of credibility than that for solenoid valves simply because the former population is much better defined, has a known number of units, etc. The degree of credibility should be reported in the RAC.

The unsatisfactory conditions should also be examined to see if there are any obvious similarities or differences; for example, the launch complex or functional system where the UCR originated. The fact that all UCRs on a particular subsystem originated at launch complex 34 would be highly significant. The same type of failure being repeated over and over also has an important bearing on the subsequent analysis.

The corrective actions indicated should also be carefully scrutinized to see if any instituted action might have caused a significant difference in the field failure rate. Also note corrective actions suggested repetitively which have not been instituted.

In short, total familiarity with the data base in engineering terms should be achieved in this step. This will be highly useful in all the subsequent steps and is necessary to place the entire RAC in the proper perspective.

Perhaps the easiest way to begin this step in the methodology is to simply take the first UCR printout in the data base and read it in detail. Then do likewise with the second, and the third, and so on. By about the fifth or sixth UCR, certain similarities imposed by the component definition become evident. Continuing through the data base, scanning at a high rate, other similarities as well as disparities begin to appear. Finally, flipping through the entire set will tend to lend support to some of the preliminary hypotheses, destroy others, and leave others still in doubt.

Once a number of candidate hypotheses have been established, a tabulation or two on a restricted number of UCR elements can often be performed to give further insight into the preliminary hypotheses and will perhaps suggest further hypotheses to be examined, etc. The point is that although clerical level personnel can easily perform the tabulations, only an experienced investigator, by studying the UCR data base himself, can formulate fruitful hypotheses and establish efficient lines of investigation.

Also, while it is natural to focus the engineering analysis in such a way as to most readily provide the other specific requirements of the methodology, and particularly of component populations and times, the investigation should remain open to other information contained in the data base. For example, some sets of UCRs contain considerable information with respect to component repair times, a data element not specifically called for in the methodology but certainly pertinent to any complete consideration of component reliability and one that should be reported, when available.

The entire engineering analysis documentation for the Phase II assessment of tail service masts[1] is contained in Exhibit 11 and the following three paragraphs.

> "Preliminary consideration of the data base results in some interesting, and sometimes contradictory, conclusions. The UCRs indicate that there are nine individual TSMs bearing serial numbers 1001 through 1009, and that these nine TSMs are utilized for launch support in sets of three. This can be clearly seen from Exhibit 11, where each short vertical line represents one unsatisfactory condition of a particular TSM at the date indicated. Launch dates and the mobile launcher utilized are also indicated for vehicles AS 501 through AS 506. Note that the TSM serial numbers and mobile launcher assignments are not entirely consistent with the assumption of a permanent correspondence between the two.

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[1]The complete report is the first citation in the bibliography of subsection VI.D.

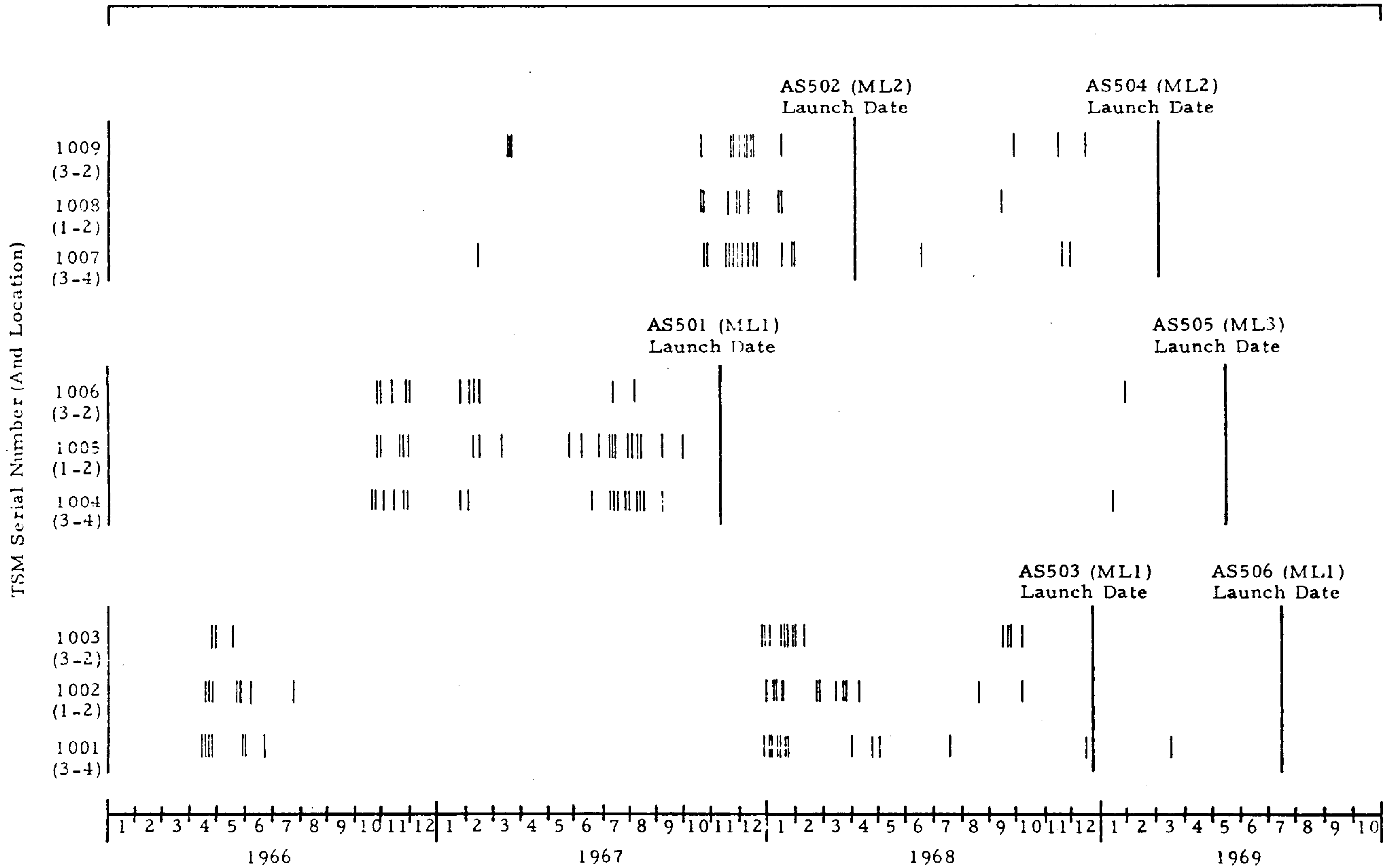
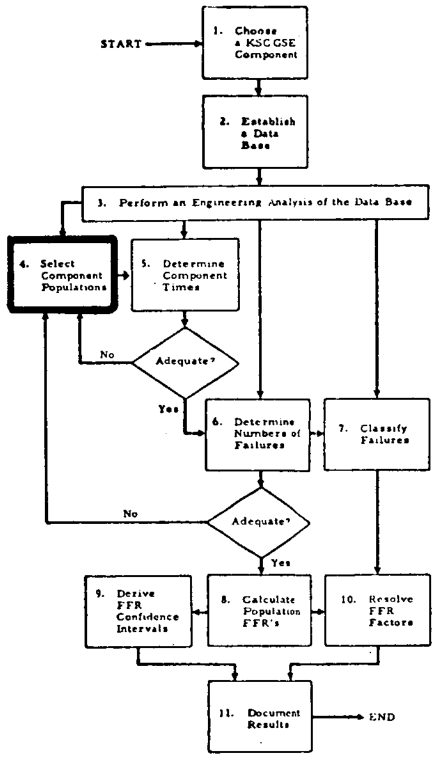


EXHIBIT 11 - TSM UNSATISFACTORY CONDITION OCCURRENCE DATES BY TSM SERIAL NUMBER

The preliminary analysis indicates quite strongly that the unsatisfactory conditions occurring prior to about April 1967 (on all TSMs) reflect an initial acceptance or checkout situation of some kind rather than an actual launch support role as is the case subsequent to that date.

In general, the UCRs are quite complete. However, they are written against a major item, that is, at a lower level than the TSM, and hence the impact of the reported condition on the TSM must be largely deduced."

4. Select Component Populations



A component population, as defined in Section III, represents the complete inventory of individual components installed for operation that are functionally and structurally alike. In order to increase the utility of the study, it is desirable to keep the component populations as specific as possible. Increasing specificity, however, sharply curtails the available UCR data for each population. From the engineering analysis, this step in the methodology selects a likely set of populations--likely, in the sense that there are a sufficient number of UCRs associated with each population to yield the requisite time and failure data upon which an estimate of FFR can be made.

As indicated in Exhibit 10, this is an iterative process, starting with the most specific set of component populations and proceeding to the more general, until the time and failure data requirements are satisfied. With solenoid valves, for example, one might attempt to group UCRs by individual part numbers which if unsuccessful might then proceed to location or medium controlled and might end up with only the single population "solenoid valves." More than one grouping of the same data is often possible and is to be encouraged as long as each is well defined. For launch complex 39 tail service masts potential populations include each individual mast (9 populations), locations on the mobile launchers (3 populations, TSM 1-2, 3-2, and 3-4), the TSMs associated with a particular mobile launcher (3 populations) or even a particular launch (the TSMs in support of AS 504, for example).

It is probably not particularly useful to report highly similar results for a multitude of populations. It is preferable to combine such data and then to simply indicate the near equality of the results for the various populations. That is, it might be possible, to give FFRs for a particular component as observed at Launch Complex 39, Launch Complex 34, and Launch Complex 37. If all the results are within a few percentage points of each other, it would be preferable to combine the data to provide one widely applicable FFR together with a statement of the observed similarity in magnitudes by launch complex.

It is strongly urged that the UCRs or copies thereof be filed by population for ease in reference and for accomplishment of the remaining steps in the methodology.

The component populations for the tail service mast analysis were defined in the Phase II study[1] this way:

> "The engineering analysis indicates that a large number of likely, or possible, tail service mast sub-populations exist. Ten of these will be treated explicitly here. Nine of them are defined as those TSMs in support of the first three Saturn V launches. The tenth consists of all TSMs."

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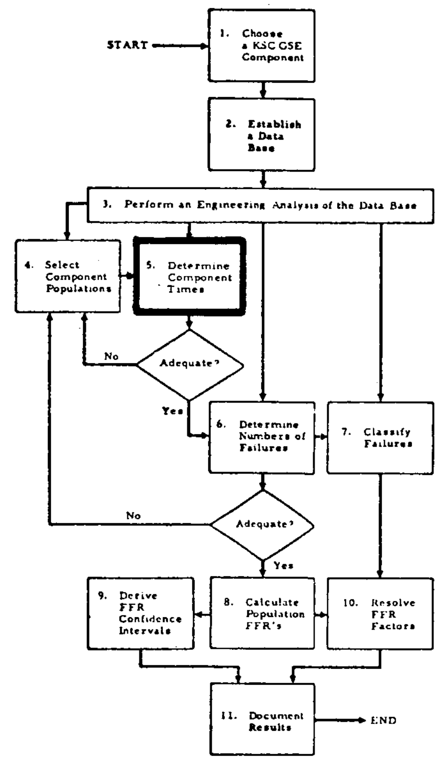
[1] The first citation in the bibliography of subsection VI.D.

5. Determine Installation Times



The determination of installation or component times is beset by two problems. First, if the component of interest is a major item there is generally no way to determine either the total number of units in the component population or the actual installation or removal dates for more than a very small subset of these units. On the other hand, if the component is a functional system or similar high-level aggregate of major items, the population is either only one unit or is known exactly (as for the three tail service masts for each mobile launcher at launch complex 39) but component times are not entered on the UCR since the UCR's are written only against major items.

To circumvent these problems, two alternate approaches to the derivation of a time base can be utilized, depending on the type of component under analysis. If the component is a major item, then the age or time entry, as given on the UCR, is interpreted to mean the installation time of the specific major item, immediately prior to the date of occurrence shown on the UCR. Component populations with four or more such entries (which are stochastically independent) are assumed to have an adequate time base to proceed with the methodology. If all the component populations defined in Step 4 are not adequate, then Steps 4 and 5 are reiterated until the populations are adequate.

If the component under consideration is not a major item, but is rather some higher level of assembly, the procedure for deriving a time base is as follows. Order the UCRs by component population and their dates of occurrence. The first such date for a component population provides a quasi-date of installation and the last, a date-of-termination; all intermediate dates, subject to the refinements of the next step, represent failure times. The same criteria for adequacy and iterative nature of the process apply the way they do in the preceding paragraph.

Component survival time information is probably the single most unreliable data element in the entire UCR system and at the same time one of the most important. Some of the more noticeable difficulties are the absence of data, the tendency of available data to cluster (6, 12, and 24 months are particularly popular) in contradiction to what would be expected from the remainder of the UCR information, and the frequent ambiguity of data in terms of what the originator of the UCR meant by the entry. In spite of these difficulties, the collection of reasonably large samples of data can overcome most of the problems. For example, three age entries at 24 months, two at 12 months, and one at 6 months, give the same mean failure time as six individual entries at 5.5 months, 10.5 months, 14 months, 20 months, 23.5 months, and 28.5 months. That is, the reported ages are assumed to be in the correct ball park and, hence, tend to balance out with large samples. The same is true of originator errors or biases; given enough originators the biases tend to average out.

Thus, while every effort should be made to get as large and accurate a sample of component time data as possible, it is by no means necessary to stop the analysis because of observed irregularities. These irregularities should of course be reported, but they should not become a bottleneck in the implementation of the methodology.

A considerably simplified output of the Phase II tail service mast analysis[1] of component times is summarized in the following three paragraphs:

> "There are no UCR time or age entries as such pertinent to the TSMs. From the UCR occurrence date, however, a partial time profile for each component above may be derived, much in the manner of Exhibit 11.
>
> "The component times for the nine identified populations (each of which is identical to one TSM supporting a specific launch) is derived as follows. The first UCR occurring in the group of three to which a given TSM belongs will be taken as a conservative approximation to its "date of installation." The end date is taken as the day the vehicle, which the TSM in question is supporting, is launched. Thus, the component times are 168 days for populations 1, 2, and 3; 168 days also for populations 4, 5, and 6; and 358 days for populations 7, 8, and 9.
>
> "For the tenth population, all TSMs, again the first UCR occurrence date (4/13/66) will be used as the beginning time and the launch of AS 503 will be taken as the end date, since all UCRs occurring prior to this date should be included in the data base. Only the three UCRs which occur in 1969 are thus excluded from this analysis. The time period for the overall TSM population is therefore 983 days."

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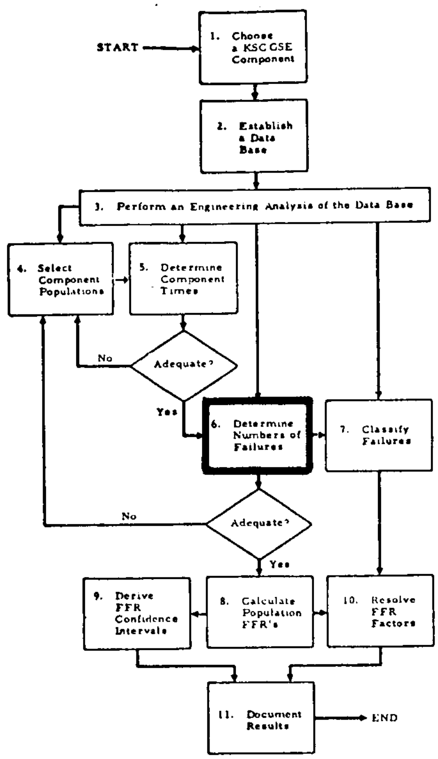
[1]The complete report is the first citation in the bibliography of subsection VI.D.

6. Determine Number of Failures



To begin this step, there are n sets of UCRs, each set representing one component population. Within each set of UCRs some specified subset contains time data. Each such UCR must now be subjected to further engineering analysis to determine first whether or not it represents a component failure as defined in subsection VI.B. In this step only two categories result--UCRs classified as failures and those classified as not failures. All doubtful cases should be assigned to the failure category. There are two reasons for this assignment: (1) without it, the resultant FFR estimates might become unjustifiably optimistic, and (2) in subsequent steps, all relevant failures will be further analyzed to reveal the factors contributing to the magnitude of the FFR. Excluded failures obviously cannot be analyzed for this purpose. Note that multiple failures are sometimes reported on one UCR.

This step of the procedure is again an iterative one. That is, if all the component populations resulting from Step 5 do not have a minimum of four failures and four associated time entries, then it is necessary to return to Step 4 and begin the process anew.

Experience with the old system has shown that nearly every UCR in fact represents a failure (or failures). Since the UCRs in the new system are screened to eliminate failures that are not design-related, each UCR should again represent a failure.

The screening process does render the two sets of UCRs incommensurate as mentioned previously.

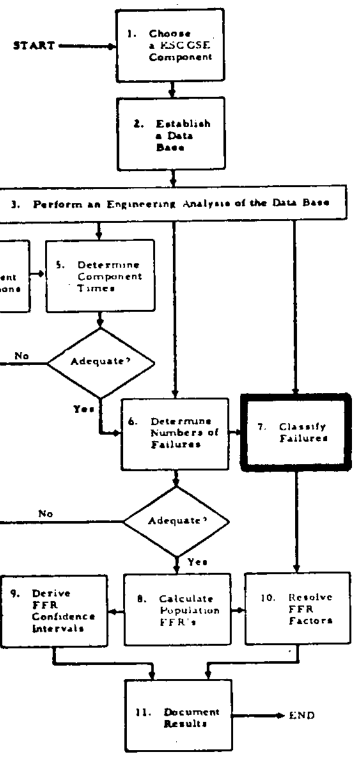
Some UCRs do not represent failures of the component under consideration but rather a failure at some higher equipment level. If there are many such failures they should be treated separately in the component analysis; otherwise, they may simply be deferred to a higher level reliability assessment. The cable assemblies assessment previously completed by PRC is an example of component UCRs reporting many failures at a higher level.

The results of this step for the tail service mast analysis previously alluded to were reported as follows:

> "Each entry of Exhibit 11 represents one TSM failure. In the course of the engineering analysis those UCR's which were judged not to represent a TSM failure (under the most stringent interpretation) were eliminated from the data base; multiple failures represented on a single UCR were separated in the construction of the previously mentioned exhibit. The number of failures for each of the ten populations is as follows:

Population	1	2	3	4	5	6	7	8	9	10
Number of Failures	11	13	2	15	7	9	13	15	13	160 "

7. Classify Failures



Although those UCRs for which component times are available are of particular interest, there is a large amount of data on all the UCR's--each of which represents a failure of some kind--whether or not any time information is available. To extract this information is the object of this step in the methodology. Accomplishment of this step occurs through the continuation and refinement of the engineering analysis discussed in Step 3 above, but is focused on the failure or unsatisfactory condition itself.

Of particular interest are the failure modes and causes. One way to approach the whole problem of classification is to examine each UCR carefully (particularly the narrative section) and answer the following three questions with no more than a short phrase devoted to each answer.

- What happened?
- Why?
- Who is to blame?

The detailed tabulation in Exhibit 12 (devoted to pressure switches) is a good example of the results of applying this procedure. The operating modes answer the first question with typical responses being "out of tolerance," "won't deactivate," etc. The condition modes answer the second question with typical responses of "normal wear," "corroded pressure switch," "installed wrong," etc. The column headings "Design," "Quality Control," etc., try to assign the blame in the sense that any corrective action to be taken would be the responsibility of that group.

There are, however, many other ways to approach the problem of failure classification; each assessment will differ to some extent; those already completed may be used as a starting point in the classification of failures for similar components.

Failure classification, performed well, is not a trivial or routine task. Unfortunately, the usual approach, typified by the coded data elements "Failure" and "Reason" on the UCR, is to prepare a list of descriptions that are then applied to each case as it arises. The list for the UCR element "Failure" contains 190 items, but it is manifest (by comparing the selected entry to the narrative portion of the UCR) that the selected descriptor is usually totally inadequate. The inadequacy, moreover, is not removed by adding to the list. What is likely to happen is that a catch-all descriptor like "inoperative" will be applied excessively. Furthermore, thereis no completely satisfactory definition of a failure, to say nothing of failure categories (modes, mechanisms, effects, causes, etc.).

The best way to proceed is probably as suggested above or some variation thereof. That is, from each total UCR printout, but particularly the narrative section, an attempt should be made to summarize the entire incident in as few words and with the highest informational content possible. After this is done for a few UCRs patterns begin to emerge, descriptions repeat themselves, and so on.

By refining the summary descriptions and by combining similar ones, certain failure categories become clear. These are, in general,

EXHIBIT 12 - CLASSIFICATION OF PRESSURE SWITCH FAILURES BY FAILURE TYPE AND FAILURE MODE FOR TWO MODAL CLASSES[1]

		Number of UCR's					Number of Rejected SWS				
Operating Mode		Design	Quality	Operation	Normal Service	Total	Design	Quality	Operation	Normal Service	Total
Out of Tolerance	#	8	8	0	17-2/3	33-2/3	35	9	0	23	67
	%	6.7	6.7	--	14.7	28.0	18.0	4.6	--	11.9	34.6
Won't Deactivate	#	3	0	0	18	21	7	0	0	19	26
	%	2.5	--	--	15.0	17.6	3.6	--	--	9.8	13.5
Fails to Operate	#	1	4-1/3	0	15	20-1/3	1	8	0	16	25
	%	0.8	3.6	--	12.5	16.9	0.5	4.1	--	8.2	12.8
Erratic/Intermittent	#	0	5	0	12	17	0	5	0	1[illegible]	18
	%	--	4.2	--	10.0	14.2	--	2.6	--	6.7	9.3
Other/Unknown	#	10	8	3	7	28	38	9	4	7	58
	%	8.3	6.7	2.5	5.8	23.3	19.6	4.6	2.1	3.6	29.8
Total	#	22	25-1/3	3	69-2/3	120	81	31	4	78	194
	%	18.3	21.1	2.5	58.1	100	41.8	16.0	2.1	40.2	100
Condition Mode											
Corroded	#	6	3	0	9	18	9	6	0	9	24
	%	5.0	2.5	--	7.5	15.0	4.6	3.1	--	4.6	12.4
Cracked/Broken	#	3	5	2	8	18	24	6	2	8	40
	%	2.5	4.2	1.7	6.7	15.0	12.4	3.1	1.0	4.1	20.6
Wrong Switch for Requirement	#	8	1	0	0	9	39	2	0	0	41
	%	6.7	0.8	--	--	7.5	20.1	1.0	--	--	21.1
Switch Assembly Wrong	#	1	7-1/3	0	0	8-1/3	2	8	0	0	10
	%	0.8	6.1	--	--	6.9	1.0	4.1	--	--	5.2
Normal Wear	#	0	0	0	2	2	0	0	0	2	2
	%	--	--	--	1.7	1.7	--	--	--	1.0	1.0
Installed Wrong	#	0	0	1	0	1	0	0	2	0	2
	%	--	--	0.8	--	0.8	--	--	1.0	--	1.0
Other/Unknown	#	4	9	0	50-2/3	63-2/3	7	9	0	59	75
	%	3.3	7.5	--	42.2	53.[illegible]	3.6	4.6	--	30.4	38.7
Total	#	22	25-1/3	3	69-2/3	120	81	31	4	78	194
	%	18.3	21.1	2.5	58.1	100	41.8	16.0	2.1	40.2	100

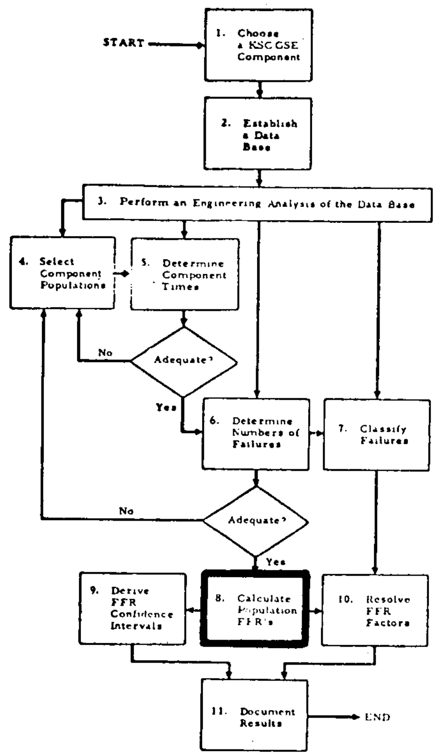
Note: (1) Percentages do not necessarily add, due to rounding error.

unique for each component assessment and should be reported in as concise and clear a manner as possible without regard to previously established categories.

While perhaps not as instructive as some other component, the results of the tail service mast failure classification were reported as follows:

> "The data base does not provide a great deal of information with which to classify TSM failures since the UCRs are written against a lower level item. In fact nearly half the TSM failures were generated by the following six part types: Regulators 75M11856, -859, and -875; Transducers 75M11857 and -13108; and Solenoid Valve 75M11936. On an overall basis, valves (of all types) contribute approximately 37 percent of the failures, regulators 26 percent, transducers 16 percent, hose assemblies 15 percent, and all other contributors 10 percent. An insignificant number of failures were attributed to the design, quality control, operation, etc., of the TSMs themselves, although the unsatisfactory condition of their constituent parts were often so classified."

8. Calculate Population Field Failure Rates



The output of Step 6 consists of a set of defined component populations together with a measure of component time and the number of failures observed for each. Because of the nature of the component time measure, there are essentially three different ways to calculate field failure rate (FFR) estimates.

If the time measured is essentially time to failure, as generally will be the case for solenoid valves and other major items, then the FFR estimate is derived as the reciprocal of the mean time to failure (MTTF). The MTTF is, of course, simply the sum of the times to failure divided by the number of such observations.

If a number of failures are observed for a particular unit, as in the case of the individual tail service masts at launch complex 39, the FFR estimate may be calculated as the reciprocal of the mean time between consecutive failures. The times between consecutive failures are obtained by subtracting the date of the first failure from that of the second, the date of the second from that of the third, etc.

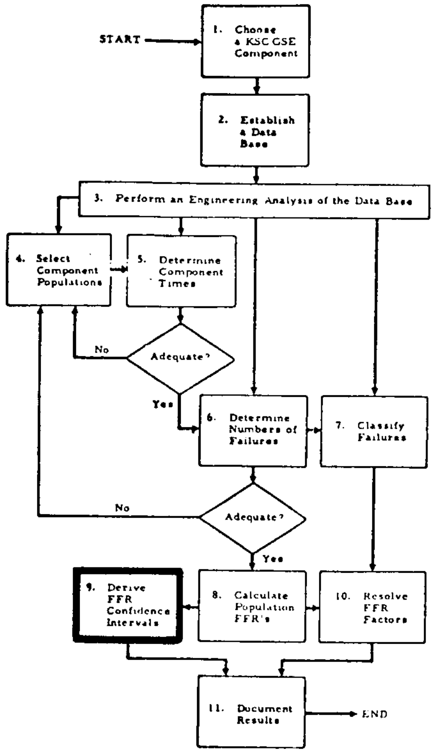
Finally, if only total installation time and total number of failures are known or can be estimated for a component population, then dividing the total number of failures by the total installation time provides an estimate of FFR. This situation is most likely to occur at the functional system level.

For tail service masts in Phase II[1] the output of the step was reported as follows:

> "The UCRs on the nine selected sub-populations are assumed to arise in the course of the normal activities associated with readying a vehicle for launch; that is, these TSMs are assumed to be in service in their designed mode of operation.
>
> The FFR is calculated as the total number of TSM failures divided by the total TSM time as derived in the preceding sections. These FFRs are:
>
> | Population | FFR (failures/1000 hours) |
> |---|---|
> | 1 | 2.73 |
> | 2 | 3.22 |
> | 3 | 0.50 |
> | 4 | 3.72 |
> | 5 | 1.74 |
> | 6 | 2.23 |
> | 7 | 1.51 |
> | 8 | 1.75 |
> | 9 | 1.51 |
>
> For the tenth, or overall, population a similar calculation is made; this rate however, includes all failures prior to 1969. The result of this calculation is a population 10 FFR of 0.75 failures per TSM per 1000 hours."

[1] Complete results are reported in the first citation of the bibliography, Subsection VI.D.

9. Derive FFR Confidence Intervals



The primary purpose of this step in the methodology is to indicate the distribution and variance of the underlying data and to derive confidence intervals for the FFR estimate. In the first two FFR estimating procedures, individual times to failure or times between failure are necessarily derived. The distribution of these random variables is found by constructing charts, such as those shown in Exhibit 13, where the percent of all observations is plotted as a function of time to, or between, failure. The variance of the data is indicated by recording the MTTF (MTBF) and the minimum and maximum observations (i. e., the range) for each population. In cases where the only available data are total time and total number of failures, this procedure cannot be followed exactly. MTBF, however, can be calculated as the reciprocal of the estimated FFR, and some individual observations may be available; thus, even though the distribution of time to failure may not be obtainable, some indication of variance usually is.

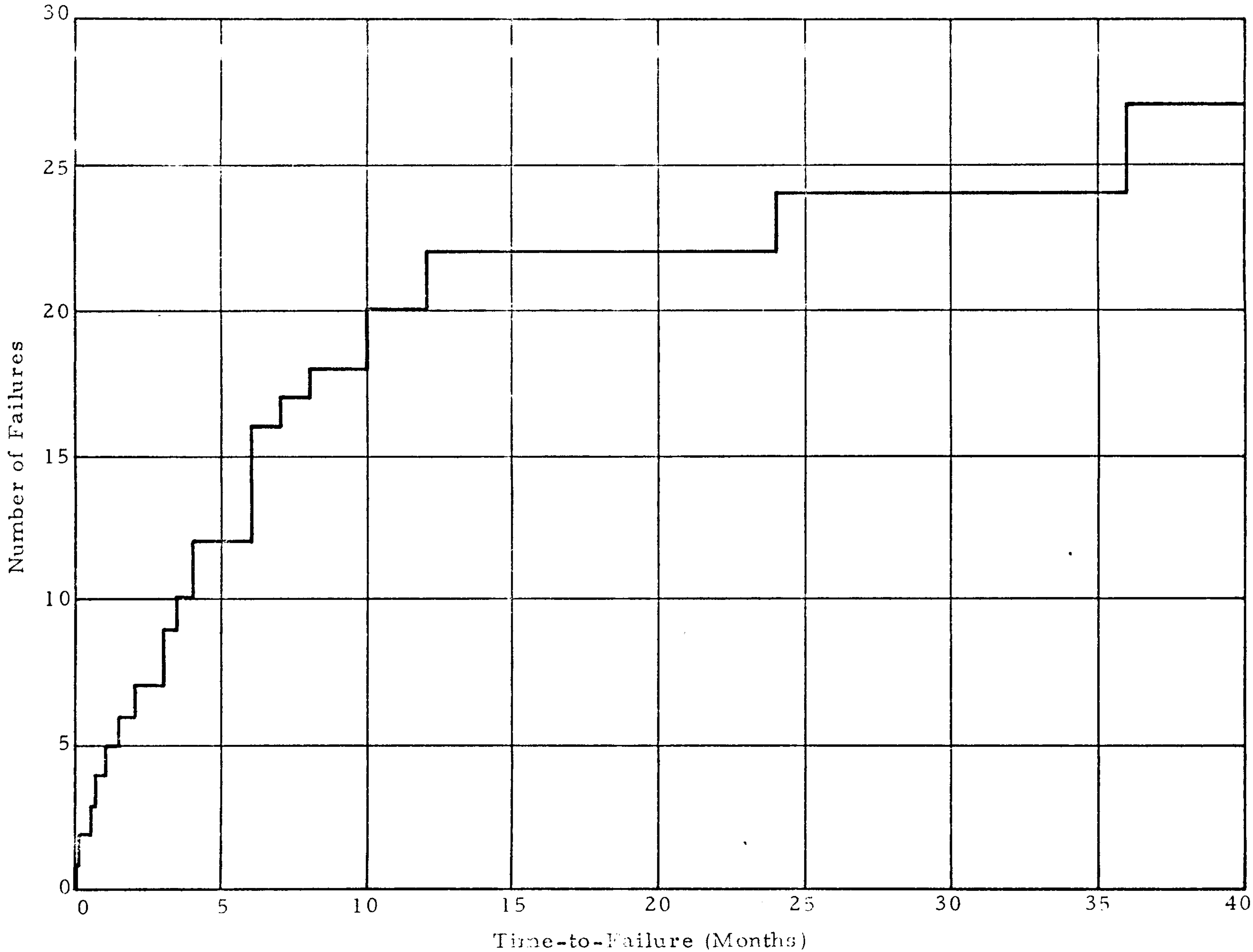


EXHIBIT 13 - CUMULATIVE DISTRIBUTION OF CONNECTOR TIMES-TO-FAILURE

For all three FFR estimates, the same procedure is used to derive confidence intervals. First, the time-to-failure data are assumed to be exponentially distributed. The total observed time, T, for each population is then derived as the sum of the time to, or between failures for each population as described above, and the total number of failures, r, pertinent to each population is determined. For the third FFR calculation approach, T and r are given directly. For the first method, r is simply the number of observations; for the second, r is one less than the number of observations because the first failure merely establishes an installation time.

The lower confidence limit, L, is then given by

$$L = \frac{X^2_{\alpha/2}(2r)}{2T}$$

and the upper confidence limit, U, by

$$U = \frac{X^2_{1-\alpha/2}(2r)}{2T}$$

where $X^2_{\alpha/2}(2r)$ is the lower $\alpha/2$ percentage point of the Chi-square distribution with 2r degrees of freedom, and $X^2_{1-\alpha/2}(2r)$ is the upper $1-\alpha/2$ percentage point. Although α may assume any value between 0 and 1, it is generally assumed to be 0.10.

For the tail service masts, results were reported as follows:

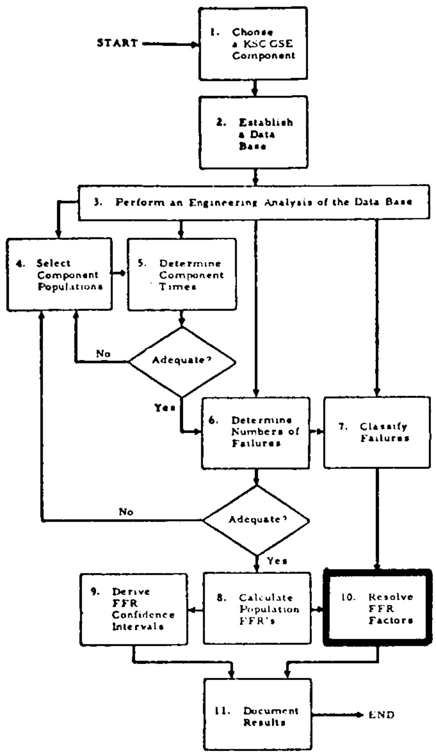
> "Assuming that the time to failure of TSMs is exponentially distributed, 90 percent confidence intervals for the estimates of population FFRs may be calculated using Equation 1.

$$\frac{X^2_{\alpha/2}(2r)}{2T} < \text{FFR} < \frac{X^2_{1-\alpha/2}(2r)}{2T} \qquad (1)$$

"These intervals are presented in the following table for each population with failure rates in units of failures per 1000 hours.

Population	Upper Confidence Limit	FFR	Lower Confidence Limit
1	4.20	2.73	1.53
2	4.83	3.22	1.91
3	1.15	0.50	0.09
4	5.44	3.72	2.30
5	2.94	1.74	0.82
6	3.58	2.23	1.16
7	2.26	1.51	0.90
8	2.55	1.75	1.08
9	2.26	1.51	0.90
10	0.86	0.75	0.66 "

10. Resolve FFR Factors



The penultimate step in the methodology is to indicate what major factors are contributing to the unreliability of the assessed component in general and to the selected component populations in particular. As in the case of failure classification, only guidelines and the sample analyses previously performed by PRC can be offered to assist in this step. The guidelines are as follows: (1) Compare the FFR estimates for the various component populations. If there appears to be no significant difference, it can be concluded that those descriptors used to distinguish the population have no bearing on the magnitude of the FFR. If there is a significant difference, those factors resulting in the higher rates of failure can be identified. (2) For each component population, examine the percentage of all failures arising from the various classifications of Step 7. A significant difference in these sets of ratios might prompt further engineering analysis in order to determine the causes. In the event of no significant difference, a computation of the proportion of failure classes among all failures in the data base is made and can be used to apportion the FFR into its major contributory sources, if desired.

The FFRs as calculated in previous analyses appear to be considerably higher in every case than the failure rates one would anticipate using standard failure rate tabulations and standard reliability modeling techniques. Some of the reasons for this difference may be found in the results of this step of the methodology. More importantly, perhaps, it indicates where corrective action could be most effectively implemented.

For the Phase II[1] tail service mast analysis this step is as documented in Exhibit 14 and the remaining paragraphs of this subsection.

> "A number of factors appear to be influential or potentially so on the magnitude of TSM failure rates. A number of these will be investigated briefly in this subsection.
>
> "The TSM location does not appear to have a strong influence on field failure rate; however, the overall averages given below do indicate the general tendency.

TSM Location	FFR(1)
3-4	2.34
1-2	2.10
3-2	1.44

> " With respect to the launch vehicle being supported, the average TSM FFRs are as follows:

Launch Vehicle	FFR(1)
AS-501	2.15
AS-502	2.56
AS-503	1.59

> These differences are not so great as to be alarming, but great enough to indicate some caution in extrapolating the results found here to future launches.

[1]Complete results reported in the first citation of the bibliography of subsection VI.D.

"The overall average FFR of TSMs in their normal support service (i. e., the average of the nine subpopulations) is 1.96 failures per 1000 hours per TSM.

"Another classification is prompted by the appearance (see Exhibit 11) of a general reduction in failure rate with time when considering all TSMs and all failures. The plot of Exhibit 14, however, does not lend much support to this hypothesis. Although the last three quarters in 1968 exhibited an FFR essentially half the overall average (6 failures per quarter compared to approximately 13), the wild fluctuations of the previous quarters again imply considerable caution in extrapolating the recent favorable results."

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(1) All values in failures per TSM per 1000 hours.

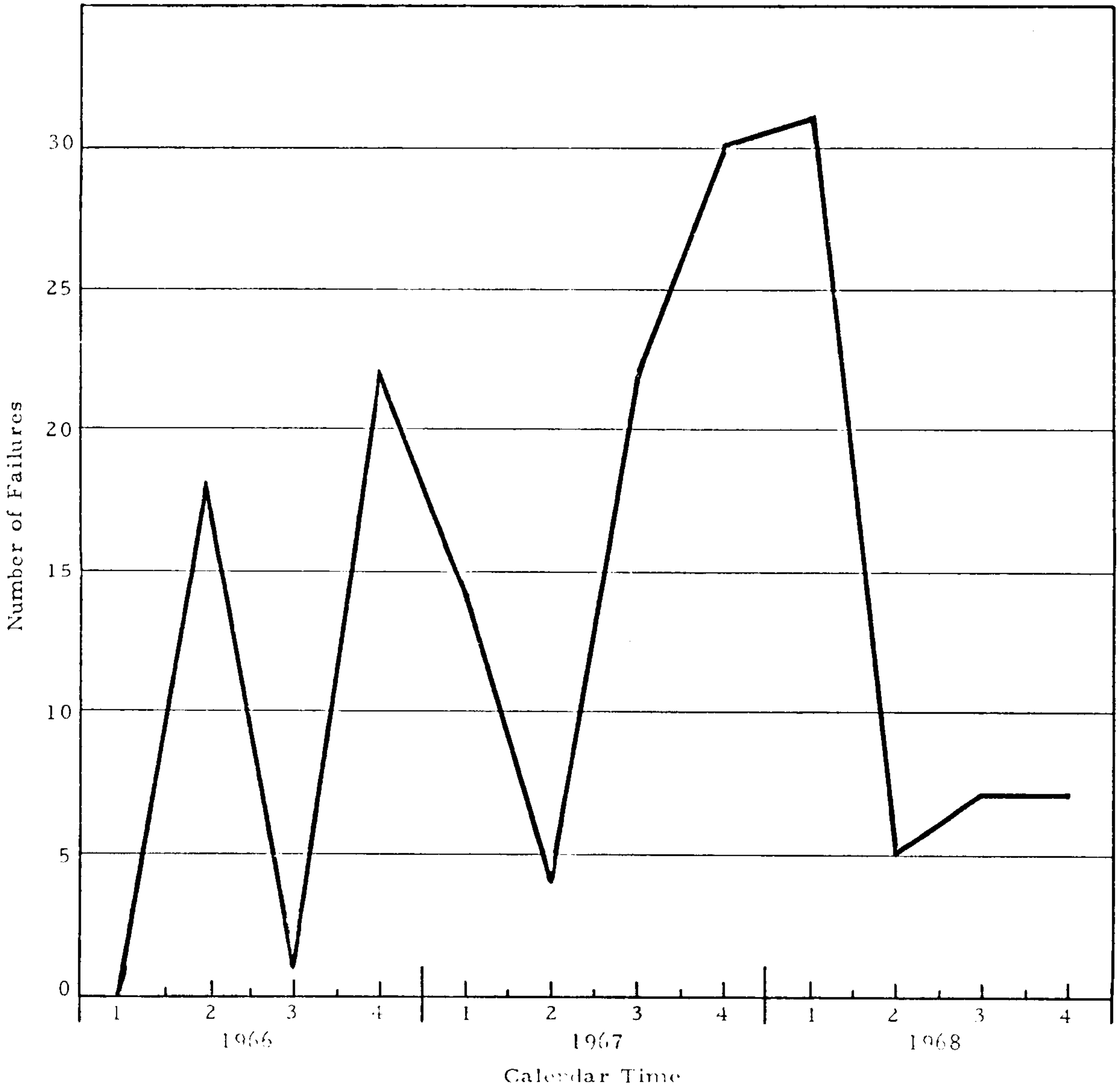
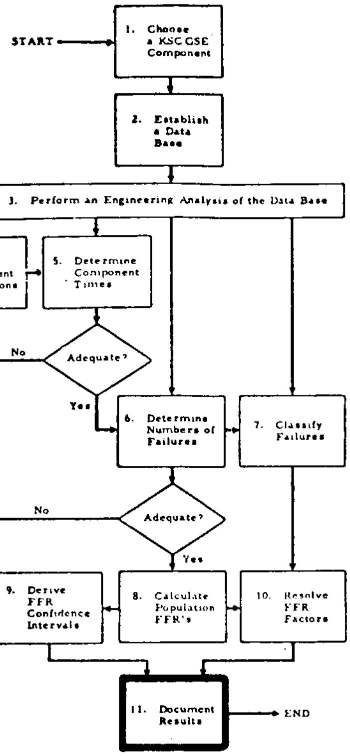


EXHIBIT 14 - NUMBER OF TSM FAILURES PER QUARTER

11. Document Results



Once the data analysis is accomplished for any component, regardless of how the data base is obtained from the UCR file or the depth of its detail, the problem of how and in what format the reliability information is to be presented must be addressed. This section describes the recommended format.

The primary output of the methodology is a set of FFR estimates and an analysis of the factors which influence their magnitude. In performing the assessment, however, a great deal of reliability information other than FFRs is generated (failure modes, problem classifications, time of UCR occurrences, for example.) This information is relevant both to the data base as a whole and to the component population(s) for which FFRs can be estimated. The recommended presentation format is such that all significant reliability information is retained.

Essentially, the format is a self-contained report, called a Reliability Assessment. A summary page is provided as the first page of the assessment. Exhibit 15 is the summary page for the component, connectors.[1] The component is identified, the date the UCR historical file was interrogated for relevant UCRs, the number of UCRs forming the data base, the estimated FFR based on the analysis, an indication of the range of failure times involved in the FFR calculation together with the total observations used in the calculation, total repair time involved in correction of the reported UCR problem, and finally a table showing the relationship between identified failure modes and cause of failure. The intent is to provide a convenient reference for selected reliability elements as they pertain to the data base as a whole and to component populations within the data base.

The remaining pages of the Reliability Assessment provide backup information for the summary page and other data of interest that result as the methodology is applied to the particular data base. The elements discussed in the remaining sections of each assessment are as follows:

- o Component Description
- o Data Base
- o Engineering Analysis
- o Component Populations
- o Component Times
- o Component Failures
- o Failure Classifications
- o Field Failure Rates
- o FFR Confidence Intervals
- o Resolution of FFR Factors

Each of these document the results of one step in the methodology. Additional sections are added to discuss particular problems of interest to the given component, to analyze repair time data or for any other reason which will enhance the overall reliability assessment.

Twenty examples of the output of this step are documented in Section II.

[1]The format of the summary page has been altered somewhat from that shown in Exhibit 15 but retains the same basic information. The new format is used for all 20 RACs of Section II.

RELIABILITY ASSESSMENT

Component: Connectors (UCR Major Item Code 423)

Currency(1): 16 June 1969

Number of Relevant UCR's: 163

Field Failure Rate (Failures/1,000 Hours): 0.134

	Minimum	Mean	Maximum	Number of Observations
Time-to-Failure (Hours)	70	7,460	26,280	25
Time-to-Repair (Hours)	~0	3-1/3	36	100

Proximate Cause of Failure

Mode of Failure	Normal Service	O & M	Quality	Design	Preventive Maintenance	All
Damaged Connector	19.6	8.6	-	1.8	-	30
Unsatisfactory Connection	13.5	-	9.2	3.1	1.2	27
Damaged Pins	9.2	8.6	1.8	3.6	-	23
Miscellaneous	8.0	-	2.5	0.6	1.2	12
Inoperative	7.5	-	-	-	-	8
All	58	17	14	9	2	100

Problem Classification (Percent)

Note: (1) Date of the UCR run from which the analysis was performed.

EXHIBIT 15 - SUMMARY PAGE FOR RELIABILITY ASSESSMENT OF CONNECTORS

12. Analyze Repair Time Data

In the old UCR system repair time data is often entered on the UCR, it is not an element in the new system. These data are entered in three categories (1) time-to-locate, (2) time-to-repair, and (3) total down time, and should be analyzed wherever possible.

Cumulative plots of the frequency of occurrence versus downtime might be constructed for various populations and subpopulations of interest. For example, a previous analysis of amplifiers indicated an overall median repair time five times greater than that exhibited when repair was effected by modular replacement.

Experience indicates that the distribution of the various downtime elements, particularly total downtime, is logarithmic-normal. Hence, the median values and the range for each distribution should be included. The cumulative plots suggested above are quite suitable for this purpose, particularly if the abscissa (time in minutes) is entered on a logarithmic scale.

An example of such an output is shown in Exhibit 16. This data is taken from the Phase II assessment[1] of cable assemblies.

[1] The complete assessment is contained in the first cited report of the bibliography, Subsection VI.D.

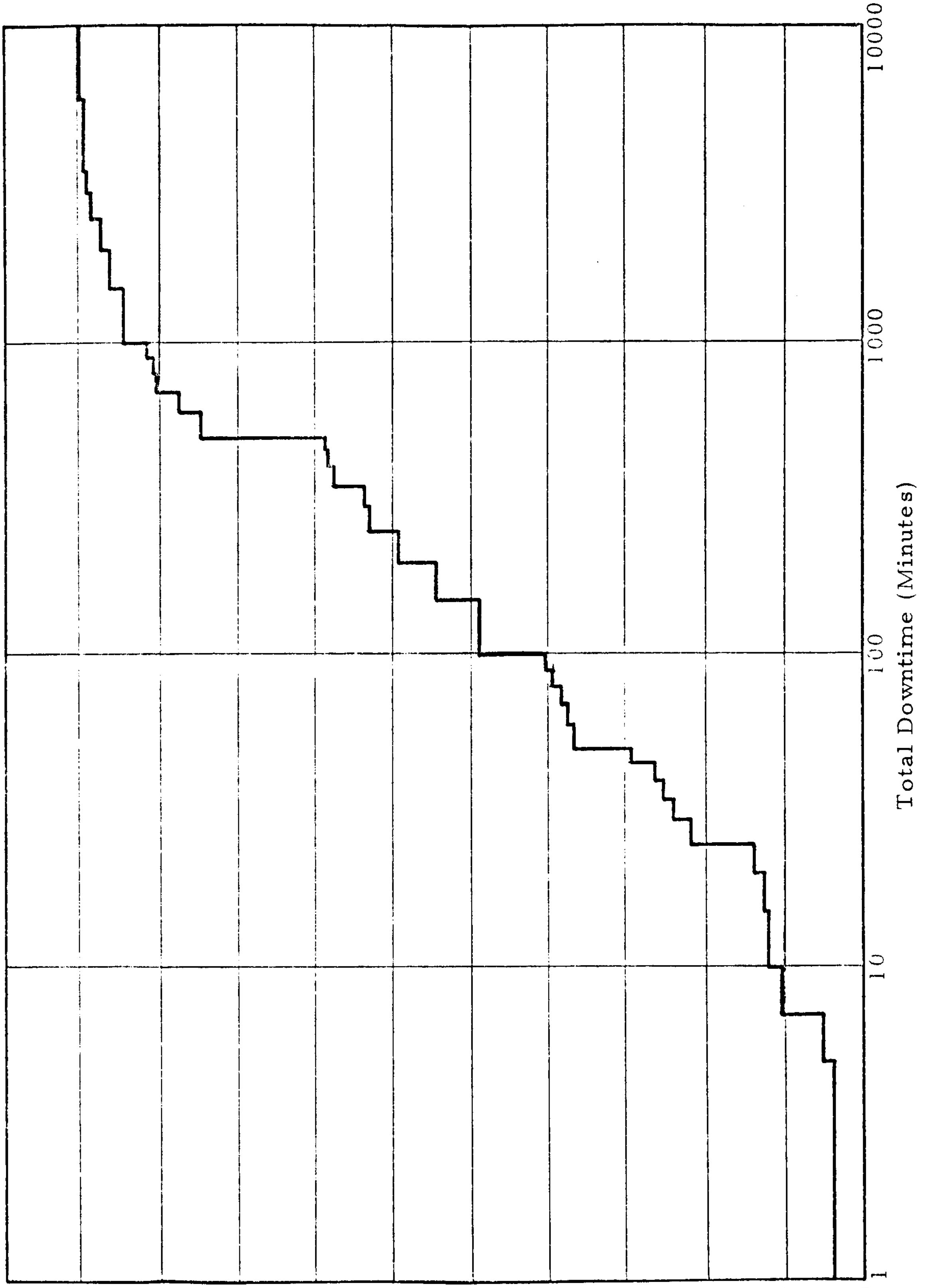


EXHIBIT 16 - CUMULATIVE DISTRIBUTION OF TOTAL CABLE ASSEMBLY DOWNTIME

D. Bibliography

This section lists those documents which are of general interest in attempting to implement the methodology. Each bibliographical entry is followed by some remarks indicating its specific utility.

1. Planning Research Corporation, PRC R-1432, KSC Program for Investigating and Generating Field Failure Rates, Phase II, Eloise E. Bean and Charles E. Bloomquist, 1 May 1970 (Restricted to Kennedy Space Center)

This document is very nearly indispensable in the generation of component reliability assessments. Seven complete assessments are included covering connectors, tail service masts at launch complex 39, holddown arms, cable assemblies, capacitors, amplifiers (15 types) and pressure switches. In addition a summary of the methodology is included and a list of potential applications of the results of the assessments is given.

2. Planning Research Corporation, PRC R-1248, KSC Program for Investigating and Generating Field Failure Rates, Eloise E. Bean and Charles E. Bloomquist, 31 December 1968 (Restricted to Kennedy Space Center)

This report covers the first (or Phase I) effort by PRC in the reliability assessment of KSC GSE components. Four electromechanical components were analyzed and the results are contained in Section IV of this report. The components are tail service masts, umbilical swing arms, regulators, and solenoid valves. A detailed analysis of the data base collected under the old UCR system is contained in this report as well as a block by block analysis of the UCR report form itself.

3. John F. Kennedy Space Center, K-AM-050/1, Guide for the Preparation of Discrepancy Records Unsatisfactory Condition Reports, and Investigative and Corrective Action Reports, Revision 1, 1 December 1966

This document explains the operation of the UCR system in effect prior to 15 October 1969 and together with the appropriate code tables should be of considerable assistance in retrieving UCRs from the computerized data bank and resolving any problems of interpretation for the old UCR system.

4. John F. Kennedy Space Center, NASA Management Instruction KMI 5310.11A/QA, Nonconformance Reporting and Corrective Action System, 8 January 1971

This document explains the operation of the UCR system in effect since 15 October 1969 (the new system) and together with the appropriate code tables should be quite useful in retrieving UCRs from the data bank and resolving any problems of interpretation for the new UCR system.

5. Epstein, B., Statistical Techniques in Life Testing, PB171580, distributed by U. S. Department of Commerce, Office of Technical Services

This document contains the details of the derivation of confidence intervals for failure rates that is used in the methodology.

STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle
RELIABILITY HANDBOOK FOR GROUND SUPPORT EQUIPMENT

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7. Author(s)
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8. Performing Organization Report No.
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John F. Kennedy Space Center
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Systems Assurance Office
Kennedy Space Center, Florida

10. Work Unit No.

11. Contract or Grant No.
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12. Sponsoring Agency Name and Address
John F. Kennedy Space Center
Kennedy Space Center, Florida

13. Type of Report and Period Covered
Final

14. Sponsoring Agency Code

15. Supplementary Notes Planning Research Corporation completed the Handbook by contract with KSC, Design Engineering, under management of O. H. Fedor and R. E. Cato, Jr.

16. Abstract
A unique methodology has been developed at the Kennedy Space Center as a result of a study recently completed by Planning Research Corporation, Los Angeles, California, to determine "Reliability Assessment of Components" (RAC) for various components used in launch facilities. Results of the initial effort have been compiled into a Handbook for use by KSC designers.

Each RAC is based on recorded data from field usage at the Kennedy Space Center. The basis of a RAC is actual experience, not a theoretical construct. This fact carries with it some implications for effective utilization of the results.

Each RAC is a summarization of actual experience of actual components in the environment of interest. There is no requirement to convert "standard" failure rate values to those applicable to the KSC GSE, for the rates presented are derived from component experience in the KSC environment. Furthermore, these data are not static but are continually changing reflecting changing conditions of utilization at KSC.

Each RAC presents not only failure rates but also failure modes, failure causes, repair times, and other information unique to the component under discussion. Supporting curves and tabulations for each of these elements are included in each RAC. Except for the

(continued next page)

17. KeyWords
Field Failure Rates,
Ground Support Equipment

18. Distribution Statement
STAR

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
unlimited	unlimited	360	

failure rate itself there is no reason to suspect that the information given is not totally representative of the population at large.

The RAC methodology developed to utilize field experience to generate field failure rates may be of particular interest to other government or industry facilities where a high degree of reliability is a stringent requirement. It is anticipated that studied application of the developed methodology could provide useful data for systems analysis.