NASA Contractor Report 159268

Study of Intermittent Field Hardware Failure Data in Digital Electronics

Edward J. O'Neill and
James R. Halverson

Sperry Univac Defense Systems
St. Paul, MN 55165

CONTRACT NAS1-15574
JUNE 1980

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

CONTENTS

NSN-29746#

STUDY OF INTERMITTENT FIELD

HARDWARE FAILURE DATA IN DIGITAL ELECTRONICS

Edward J. O'Neill and James R. Halverson

Sperry Univac

1.0 Summary

Under this contract (NASA Contract NAS 1-15574) Sperry Univac was asked to investigate their data recording and retrieval system for failures of an intermittent nature that occurred in field operation. Due to the nature of an intermittent problem and the reporting of the problem being at the discretion of the user, data referring to the first manifestation of an intermittent failure is not available. However, Sperry Univac developed a list of failure mechanisms that could manifest themselves as intermittents. This list was used to retrieve, from the data system, those failures and their times that could be the final manifestation of a previously intermittent problem.

Three time periods were studied and probability functions were fitted and tested for goodness of fit to the data of intermittent and potentially intermittent failures. This was done for the computer and for the SSI digital microcircuit components.

Results show that the exponential model of time to intermittent failure is adequate for the microcircuits. However, the Weibull distribution gives a slightly more accurate fit in some time periods. The results from the different time periods indicates that the failure rate for intermittents increases as the age of the microcircuits increases. However, it is felt that the further investigation of larger time periods is necessary to confirm the results indicated in this study.

2.0 Introduction

2.1 Introduction

Intermittent hardware failures are known to have an important impact on the reliability of digital systems. However, accurate intermittent failure models of the type required to make realistic reliability assessments are not readily available. This study makes available a data base of intermittent failure information, based on field failure data, which were classified by failure mechanisms and their likelihood of having been intermittent (quasi-intermittent).

This study will direct its attention toward actual failures that occurred in field-installed hardware and were introduced into our failure analysis cycle. This approach, while limited in the total population of failures, provides a new data base of quasi-intermittent failure data for possible application to future reliability assessments.

2.2 Study Objective

The objective of this study is to develop a data base of information, based on available field failure data, for intermittent digital hardware failures.

2.3 Study Plan

To meet this objective this study will i) define the problem of intermittent failure, ii) describe Sperry Univac's data recording and retrieval system, iii) study the problem at the computer level and iv) study the problem at the micro circuit-device level.

3.0 Study Definition

3.1 Intermittent Definition

An intermittent is defined as a detected malfunction of a logic net which was operating properly prior to the malfunction and resumes normal operation in less time than the time needed to isolate the malfunctioning net to the lowest replaceable unit (LRU).

In presently deployed computers, the time to isolate is of critical importance; that is, the time for the maintenance technician or the Built-in-Test (BIT) logic to find the problem and replace the component.

The impact of the duration of intermittency of any given malfunction and its frequency are dependent on the system architecture, software, and maintenance tools.

In older systems, and to some extent the systems of today, the intermittent was always detected by the operating software. The maintenance technician was then called and by utilizing his tools, i.e., test programs, scope, VOM, etc., he was expected to recreate the detection scenario and isolate the problem to some LRU. In this case, any intermittent with a duration of less than, say, 30 minutes, would not be isolated and would be declared an intermittent thus remaining in the system to cause trouble when it again fails.

In some present day equipment and potentially most new equipment, the task of both intermittent malfunction detection and isolation will fall upon BIT. If BIT were designed to constantly monitor all logic nets, the detection and isolation of malfunction would occur almost instantaneously. This would mean that only malfunctions having a duration of a few nano-seconds would be classified as intermittent.

The definition of the duration of an intermittent has been specifically bounded by malfunction isolation time. This is due to the assumption that once the malfunction has been isolated and, consequently, removed from the system, the fact that the replaced item may once again resume normal operation is of no consequence to the system operation. This does, however, pose a significant problem for the failure analysis task.

3.2 Constraints on the Study

Historically, Sperry Univac has not maintained a data base of intermittent malfunctions. This is due to the following reasons:

> Most of Sperry Univac's exposure to the system is that of equipment checkout. Once the equipment is running properly, it is delivered to the customer. The checkout time is but a small fraction of the total system life cycle and, as such, the quantity of intermittent failures experienced is very minute. Only with the advent of such activities as the 1000 hour burn-in testing, has the quantity of intermittents and the re-

porting structure been sufficient to justify the recording of intermittent malfunction data.

The field failure reporting has been at the customers' discretion. The failure data reported from the field is made up almost exclusively of hard failures. Due to the complex nature of customer operational software and customer hardware configurations, of which Sperry Univac normally provides only the computer, it is most likely that intermittent failures (particularly those with long time between manifestations) are rarely isolated and consequently not reported in the field unless they become hard or their frequency increases to the point where they appear hard.

Due to the lack of data on isolated intermittent failures as explained above, the only method of arriving at a data base pertaining to intermittent failures was to examine the reported hard failures and decide which failure mechanisms could manifest themselves as intermittents. This decision was arrived at by a joint effort by engineering personnel from the Sperry Univac Product Reliability Department and Failure Analysis Laboratory. Each failure mechanism was examined and placed in one of the following categories based on the best judgement of the above mentioned departments:

Intermittent - A relatively high possibility of causing intermittent hardware failure.

Potential Intermittent - Some possibility of causing intermittent hardware failure.

Hard Failure - Little possibility of causing intermittent hardware failure.

Due to the lack of empirical data, the above failure categorization was accomplished by engineering judgement. Confidence in this categorization will be maintained until data is available to either confirm or reject any of these judgements.

Due to these constraints and the data base that was available for this study, all reporting and analysis of failures in this study are on field failures after they became hard.

4.0 Description of Sperry Univac's Failure Reporting System

4.1 Fail Codes

In Sperry Univac's failure reporting system there are 174 fail codes used to describe the failure mechanism. These refer to failures of an electrical, magnetic, electro-magnetic, and mechanical nature. Of these 174 codes, 43 are not applicable to this study, 86 would be considered "hard", 28 are considered potentially intermittent, and 17 are considered intermittent according to the definition of these classes in 3.2. A brief description of the codes that were intermittent or potentially intermittent are given in Figures 1-5.

Some contracts on individual computers call for the reporting of field equipment utilization, failure reporting, and failure analysis. The data on these computers goes into Sperry Univac's failure reporting system.

4.2 Reporting Forms

The sources of the data for this study utilized three reporting forms. The first is an "Equipment Utilization Report". (See Appendix A.1.) This report is filled out monthly for each equipment that is participating in the utilization reporting program. This report is used even if the equipment does not experience any

POTENTIALLY INTERMITTENT

Fail Code	Description
10D	Broken Weld: possible intermittent operation resulting from partial contact of wire to pad.
11F	Smeared Open Chip Bond: possible intermittent failure resulting from partial electrical contact of the lead wire to the bond pad or bond to adjacent metal.
11G	Smeared Open Post Bond: possible intermittent failure resulting from partial electrical contact of the lead wire to the bonding post.
11L	Bond Short to Metallization or Chip Edge or Mislocated: possible intermittent operation caused by partial shorting of the wire bond to metal interconnects or adjacent bond pads.
12G	Interlayer Metal Short: possible intermittent operation resulting from partial shorting of metal interconnects (used for multi layer metal devices).
13C	Cracked Die: possible intermittent failure resulting from partial electrical contact of the parts of the semiconductor die.
15A	Out of Spec(Elect): possible intermittent operation resulting from out of specification electrical parameters; this is dependent upon operating design margins.
15E	Slow Recovery: possible intermittent operation caused by slow reverse recovery (Trr) of diodes; this is dependent upon the design operating margins.
15F	Core Cracked/Defective/Noisy: possible intermittent operation caused by cracked/defective/noisy cores resulting in bits being "picked" or dropped.

Figure 1

15G - Early Peaking Core: possible intermittent operation caused by an early loss of core signal output; this is dependent upon the design operating margins.

20K - Timing - Delay Line Taps: possible intermittent operation caused by out of specification timing adjustment of delay line.

21A - Delay Time: possible intermittent operation caused by out of specification delay time of printed circuit assemblies or subassemblies.

21L - Low Output: possible intermittent operation caused by an output signal which does not achieve the specified output level.

21M - Magnetostriction: possible intermittent operation caused by a change in electrical characteristics (e.g. ringing) of a core caused by excessive external pressure.

22H - Not Verified, Elect cause unknown
22J - Not Verified, Elect plating anomolies
22K - Not Verified, Elect restriction of wire
22L - Not Verified, Elect scratch/abrasion
22M - Not Verified, Elect bond
22N - Not Verified, Elect corrosion
22P - Not Verified, Elect substrate defects
22Q - Not Verified, Elect nonrestrict foreign material

Failures with the above fail codes could be considered to cause possible intermittent operation since a failure was experienced for which no cause could be determined but only suspected.

23B - Noisy Bit: possible intermittent operation caused by excessive noise, ringing, excessive recovery, or impedance mismatch of a core or film output signal.

Figure 2

POTENTIALLY INTERMITTENT (continued)

23K - Weak Bit: possible intermittent operation caused by a narrow output pulse or an output level below that for system operation (see 21L).

31A - Unverified failure

31C - No defect found by failed item analysis

31H - Unverified failure/suspect part replaced

31J - Scrap-unverified failure

Failures within the above codes could cause intermittent operation since a failure did exist which could not be verified through failure isolation.

Figure 3

INTERMITTENT

10G - Shorted Lead Wire, Poor Lead Dress: intermittent shorting to the edge of the die or adjacent wire bonds.

10L - Internal Particle or Contamination: intermittent shorting between die metallization stripes, bonding ponds/wires or edge of die to package.

10N - Lead or Metal Migration (Grow Back): intermittent contact of metal links, originally fused to create an open (logic "1"); this is used primarily for PROM's with fused link technology.

11D - Plagued Open Chip Bond:
11E - Plagued Open Post Bond: intermittent open of the chip or post bond resulting from the formation of "purple-plague" in Au-Al intermetallic systems.

11H - Underbonded Chip Bond:
11J - Underbonded Post Bond: intermittent open of the chip or post bond resulting from inadequate ultrasonic bonding interface in Al-Al systems.

12B - Open Metallization Due to Microcrack: intermittent open of metallization stripes, primarily over ohmic steps, resulting from discontinuous (cracked) metallization.

12C - Open Metal Electromigration: intermittent open metallization due to migration within thin areas of metal stripes caused primarily a combination of excessive current density/temperature.

15M - Pattern Sensitive: intermittent logic failure resulting from a particular pattern within memory causing an undesired change of memory bit (primarily used for RAM's).

20B - Bent, Broken or Pushed in Pins: intermittent open contacts resulting from damged connector pins.

Figure 4

INTERMITTENT (continued)

20C - Cold Flow, Abraded or Damaged Wire Insulation: intermittent shorting resulting from damaged wire insulation causing shorts to adjacent connector pins, wires, terminals or ground.

20F - Warped, Splitting, Uneven Mat Area: intermittent electrical failure caused by a change of magnetic core characteristics or core damage resulting from warped, split or uneven core mat.

21G - Damaged Foil: intermittent open caused by raised or damaged metallic interconnects (foil) on a printed circuit card.

23G - Disturb: intermittent logic failure within memory resulting during a READ or WRITE cycle at one location causing another location to change states.

30H - Reseated Cards: intermittent failure resulting from improperly or unseated printed circuit cards causing intermittent connection.

31D - Intermittent/Cause Unknown: intermittent computer, assembly or sub-assembly failure experienced for which no specific cause could be established.

Figure 5

failures. When a computer, which is covered by this reporting system experiences a failure and the failure results in a repair, it is reported on either a, "Failure/Malfunctional Report" (FMR), or an "Equipment Malfunction Report" (EMR). See Figure A.2 and Figure A.4 for the format of these reports. Figures A.3 and Figure A.5 of the Appendix A give the explanation of the fields contained in the reports. When an EMR or FMR is filled out, the failing assembly and the form are sent back to the factory. The failing assembly is analyzed to determine the cause of the failure. The information on the report is then entered into a data base. All of the computers using the utilization reporting system use the FMR or the EMR; however, all of the computers using the FMR or EMR do not use the equipment utilization report. Part of this study required that the number of computers under investigation be known for each time interval. This is the reason that only the 169 computers that are in the field utilization program were used in the distribution analysis.

An example of the raw failure data is given in Figure 6. This failure was isolated to a control memory printed circuit card in the field. The failure analysis laboratory determined that the failure was in the integrated circuit at location 16 on the card and that the failure mechanism within the chip was open metal electromigration (12C). The FMR and EMR both contain a block within field 36 to explain the observed failure characteristics;

UNIVAC

EQUIPMENT MALFUNCTION REPORT

1 EMR NUMBER: L 40147

0 FORM DATE	32 SITE LOCATION						

2 FR	4 CL R	5 SITE	6 PROJ	7 FAIL DATE (Y M M D D)	8 CABINET TYPE	9 EQUIP SN	10 ETM HOURS *	11 REPAIR MIN.	12 REPAIR TYPE (EMC, PC, FC, IC)	13 TYPE OF FAILURE (PRI, SEC)
Y		204		790518		A59	3282	40	PC	

14 MOD/CHAS TYPE	15 MOD/CHAS SN	16 SUBA TYPE	17 SUBA SN	18 SUBA REF	19 SUBASSEMBLY PART NUMBER	20 DASH	21 REPLACEMENT SN
IOC	A79	PC	2936	B70	7111906	-02	3178

22 RELATED EMR	38 FAIL TYPE	39 PART NUMBER	40 DASH	32 NAME
				Robert T. Myers

36 PROBLEM COMMENTS

Running Cont test for PM and Received stop. P= 50,775 A6= 37377 777777
A7= 00001 000000

Swapped cards per inst and stop said B71 was failing. Swapped cards back and Replaced B-70.

*IOC ETM = 6286

CHECK (√) IF YES

- [x] DIAG DETECT
- [x] DIAG ISOLATE
- [ ] LOAD FAILURE
- [ ] HEAT SENSITIVE
- [ ] SHOCK SENSITIVE
- [ ] INTERMITTENT
- [ ]
- [ ]

... RETAIN SECOND COPY. RETURN ALL OTHER COPIES TO FIELD ENGINEERING.

FAILURE ANALYSIS DATA

2 CI	24 COMP TYPE	25 COMP REF	26 COMPONENT PART NO.	27 DASH	28 VEND CODE	29 DATE CODE (Y Y W W)	30 FAIL CD	31 RES	37 ANALYST EMPL NO.
	2	16	7902898	00	5	7422	12C		55522

35 ADDITIONAL DATA

FAILURE ANALYSIS

Figure 6. Example of Field Failure Report

"INTERMITTENT" is one of the possible characteristics to check in this block. Unfortunately, reporting in this block has been erratic and this block was not entered into the data base. This is the reason the failure mechanism was used to define which failures have been intermittent prior to going hard.

Once the EMR and FMR are completed, the data is entered into Sperry Univac's reporting and retrieval system. The computer file has, theoretically, a field for every block of data on the EMR or FMR. The failure data can be sorted and ranked by the fields in any order that the user wants. This allows for quick and easy access to the specific information that the user wants. An example of retrieval data is given in Figure 7.

4.3 Components

A brief description of the components that Sperry Univac uses is as follows:

1) Integrated Circuits: The integrated circuits used are purchased to Sperry Univac specifications which require processing, inspection and both screening and sample testing in accordance with MIL-M-38510, and MIL-STD-883 for Class B devices.

2) Semiconductor Devices: The semiconductor devices used are purchased to Sperry Univac specifications which require processing, inspection and both screening and sample testing in

PROCESS D052D REPORT=EEI M.S. S2813 3200 FIELD FAILURES 1974 TO DATE ED S DATE 121878

PAGE 41

SUB ASSY PART	DSH	COMP PART	DSH	FAL COD	FAILURE CODE DESCRIPTION	ADDITIONAL DATA DATA	ETM HOURS	EEC NO	FAIL DATE
7111460	000	7901001	000	12D	-	ALUMINUM HYDROXID CORROSION	6833	537633	761018
7111905	000	7902897	000	12D	-	ALUMINUM HYDROXIDE CORROSION	8333	L08026	770311
7111905	002	7902897	000	12D	-	ALU,INUM HYDROXIDE CORROSION	9026	L00068	760909
7111750	000	7901000	000	12D	-	ALUMINUM HYDROXIDE CORROSION	10322	L02467	770103
7111505	000	7902139	000	12D	-	CHIP BOND OPEN	10370	L54125	760724
7111505	000	7902139	000	12D	-	ALUMINUM HYDROXIDE CORROSION	11070	L60006	770202
7111905	002	7902897	000	12D	-	ALUMINUM HYDROXIDE	12941	L00714	770125
7111436	000	7901732	000	12D	-	ALUMINUM HYDROXIDE CORROSION	14460	L04692	761222
7111905	002	7902897	000	12D	-	ALUMINUM HYDROXIDE CORROSION	16094	L02241	770126
7112855	000	7902897	000	12D	-	ALUMINUM HYDROXIDE CORRISION	16609	C63414	741019
7111981	000	7901000	000	12D	-	ALUMINUM HYDROXIDE CORROSION	17806	L04562	761201
7111926	000	7901001	000	12D	-	ALUMINUM HYDROXIDE CORROSION	24580	L04217	770216
7111905	002	7902897	000	12E	OPEN METAL(MASKING FLAW)ETCHING	OPEN METAL MASKING FLAW		C49543	780203
7111005	000	7901001	000	12E	OPEN METAL(MASKING FLAW)ETCHING	OPEN METAL MASKING FLAW		L66745	770930
7112835	000	7902897	000	12E	OPEN METAL(MASKING FLAW)ETCHING	OPEN METAL	2200	L02701	761102
7111517	001	7903170	000	12E	OPEN METAL(MASKING FLAW)ETCHING	OPEN METAL MARKING FLAW	4015	L15184	771003
7111905	002	7902897	000	12E	OPEN METAL(MASKING FLAW)ETCHING	OPEN METAL	32427	L05748	770609
7111905	001	7902897	000	12E	OPEN METAL(MASKING FLAW)ETCHING	OPEN METAL	34096	L05729	770429
7111530	000	7901610	000	12F	METAL BRIDGE (MASKING FLAW)	METAL BRIDGE	406	C50054	740731
7111530	000	7901610	000	12F	METAL BRIDGE (MASKING FLAW)	METAL BRIDGE	406	C50053	740731
7111530	000	7901610	000	12F	METAL BRIDGE (MASKING FLAW)	METAL BRIDGE	406	C50051	740731
7111517	001	7901610	000	12F	METAL BRIDGE (MASKING FLAW)	METAL BRIDGE	3550	C62450	740725
7111517	001		000	12F	METAL BRIDGE (MASKING FLAW)	METAL BRIDGE MASKING FLAW	9290	L13695	771015
7111517	001	7901610	000	12F	METAL BRIDGE (MASKING FLAW)	SHORTED DUE TO METALLIC BODY	23053	C53642	741206
7111520	000	7901102	109	12G	INTERLAYER METAL SHORT	INTERLAYER METAL SHORT THERMO CRACKS	170	L06371	771115
7111615	000	7903309	010	12G	INTERLAYER METAL SHORT	INNERLAYER METAL SHORT	7109	L04403	770414
7111505	000		000	12G	INTERLAYER METAL SHORT	INNERLAYER SHORT	11115	C08639	760804
7111520	000	7901102	109	12G	INTERLAYER METAL SHORT	INTERLAYER METAL SHORT	25665	L16322	770906
7112840	000	7901001	000	12H	OXIDE DEFECT/PIN HOLE SHORT	OXIDE FLAW		D37363	761012
7112010	000	7901001	000	12H	OXIDE DEFECT/PIN HOLE SHORT	OXIDE FLAW		L01255	760525
7111905	002	7902897	000	12H	OXIDE DEFECT/PIN HOLE SHORT	PIN HOLE SHORT		D37309	760825
7111905	002	7901001	000	12H	OXIDE DEFECT/PIN HOLE SHORT	OXIDE FLAW		D15148	760924
7111610	000	7901001	000	12H	OXIDE DEFECT/PIN HOLE SHORT	OXIDE FLAW UNDER COLLECTOR METALIZATION		D15141	760805
7111615	000	7901001	000	12H	OXIDE DEFECT/PIN HOLE SHORT	OXIDE FLAW		D46371	761004
7111945	000	7901000	000	12H	OXIDE DEFECT/PIN HOLE SHORT	OXIDE FLAW UNDER BASE METAL		D15155	760912
7111005	000	7901000	000	12H	OXIDE DEFECT/PIN HOLE SHORT	OXIDE FLAW INTERNAL DEVICE		D15153	760911
7111981	000	7902897	000	12H	OXIDE DEFECT/PIN HOLE SHORT	OXIDE FLAW		C59013	760624
7111905	002	7902897	000	12H	OXIDE DEFECT/PIN HOLE SHORT	OXIDE FLAW UNDER METAL		C12504	760708
7111517	001	7903170	000	12H	OXIDE DEFECT/PIN HOLE SHORT	PIN HOLE SHORT		C31955	770808
7111436	000	7901732	000	12H	OXIDE DEFECT/PIN HOLE SHORT	OXIDE FLAW		[illegible]	760912
7111635	000	7901001	000	12H	OXIDE DEFECT/PIN HOLE SHORT	OXIDE FLAW UNDER METAL		D37638	761008
7111905	002	7902897	000	12H	OXIDE DEFECT/PIN HOLE SHORT	PIN HOLE SHORT		C05640	770518
7111905	002	7902897	000	12H	OXIDE DEFECT/PIN HOLE SHORT	OXIDE DEFECT		L14510	770825
7112830	002	7902897	000	12H	OXIDE DEFECT/PIN HOLE SHORT	PIN HOLE SHORT		L17620	780920
7112050	000	7901001	000	12H	OXIDE DEFECT/PIN HOLE SHORT	PIN HOLE SHORT		L66077	770831
7111436	000	7901732	000	12H	OXIDE DEFECT/PIN HOLE SHORT	OXIDE DEFECT		L31215	780831
7111517	000	7903170	000	12H	OXIDE DEFECT/PIN HOLE SHORT	OXIDE DEFECT		L06033	770606
7112840	000	7901001	000	12H	OXIDE DEFECT/PIN HOLE SHORT	OXIDE DEFECT		L01745	770805
7112335	000	7901001	000	12H	OXIDE DEFECT/PIN HOLE SHORT	PIN HOLE SHORT		L71572	770721
7112865	000	7902897	000	12H	OXIDE DEFECT/PIN HOLE SHORT	OXIDE DEFECT		L22437	780131

Figure 7 **Retrieved Example of Failure Data**

accordance with MIL-S-19500 and the applicable slash specs for JAN TX devices.

3) Passive Devices: The majority of the passive devices used are MIL or ER equalifiers and are purchased to the applicable military specifications.

4.4 Data Base

Sperry Univac had four programs in the above data reporting system which were applicable to this study. The application of these programs were two shipboard, one submarine and one avionics. For these programs approximately 21,000 field failures were on file from the past five years. However, not all the failures in this data base were reported with the time of failure (Elapse Time Meter). In addition, the reporting system is dynamic with computers of all age groups being included. It was decided to concentrate upon the one ship-board program that made up the majority of the failures and the population of computers in our data base. To address the problem of changes in the occurrence of failures over time, it was decided to "freeze" the data base into three time periods and to include a computer in the time period only if that computer ran throughout the entire time period.

4.5 Computer Description

The computer which yielded sufficient data for use in this study is a highly reliable, ruggedized multiple-processor system designed by Sperry Univac for military applications. To meet stringent environmental and functional specifications, this computer was designed to meet MIL-E-16400 (ship and shore) environmental requirements. Other specifications and standards used for design objectives are as follows:

Radio Frequency Interference: MIL-I-16910

Shock: MIL-S-901 Class I Medium Weight

Vibration: MIL-STD-167 Type I

Salt Spray: FED-STD-151 Method 811

Environmental Characteristics:

Temperature Range:

$-54^{\circ}C$ to $+65^{\circ}C$ (Operating)

$-62^{\circ}C$ to $+75^{\circ}C$ (Storage)

Relative Humidity to 95%

This computer is comprised of one or more of each of the following modules:

- Central Processor
- Input/Output Controller
- Memory
- Input/Output Adapters
- Power Supplies

With the exception of the power supply, each module has a wire-wrapped back panel terminating in receptacles that mate with the male connectors on the printed circuit cards and memory modules. All heat dissipated by circuit elements is transferred to the top of the card or memory assembly by thermal conduction to metallic "T" bars. The assembled module is closed by a heat-exchange cover which makes thermal contact with all "T" bars. Ambient air drawn through the heat exchanger by the cabinet cooling system removes heat to the outside.

Man/Machine interface for maintenance actions is accomplished via a maintenance unit panel which provides operation controls and indicators which present internal computer register values needed to isolate printed circuit card failures.

This computer is presently in operation in both shipboard and shore based applications. Due to the reporting structure comprising the data base available to Sperry Univac, only the shore based computers are involved in this study. The environment of the study-related computers is that of normal commercial computer center operations. This implies ambient air temperatures of $70^{\circ}F$ to $80^{\circ}F$ with no shock or vibration exposure.

5.0 Study at the Computer Level

5.1 Histograms

All discussion that is to follow refers to the one computer discussed in Sections 4.4 and 4.5. The failure data was put into histograms for the following running time periods: 10,000 hours, 5,000 hours, and 2,000 hours. These histograms reflect the hard failures, intermittent failures, and potential intermittent failures for that period. The data for the three time periods is based on a fixed number of computers for each period. The following is that relationship.

Time Period	Number of Computers
0 - 2,000 hrs	169
0 - 5,000 hrs	116
0 - 10,000 hrs	48

These histograms are shown in Figures 8 through 16. The data has been screened to eliminate failures which may skew the data. In addition, the screening determined that if a computer had more than one failure, they occurred in different modules and at different times so that the failures can be assumed to be independent. The data represented in these histograms represents the first look at the computers in the reporting system. They have one limitation in that the failures are grouped in 250-hour blocks of time and that it was not possible to obtain raw data for this portion of the study. An interesting observation is that no intermittent failures were observed after 8000 hours. Appendix B.2 has the breakdown by time periods.

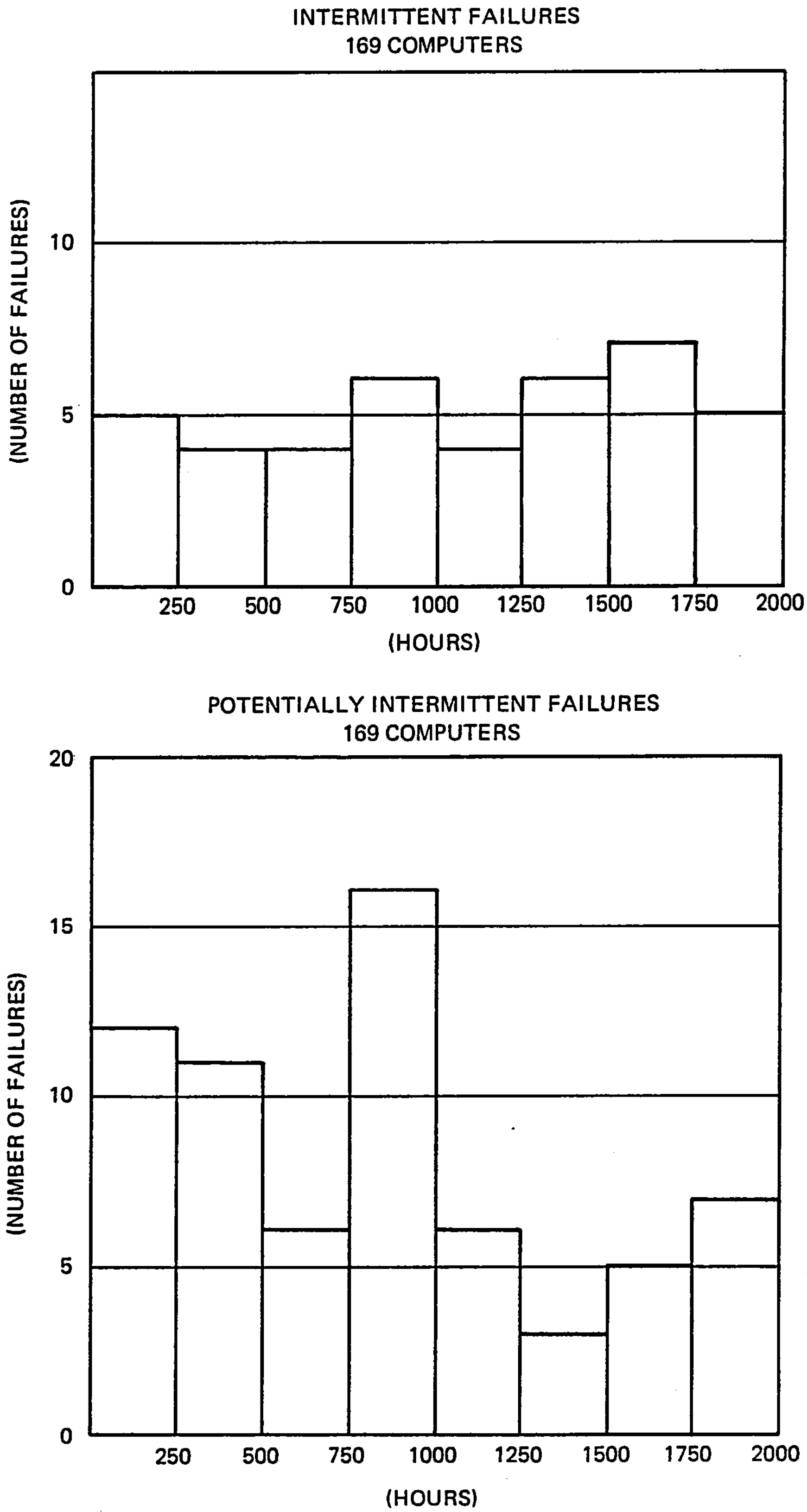

INTERMITTENT FAILURES
169 COMPUTERS
(NUMBER OF FAILURES)
0
5
10
250
500
750
1000
1250
1500
1750
2000
(HOURS)
POTENTIALLY INTERMITTENT FAILURES
169 COMPUTERS
(NUMBER OF FAILURES)
0
5
10
15
20
250
500
750
1000
1250
1500
1750
2000
(HOURS)

FIGURE 8.

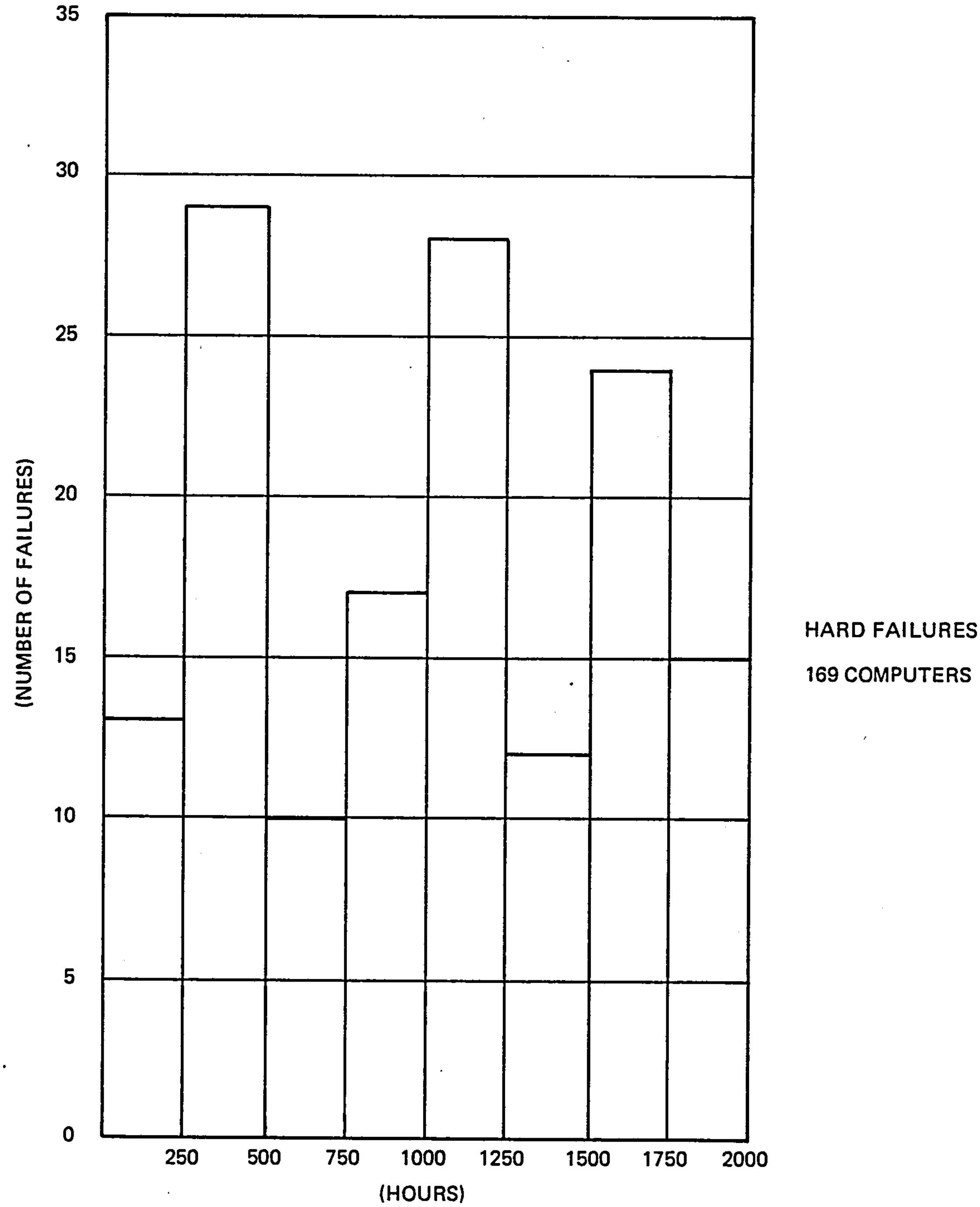
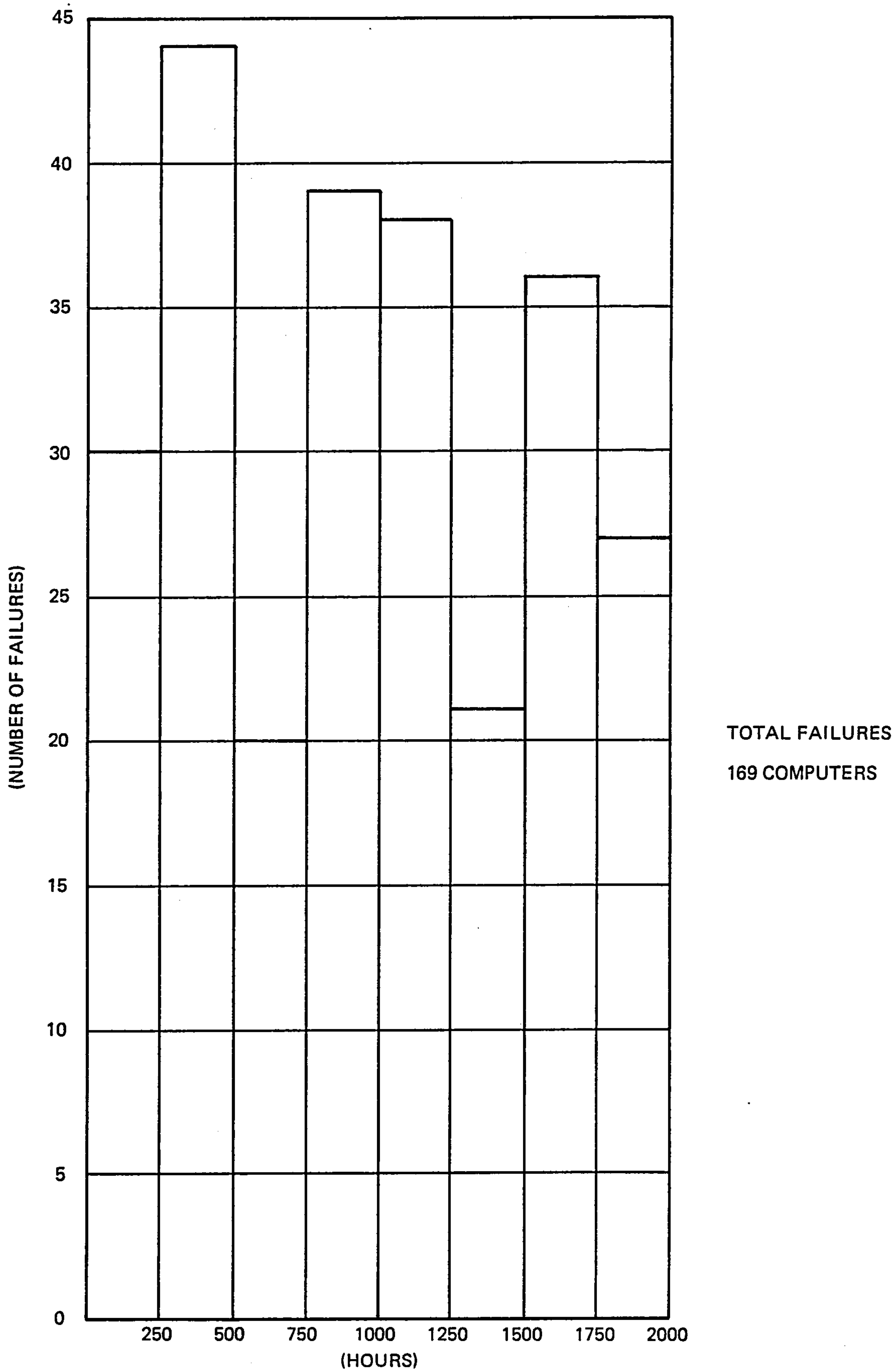
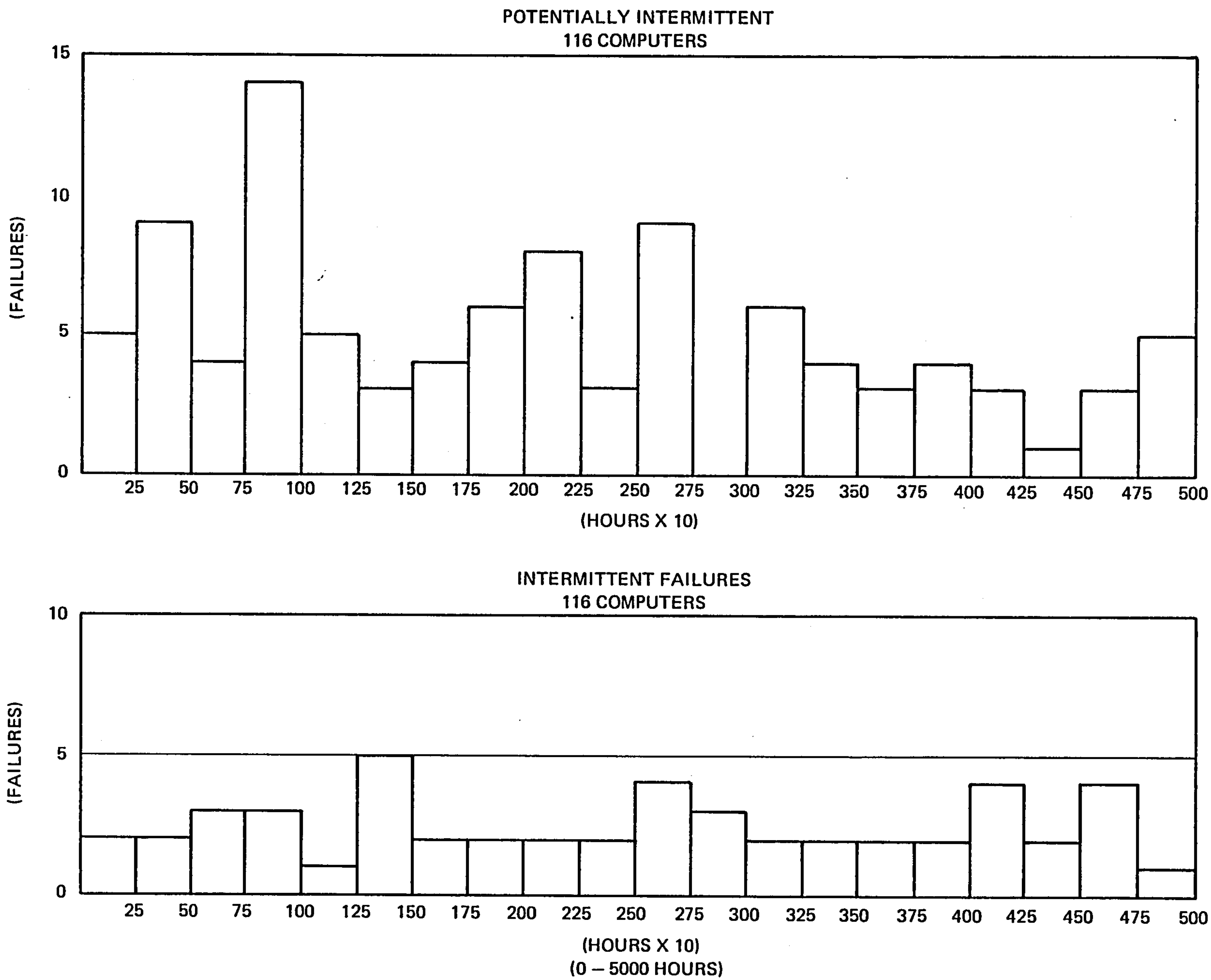

35
30
25
20
15
10
5
0
(NUMBER OF FAILURES)
250
500
750
1000
1250
1500
1750
2000
(HOURS)
HARD FAILURES
169 COMPUTERS

FIGURE 9.



(NUMBER OF FAILURES)
0
5
10
15
20
25
30
35
40
45
250
500
750
1000
1250
1500
1750
2000
(HOURS)
TOTAL FAILURES
169 COMPUTERS

FIGURE 10.



POTENTIALLY INTERMITTENT
116 COMPUTERS
(FAILURES)
0
5
10
15
25 50 75 100 125 150 175 200 225 250 275 300 325 350 375 400 425 450 475 500
(HOURS X 10)
INTERMITTENT FAILURES
116 COMPUTERS
(FAILURES)
0
5
10
25 50 75 100 125 150 175 200 225 250 275 300 325 350 375 400 425 450 475 500
(HOURS X 10)
(0 – 5000 HOURS)

FIGURE 11.

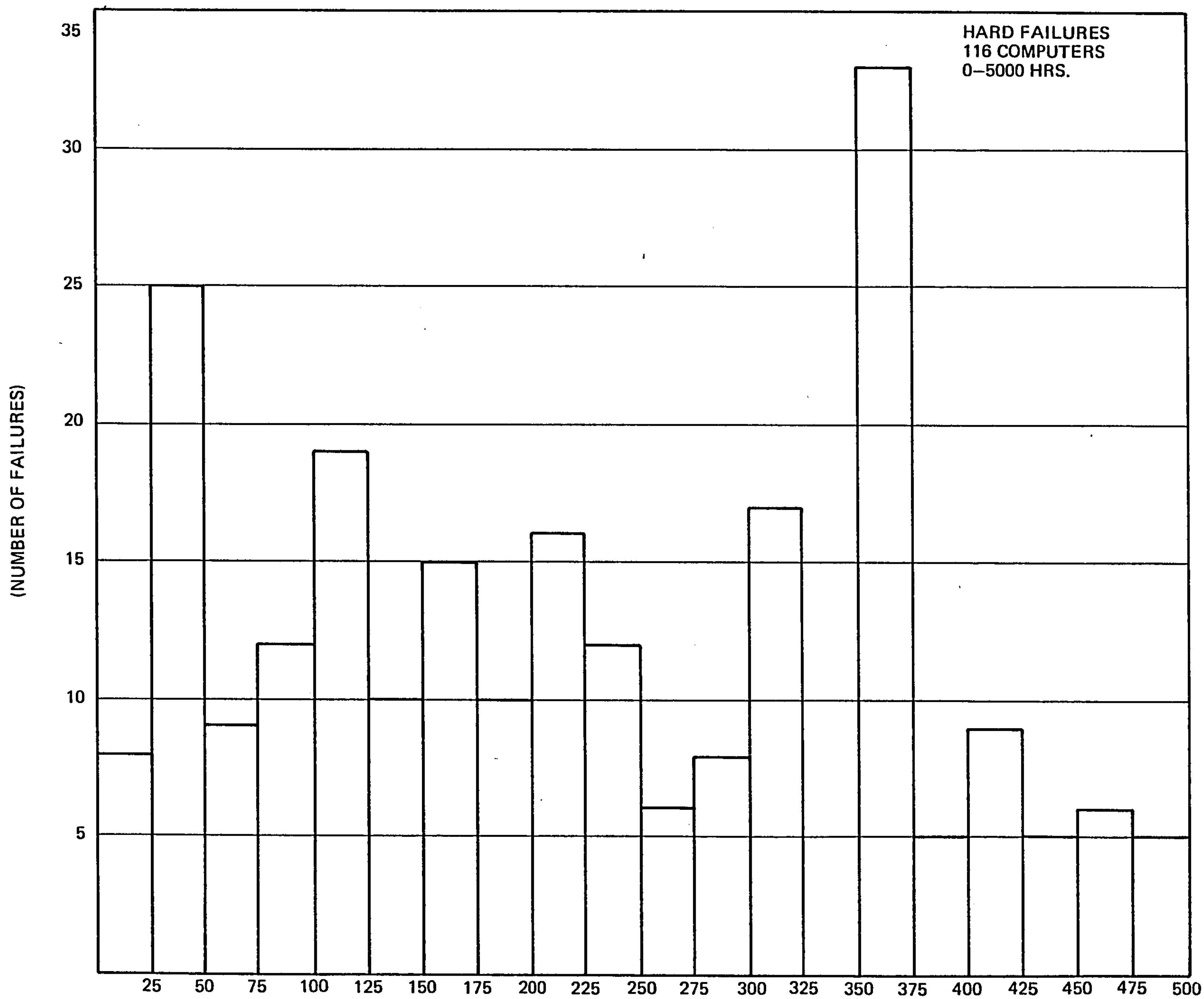
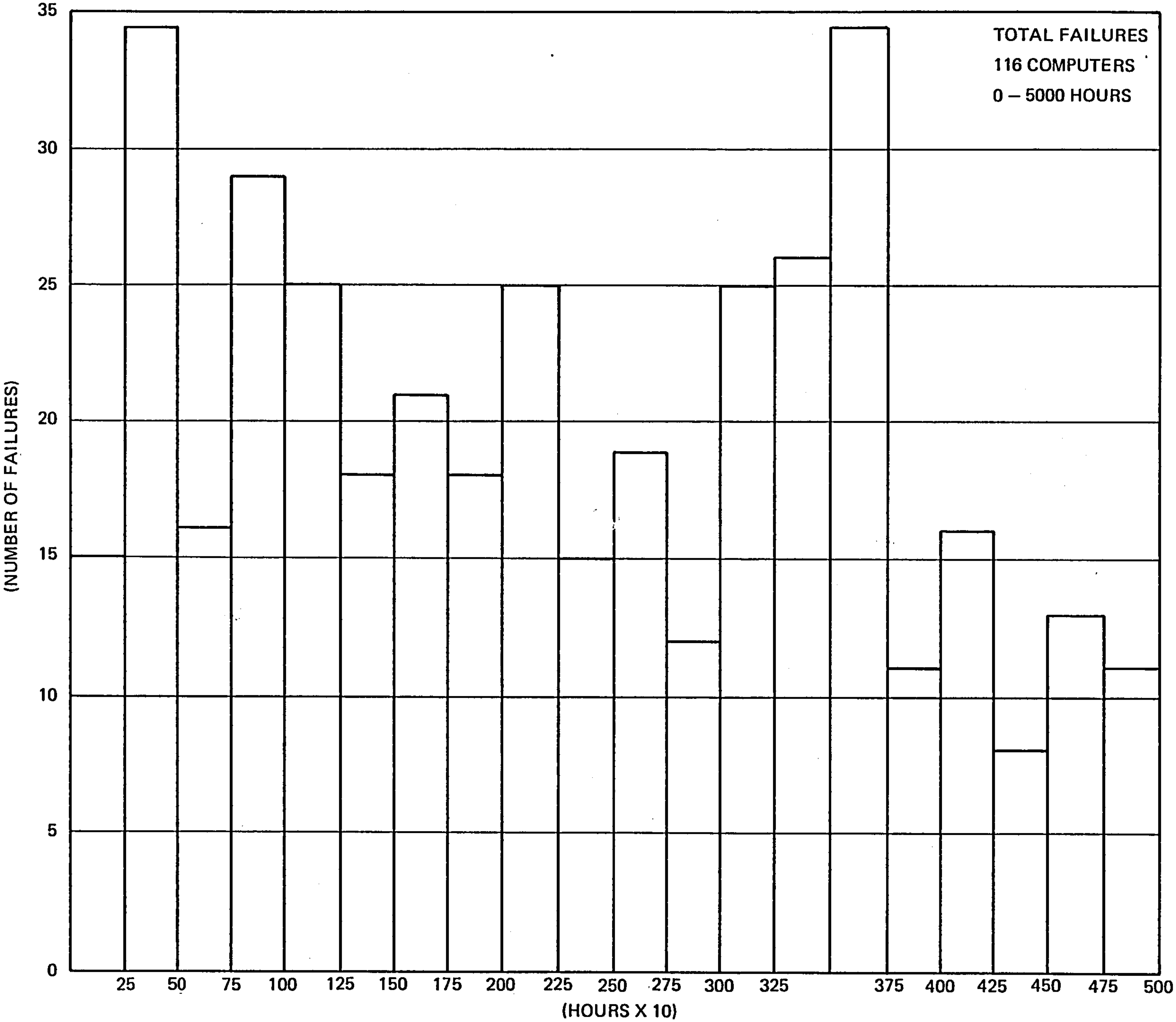
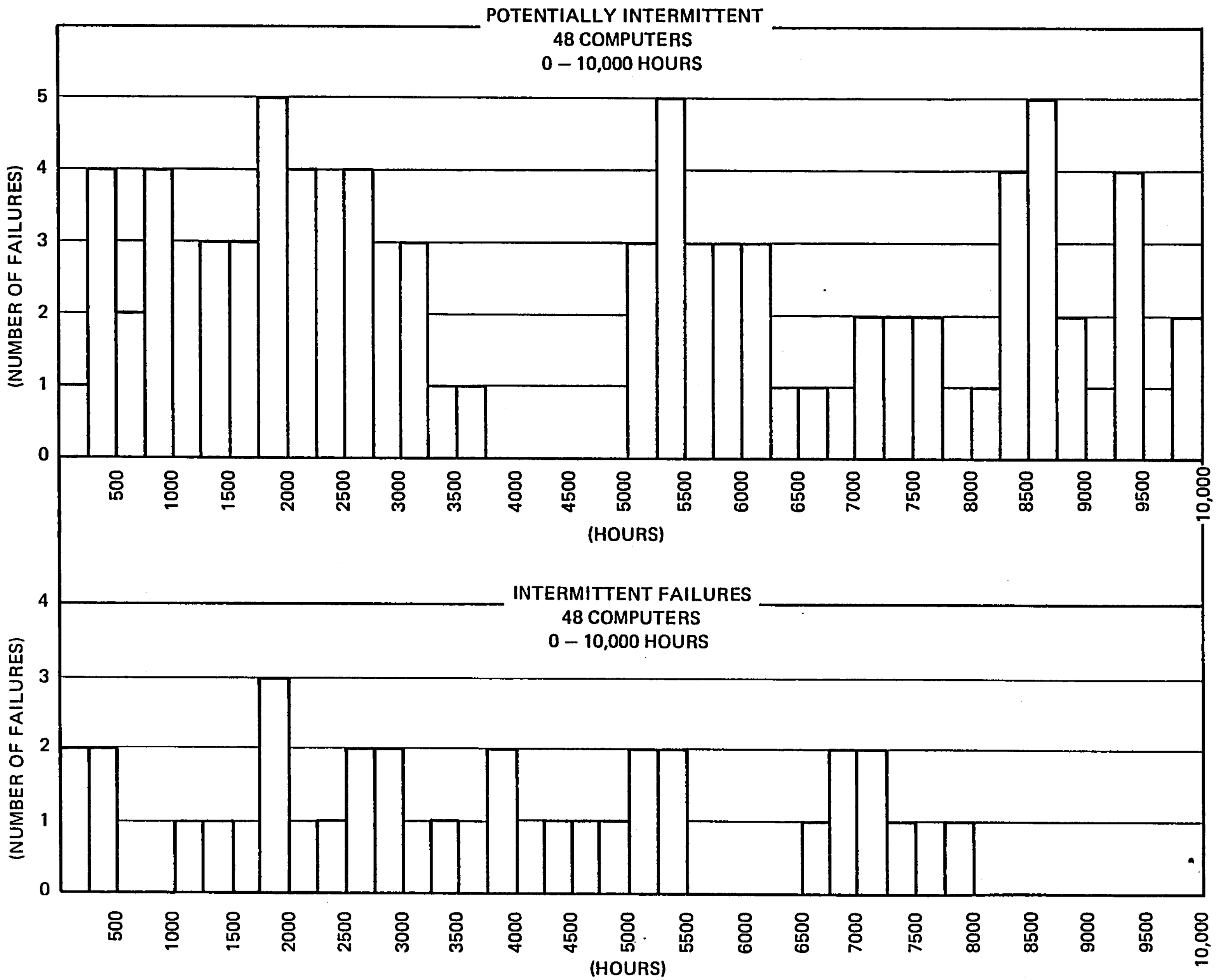

HARD FAILURES
116 COMPUTERS
0–5000 HRS.
(NUMBER OF FAILURES)
35
30
25
20
15
10
5
25 50 75 100 125 150 175 200 225 250 275 300 325 350 375 400 425 450 475 500
HOURS X 10

FIGURE 12



TOTAL FAILURES
116 COMPUTERS
0 – 5000 HOURS
(NUMBER OF FAILURES)
35
30
25
20
15
10
5
0
25 50 75 100 125 150 175 200 225 250 275 300 325 375 400 425 450 475 500
(HOURS X 10)

FIGURE 13.



POTENTIALLY INTERMITTENT
48 COMPUTERS
0 – 10,000 HOURS
(NUMBER OF FAILURES)
0
1
2
3
4
5
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500
10,000
(HOURS)
INTERMITTENT FAILURES
48 COMPUTERS
0 – 10,000 HOURS
(NUMBER OF FAILURES)
0
1
2
3
4
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500
10,000
(HOURS)

FIGURE 14.

HARD FAILURES
48 COMPUTERS
0 – 10,000 HOURS

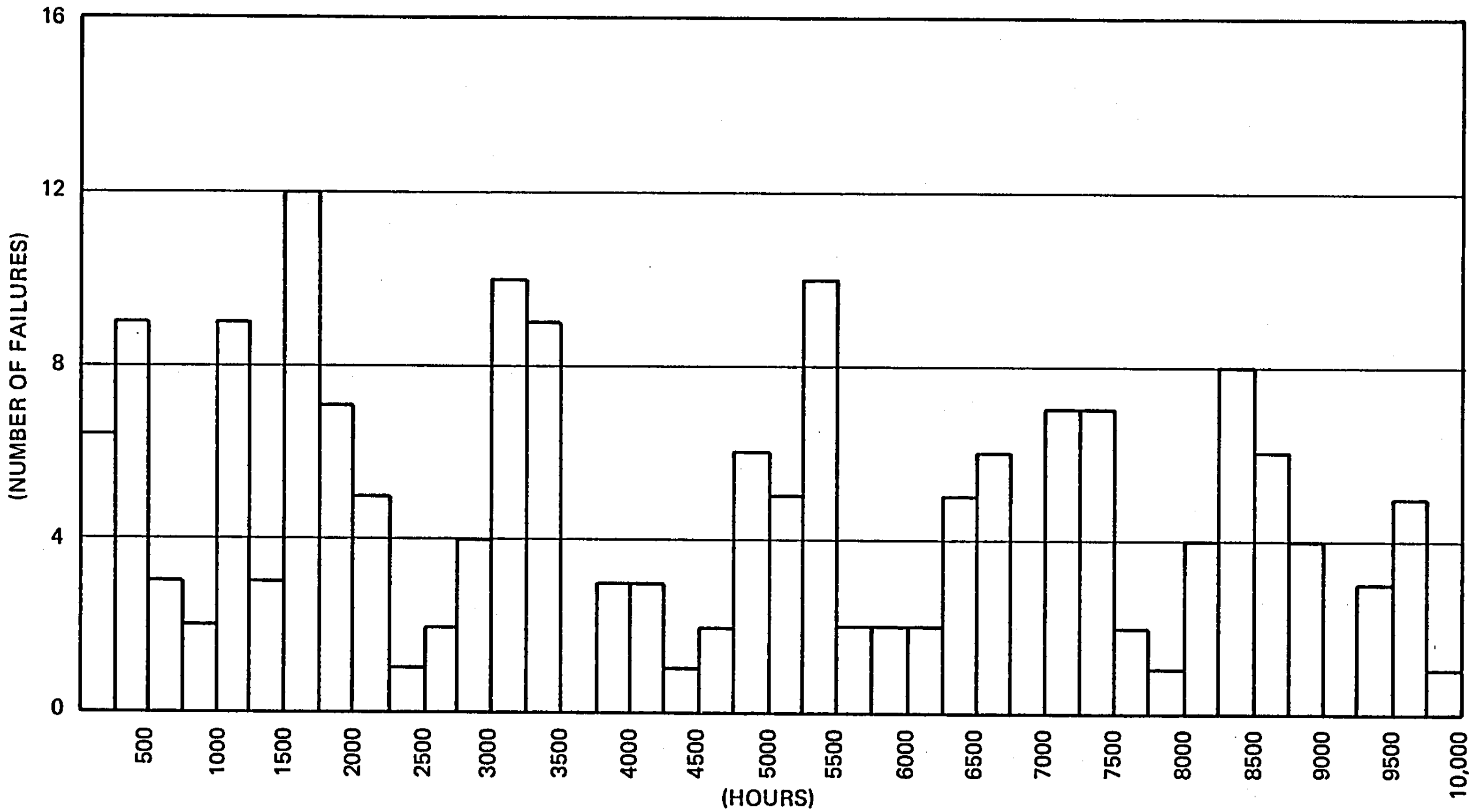


FIGURE 15.

TOTAL FAILURES
48 COMPUTERS
0 – 10,000 HOURS

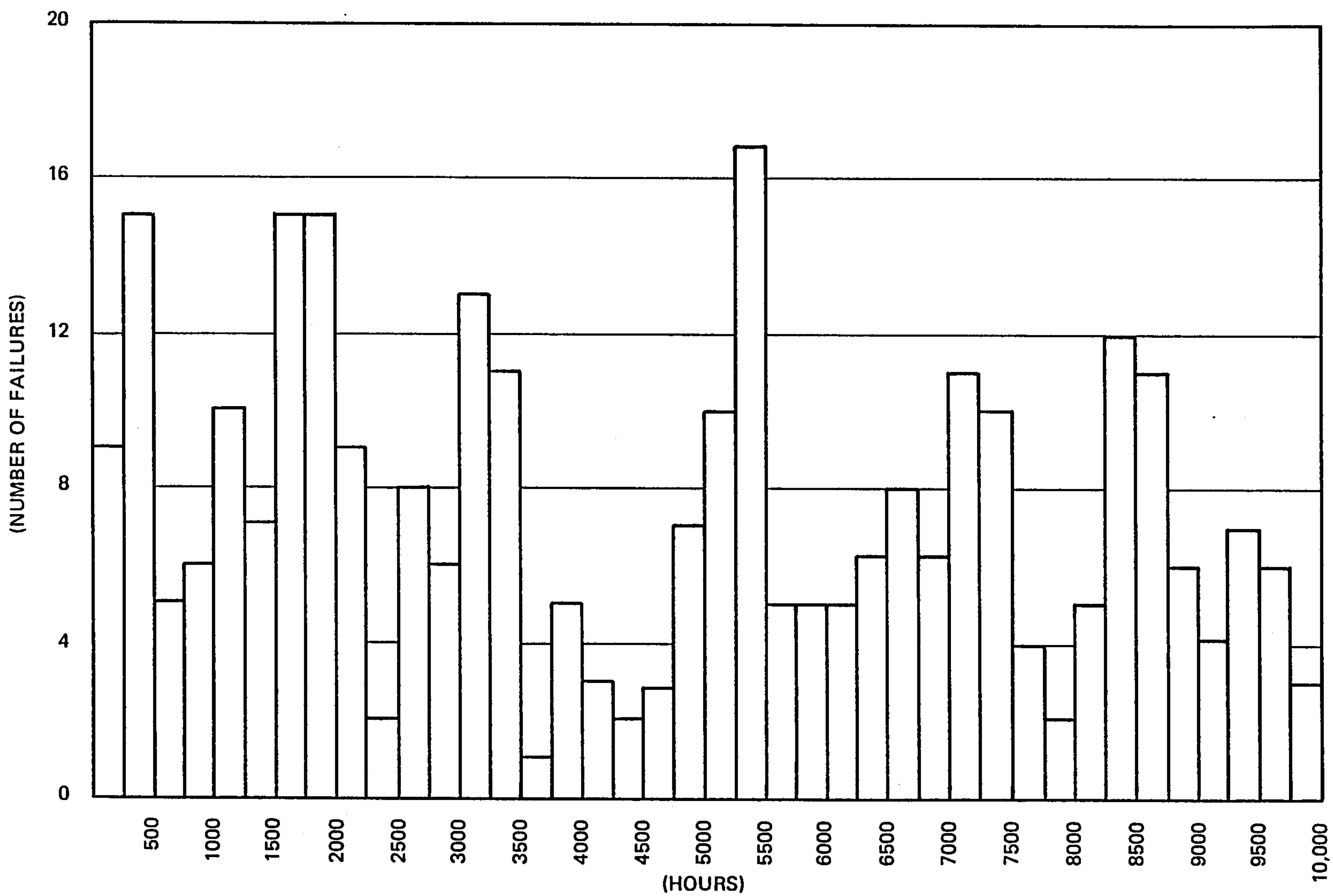


FIGURE 16.

5.2 Analysis

The failure data presented in these histograms was analyzed with respect to time to failure. Figure 17 lists the distributions functions for time to failure. In Appendix B.3, confidence intervals for the mean time to failure for the exponential distributions are given. The special form of the distribution for potentially intermittent failures in 0-10,000 hours (see Figure 14) suggests considering the time intervals 0-5000, 5000-8250, and 8250-10,000 separately when determining confidence intervals for the parameters; this is what was done in Appendix B.3.

For the Weibull distribution, confidence intervals for the parameters require the data to appear in ungrouped form which was not available. However, since the rank distribution of failures follows a beta distribution, confidence intervals for the fraction of failures are possible for the Weibull cases. At each time listed, there is a 90% chance that the fraction of failures that have occurred will be between the two values given. For example: In the potentially intermittent failures 0-2000 hours, one would expect by the time of 1000 hours between 27 and 32% of the failures to have occurred with a confidence of 90%.

5.3 Procedure

The first attempt in all cases was to fit an exponential distribution to the data. The estimate of the mean time to failure was total test time/total number of failures. The Chisquare test for goodness of fit was then used. For those distributions where the fit was poor, a Weibull distribution fit was attempted. To fit the Weibull, the data was ranked. Because the data was grouped, it was assumed that the last failure in each time interval occurred at the endpoint of the time interval.

The estimates of the Weibull shape and scale parameters were taken from the best fitted line of ln (Time to failure of cumulative ith failure) -vs-ln ln ((1-(Cumulative ith failure-.3)/(n+.4))-1). The criterion for testing the Weibull distribution fit was the Kolmogorov-Smirnoff Statistic.

For the 0-10,000 hour distributions the limitations of Chisquare goodness of fit test became apparent. The test is sensitive to the number of cells used, the expectation of each cell, the expectation varying from cell to cell, the sample size, and the testing of a continuous distribution. For the 0-10,000 hour intermittent, it was difficult to obtain a constant expectation from cell to cell or an expectation of at least 5 for the potentially intermittent failures. An alternative that is recommended in the literature is the Kolmogorov-Smirnoff test for goodness of fit. The theory has been developed, however, for ungrouped data and limited results are available in the literature for grouped data for 30 or less observations. There is a procedure to obtain a conservative upper bound on the Kolmogorov-Smirnoff statistic, D_n, when the data is already grouped. This procedure follows:

Let $\hat{F}_i$ refer to the observed cumulative distribution value of the ith cell and F_i the fitted cumulative distribution value at the right end point of the ith cell $i = 1,2, \ldots n$. Let $F_o = \hat{F}_o = 0$. Observe that for each cell and every x that is sampled from that cell:

$$\begin{aligned} &F(x) - \hat{F}(x) \le F_i - \hat{F}_{i-1} \quad \text{if } F(x) \ge \hat{F}(x) \\ (1)\quad &\hat{F}(x) - F(x) \le \hat{F}_i - F_{i-1} \quad \text{if } \hat{F}(x) \ge F(x) \end{aligned}$$

Hence for the ith cell:

$$(2)\quad \underset{x\,\in\,\text{ith cell}}{\text{Max}} \left\{ \max((F(x) - \hat{F}(x)),(\hat{F}(x)-F(x))\right\} \le \max((\hat{F}_i - F_{i-1}),(F_i - \hat{F}_{i-1})$$

But this can be rewritten as:

$$(3)\quad \underset{\substack{x\,\in\,\text{ith}\\ \text{cell}}}{\text{Max}} \left|F(x)-\hat{F}(x)\right| \le \text{Max}((F_i-\hat{F}_{i-1}),(\hat{F}_i-F_{i-1}))$$

So finally:

$$(4)\quad Dn = \sup_x \left|F(x)-\hat{F}(x)\right| = \underset{\substack{\text{all}\\ \text{cells}}}{\max} \left(\underset{x\,\in\,\text{ith cell}}{\max} \left|F(x)-\hat{F}(x)\right|\right) \le \underset{\text{all } i}{\max}(\max(F_i-\hat{F}_{i-1}),(\hat{F}_i-F_{i-1}))$$

If the right hand side of (4) is less than a tables value of the Kolmogorov-Smirnoff statistic, then clearly D_n is less by transitivity and the distribution would be acceptable as a good fit.

Figure 17 lists the fitted density functions that best describe the failure phenomenon of the computer. In addition we listed the values of the chisquare statistic and the upper bound for the Kolmogorov-Smirnoff statistic. The one situation where the Weibull and exponential fit was poor was the potentially intermittent 0-10,000 hour case. The data as seen in the histogram of Figure 14 suggests a multimodal distribution that repeats itself after 5000 and 8250 hours. A piecewise fitting by the potential distribution was attempted. The parameters were calculated by the statistic mentioned above. The constants a_1, a_2, a_3 are factors used to normalize the area under the pdf curve to 1. They are found by evaluating $x_i/n \div \int_{t_j}^{t_i} f(t)dt$ where x_i is the number of failures occurring in the time period (t_j, t_i), f is the density function for that time period and n is the total number of failures. The fit over the full 10,000 hours is acceptable.

5.4 Conclusion of Unit Study

The computers in each time period were in a repair mode, that is when a computer failed it was repaired and allowed to continue to run. The data was screened to insure that there was independence between failures in the same computer. The drawback is that the data was only available in grouped form. Another limitation is that the window size of units in the 0-10,000 hour time period, 48, was small and could lead to the pattern of failures that is seen in figures 14 and 15. This sample size magnitude for the

0-10,000 period makes the pdf's found for this period questionable. However, this sample size and their failures represent all the good data that Sperry Univac had available for this time period at the time this study was made.

The modeling of time to hard failures at the computer level was done when the data base was frozen and the failures of micro circuits was retrieved. The numbers of computers in each window are given in figure 18. The raw data of time to failure was available for this part of the study. The models of exponential or Weibull time to hard failure were rejected by the conventional tests of goodness of fit. Figure 17a summarizes the modeling that was done. It is seen that the MTBF is increasing as the age of the computer increases.

The pdf of fitted distribution of time to failure.
"The χ^2 and D values should be compared with the tables of Chisquare and Kolmogorov-Smirnoff."

Description Intermittent Failures	pdf	Test for Accepting pdf
0 - 2000 hr.	$\frac{1}{8243.9}\exp(-t/8243.9)$	$\chi^2(6) = 3.45$
0 - 5000 hr.	$\frac{1}{11,600}\exp(-t/11,600)$	$\chi^2(10) = 4.18$
0 -10000 hr.	$\frac{.9734}{(9409)^{.9734}}\, t^{-.0265} \exp-(t/9409)^{.9734}$	Kolmogorov-Smirnoff $D_{31} \leq .0943$
Potentially Intermittent		
0 - 2000 hr.	$\frac{.9305}{(4129.08)^{.9305}}\, t^{-.0695} \exp-(t/4129.08)^{.9305}$	Kolmogorov - Smirnoff $D_{66} \leq .0813$
0 - 5000 hr.	$\frac{1.23}{(3011.86)^{1.23}}\, t^{.23} \exp - \left(t/_{3011.86}\right)^{1.23}$	$D_{101} \leq .1102$
0 -10000 hr.	$a_1/6858.71 \exp(-t/6858.71) \quad 0 \leq t < 5000$	
	$\frac{a_2}{6000}\exp-\left(\frac{t-5000}{6000}\right) \quad 5000 \leq t < 8250$	
	$a_3/4941.2 \exp-\left(\frac{t-8250}{4941.2}\right) \quad 8250 \leq t < 10000$	
	$a_1 = .866905$	
	$a_2 = .7970245$	
	$a_3 = .730778$	$\chi^2(12) = 20.63$

Figure 17

Description Hard Failures	CDF F(+)	MTBF
0-2000 hr.	$-.0454 - .0523\left(\frac{t}{100}\right)^{.81}$	3663
0-5000 hr.	$-.1403 + .1069\left(\frac{t}{100}\right)^{.62}$	4860
0-10,000 hr.	$-.1015 + .0940\left(\frac{t}{100}\right)^{.64}$	5655

Figure 17a

6.0 Microcircuit Failure Data

6.1 General Information

The data base was studied according to the three time periods — 0-2,000, 5,000 and 10,000 hours. Due to the dynamic nature of the data reporting system, the numbers of computers in each window changed slightly from when the study at the unit level was made. The data base is composed of 196 computers that have run at least 2,000 hours. Of these computers, 139 have run at least 5,000 hours and 67 of these 139 have run at least 10,000 hours. The reference to failures in this paper refers to solid failures that have been categorized by Sperry Univac into intermittent, potentially intermittent, and hard classes. For brevity in the tables, these are referred to as I, II, and III respectively

There are 18 micro circuit types included in this study. These comprise all digital microcircuits of the computer of this study. The 18 types made up the population of 1,552,649 in the 0-2,000 hour period, 1,131,981 in the 0-5,000 hour period, and 528,577 in the 0-10,000 hour period. Of these 18 types, 8 types had no failures of any kind and were a total of 20,622 or 1.3% of the 1,552,649. For all failures, it was determined from the data base that no two microcircuits failed on the same card so that there is independence in the failures observed. The data base was also screened for failures that skewed the data, e.g. non-relevant overstress failures. Figure 18 summarizes the important information.

Time Period	# Of Computers	# Of IC	# Of Most Failing Digital Device	# Of Intermittents	# Of Pot.Int.	# Of Hard
0-2000	196	1552649	58043	11	7	26
0-5000	139	1131981	42249	27	10	44
0-10000	67	528577	19637	8	8	35

Total of 103 failures

Part hours : 3.1053×10^9 for 0-2000 hours

5.6599×10^9 for 0-5000 hours

5.2858×10^9 for 0-10000 hours

Computers in the 0-2000 group with no IC Failure - 629,370 IC's

Computers in the 0-5000 group with no IC Failure - 277,814 IC's

Computers in the 0-10000 group with no IC Failure - 91,764 IC's

Figure 18. Summary of Information

6.2 Analysis

The probability distribution functions for time to failure are in Figure 19. A comparison of the reliability functions according to the empirical, Weibull, and exponential distributions for each time period and failure type are in Appendix C. The criteria for determining, from the results in Appendix C.1, which of the two distributions, Weibull or exponential, appears in Figure 18 are the precision and maximum error from the empirical data these two distributions have. For example, the Weibull distribution for the 0-5,000 II group has a maximum error of 1.2 failures while the exponential has a maximum error of four failures. For the 0-2,000 I, 0-5,000 III and 0-10,000 III, the Weibull distribution has a greater maximum error than the exponential. However, this error occurs towards the end of the time periods and the Weibull gives a consistently better fit than the exponential. Therefore, the Weibull distribution was used in Table C.

The Appendix C.1 suggests that the rate of change of intermittent failure rates is increasing while the rate of change of the hard failure rate is decreasing. One reason that the failure rate for 0-10,000 I is increasing is because the first failure occurs after 1,000 hours and all occur within the next 3,600 hours. This contrasts with the earlier time periods that had failures observed as early as 100 hours. Additional data would be necessary for the 0-10,000 time period to determine if the failure rate of solid intermittents is increasing. Appendix C.2 gives

FAILURE TYPE	TIME PERIOD	DISTRIBUTION FUNCTION F(t)	DISTRIBUTION FUNCTION TYPE	HAZARD FUNCTION	MTTF (HR)
I	0-2,000	$1-\exp-\left(\frac{t}{9.254 \ X10^{11}}\right)^{.603}$	Weibull	$\frac{.603 \ t^{-.397}}{(9.254 \ X10^{11})^{.603}}$	$1.384 \ X10^{12}$
I	0-5,000	$1-\exp-\left(\frac{t}{209,626,111}\right)$	Exponential	$4.8 \ X10^{-9}$	$2.096 \ X10^{8}$
I	0-10,000	$1-\exp-\left(\frac{t}{455 \ 5450}\right)^{1.6017}$	Weibull	$\frac{1.6017 \ t^{.6017}}{(455 \ 5450)^{1.6017}}$	$4.08 \ X10^{6}$
II	0-2,000	$1-\exp-\left(\frac{t}{6.4228 \ X10^{10}}\right)^{.7}$	Weibull	$\frac{.7 \ t^{-.3}}{(6.4228 \ X10)^{.7}}$	$8.13 \ X10^{10}$
II	0-5,000	$1-\exp-\left(\frac{t}{4.8728 \ X10^{11}}\right)^{.6179}$	Weibull	$\frac{.6179 \ t^{-.3821}}{(4.8728 \ X10^{11})^{.6179}}$	$7.3325 \ X10^{11}$
II	0-10,000	$1-\exp-\left(\frac{t}{5.332 \ X10^{9}}\right)^{.8111}$	Weibull	$\frac{.8111 \ t^{-.1889}}{(5.332 \ X10^{9})^{.8111}}$	$5.98 \ X10^{9}$
III	0-2,000	$1-\exp-\left(\frac{t}{1.1943 \times 10^{8}}\right)$	Exponential	$8.4 \ X10^{-9}$	$1.1943 \ X10^{8}$
III	0-5,000	$1-\exp-\left(\frac{t}{153 \ 398 \ 200}\right)^{.964}$	Weibull	$\frac{.964 \ t^{-.036}}{(153 \ 398 \ 200)^{.964}}$	$1.56 \ X10^{8}$
III	0-10,000	$1-\exp-\left(\frac{t}{619 \ 088 \ 092}\right)^{.8451}$	Weibull	$\frac{.8451 \ t^{-.1549}}{(619 \ 088 \ 092)^{.8451}}$	$6.76 \ X10^{8}$

Figure 19. Summary of Predicted Distribution

the breakdown for the data in C.1 by vendor and C.3 has the breakdown by module function of quantities of micro circuits and failures. The vendor-failure relationship is not very strong. However, the function of input/output control has the most failures for all three failure categories. There is also a positive correlation of quantities of integrated circuits with quantities of failures.

Figure 20 has the calculations for the confidence intervals for the parameter of the exponential pdf. To determine confidence intervals for the parameters of the Weibull pdf is exceedingly more difficult. The procedure to follow could be that described by J. F. Lawless in the November 1978 issue of Technometrics.

6.3 Discussion of Significance

The procedure followed is typical of most studies of this nature. Screening was performed to get good independent data. With a type one error of .05, i.e., a significance level of .95, all time periods with the exclusion of 0-10,000 hr III (hard failures) would have the hypothesis of exponential pdf's accepted. The goodness of fit test that was used is that of Gnendenko which is the most powerful test for exponentiality for censored samples. A goodness of fit in censored samples for the Weibull pdf using the suggestions of Michael and Schucany of November 1979, Technometrics was done. For all cases, except 0-2,000 III and 0-10,000 III, the type one error is greater than .2 for rejecting the Weibull hypothesis. For 0-5,000 III the error would be

	Lower Limit	MTTF	Upper Limit
0-2000 I	2.75×10^8	2.823×10^8	1.74×10^9
0-5000 I	1.49×10^8	2.096×10^8	3.20×10^8
0-10,000 I	3.06×10^8	6.6×10^8	1.53×10^9
0-2000 II	2.66×10^8	5.17×10^8	1.41×10^9
0-5000 II	3.59×10^8	6.29×10^8	1.37×10^9
0-10,000II	3.66×10^8	6.6×10^8	1.53×10^9
0-2000 III	8.5×10^7	1.19×10^8	1.82×10^8
0-5000 III	9.73×10^7	1.28×10^8	1.78×10^8

Figure 20. 95% Confidence Intervals for Exponential pdf of Study

.05 and for 10,000 III it would be .01. Thus, there is good reason for accepting the Weibull pdf's.

The literature does not consider the problem of confidence when the magnitude of the population and failures observed are the size of our study. One could put little faith in the study if one considered the quantity failed--population size ratio of out study, 6.6×10^{-5}, as unrepresentative of a mortality study. On the other hand, the most pessimistic MTTF determined in the study suggests we should have to wait 328 years to have 38% of the devices fail. Another factor that mades the conclusions of this study doubtful is the evolving state of the art. The micro-circuits are constantly improving in reliability. The computer we ship today has a MTBF that is greatly improved over the "same" computer that was used in this study. Taking all of these factors into account, this study reflects the current state of the art of SSI digital devices operating in the field.

7.0 Conclusions

An intermittent failure is a detected malfunction of a logic net which resumes normal operation prior to the time needed to isolate the malfunctioning device. Due to the impracticability of having Sperry Univac's customers record the manifestation of intermittent failures, the phenomenon is not currently in Sperry Univac's reporting system. However, Sperry Univac engineers have determined which failure mechanism could be intermittent before they go hard and are reported.

To study the failure phenomenon three time periods — 0-2000, 0-5,000, and 0-10,000 hour, were established, and three non-exclusive groups of computers were determined. These computers were in a repair environment. Failures in the study at the computer level included non-microcircuit devices. The best fitting distributions of time between intermittent failures are exponential for the 2000 and 5000 hour time periods. The distribution is Weibull for the 10,000 hour time period. The confidence intervals for MTBF indicate that the MTBF increases as the time period increases. This suggests that the occurence of intermittent failures is more frequent in the early life of the computer. The potential intermittent failure class shows a Weibull distribution of time between failure in the 2000 and 5000 hour time period. The failure rate for potential intermittents is increasing as the life of the computer increases. The 10,000 hour time period appears to have a trimodal distribution for potentially intermittent failures. This may be due to the small number of computers in this time period.

For the same three time periods, a study of the digital micro circuits of the selected computer was made. The best fitting distributions for time to intermittent failure indicates that the rate of change of the intermittent failures rate is increasing. This means that a digital microcircuit is more likely to experience intermittent failure as the circuit gets older. The potential intermittent failure class shows a Weibull distribution of time to failure with a decreasing failure rate in all three time periods. The hard failure class shows the opposite phenomenon of the intermittent failure class. The rate of change of the hard failure rate is decreasing, which means the microcircuits are less likely to experience hard failures as they get older. These results apply up to an age of 10,000 hours for the selected computer and the microcircuits.

The data for the digital microcircuits occur in Type I censored form. Methods that are discussed in the literature regarding goodness of fit for censored samples were used. For all failure classes and time periods, with the exception of the 0-10,000 hour hard failure case, either the exponential or the Weibull distribution could be used as models. The final list of pdf's in Figure 18 is based upon an examination of Appendix C for the precision and accuracy of the goodness of fit. There is a positive correlation (.84) between the number of microcircuits in a module and the number of intermittent failures that module type has. The distribution of microcircuit intermittent and potentially intermittent failure, according to vendor is not uniform. One vendor who supplied 1.6 percent of the microcircuit population had 66.7 percent of the intermittent failures.

It is questionable whether the available data regarding the number of failures, the time periods, and the populations of microcircuits are adequate to establish accurate predictability. After 10,000 hours, only .0096 percent of the population to this time period have experienced a failure. It would require, based upon the highest failure rate found, 29.9 years to have one percent of this population fail.

8.0 References

1. A. Stuart, M. Kendall "Advanced Theory of Statistics Volume 1" rev. ed. 1958
2. Bernard Lindgren "Statistical Theory" 3rd ed. 1976 MacMillan Publishing Co.
3. A. Pettit and M. Stephens "Kolmogorov-Smirnoff Goodness of Fit Statistic with Discrete and Grouped Data" Technometrics Volume 19, Number 2, 1977
4. Mann, Schafer, Singpurwalla "Methods for Statistical Analysis of Reliability and Life Data" John Wiley and Sons, 1974
5. Michael and Schucany "A New Approach to Testing Goodness of Fit for Censored Samples" Technometrics Vol. 21, No. 4, November 1979
6. J. F. Lawless "Confidence Interval Estimation for the Weibull and Extreme Value Distribution" Technometrics, Vol. 20, No. 4, November 1978

List of Appendices to

NASA Report NAS1-15574

SPERRY UNIVAC

APPENDIX A.1

EQUIPMENT UTILIZATION REPORT

EQUIPMENT	PROJECT	UNIVAC SERIAL NUMBER	CUSTOMER SERIAL NUMBER

REPORT PERIOD			
DATE SUBMITTED	DATE STARTED	DATE ENDED	RUNNING TIME METER USE RTM ON POWER SUPPLY
LOCATION	SUBMITTED BY		RTM END ________ RTM START ________ RTM TOTAL

TAPE TRANSPORT RUNNING TIME METER READINGS (IF APPLICABLE)

TT NO.	S/N	RTM	TT NO.	S/N	RTM	TT NO.	S/N	RTM	TT NO.	S/N	RTN

EQUIPMENT FAILURES

MODULE	S/N	RTM	PART NUMBER	DATE OF FAILURE	DOWNTIME	FMR NUMBER	NOTE

SIGNIFICANT EVENTS AND ACCOMPLISHMENTS DURING REPORT PERIOD:

UNRESOLVED PROBLEMS:

NOTES:

OPERATIONAL STATUS:

☐ OPERATIONAL ☐ LIMITED ☐ INACTIVE ☐ TRANSFERRED ☐ STORAGE ☐ DOWN

DISTRIBUTION: 1. white – FIELD ENG. TECH. SUPPORT GROUP 2. yellow – QUALITY PROGRAM GROUP
3. pink – FIELD ENG. MTC. SUPPORT GROUP 4. g'rod – ORIGINATOR

UD1-3713

SPERRY UNIVAC

APPENDIX A.2

FAILURE/MALFUNCTION REPORT

1 FMR NO. D 53689 | 2 CI 0

WHAT FAILED

3 PR | 4 CL | 5 SITE | 6 PROJ | 7 FAIL DATE Y Y M M D D | 8 CABINET TYPE | 9 CAB S/NO. | 10 ETM HOURS | 11 REPAIR MIN | 12 TYPE REP'T

12 TYPE REP'T: 1 PRE FAT, 2 FAT, 8 FAN OUT, 19 ALL EQUIP, 11 TEMP, 32 RETROFIT, 21 BURN IN, 26 QUAL, 25 DEBUG, 27 SPARES, 7 COMP, 31 SCREEN, 22 CHECKOUT, ☐

13 TYPE FAILURE: P PRI, S SEC, A ADJUST, M MAINT, B BAD SP, I INTERMIT, W WEAR, ☐

14 CHAS TYPE | 15 CHAS S/NO | 16 SUBA TYPE | 17 SUBA S/NO. | 18 SUBA REF | 19 SUB ASSEMBLY PART NUMBER | 20 DASH | 21 REPL S/NO.

22 REF DOC NO. | 23 CI 1 | 24 COMP TYPE | 25 COMP REF | 26 COMPONENT PART NUMBER | 27 DASH | 28 VEN | 29 DATE CODE Y Y W W | 30 FAIL CODE | 31 RES | 32 REPORTED BY: EMPLOYEE NO.

35 ADDITIONAL DATA

33 LOCATION OR SITE | 38 CONTRACT NUMBER | EMPLOYEE NAME

WHAT WAS THE TROUBLE

36 A. FAILURE DESCRIPTION B. ACTION TAKEN C. EFFECT OF ACTION D. MAINT. PROBLEMS

CHECK (√) IF YES

- ☐ DIAG DETECT
- ☐ DIAG ISOLATE
- ☐ LOAD FAILURE
- ☐ HEAT SENSITIVE
- ☐ SHOCK SENSITIVE
- ☐ INTERMITTENT
- ☐ FAILURE VERIFIED
- ☐ SPARE AVAILABLE
- ☐
- ☐
- ☐
- ☐
- ☐

(ORIGINATOR – DO NOT WRITE BELOW THIS LINE)

FAULT FAILURE/REPAIR ANALYSIS

37 ANALYST NAME AND/OR EMPLOYEE NUMBER | Y Y M M D D

UDI-3180 (REV. 8/76)

WHITE – Quality/Reliability Programs

CANARY – Customer Rep. or – to Quality Support for Return to Originator

APPENDIX A.3

SPERRY UNIVAC
COMPUTER SYSTEMS

FAILURE/MALFUNCTION REPORT

UDI-3180 (Rev. 8/76)

Originate the Failure/Malfunction Report (FMR) for each repair action, failure, or malfunction that involves a part, sub-assembly, chassis or unit of Univac equipment. It is the responsibility of the person who makes the repair, replacement or discovers a malfunction to originate the FMR. The form is divided into three sections: (1) WHAT FAILED – describes what failed, where, when and who originated the form; (2) WHAT WAS THE TROUBLE – details what happened and what was done to correct the problem; and (3) FAULT-FAILURE/REPAIR ANALYSIS – describes the mode and cause of the failure.

The originator fills in the first two sections. Print the data using ball point pen to make the data clear on all carbon copies. Retain the goldenrod copy of the form and forward the FMR (3 copies or 2 if Customer Rep. copy is pulled on site) as listed:

NO PART INVOLVED
MAILING ADDRESS

SPERRY UNIVAC DSD, FIELD ENGR., MS M2A01
P.O. BOX 3525
ST. PAUL, MINN. 55165

FMR WITH PART
SHIPPING ADDRESS

SPERRY UNIVAC DSD, RETURNED GOODS CRIB
2750 WEST 7TH BLVD.
ST. PAUL, MINN. 55116

DETAILED INSTRUCTIONS FOR ORIGINATING THE FMR FORM

(1) WHAT FAILED SECTION

Place the hardpaper flap below the FMR set being filled out to prevent spoiling the sets below. Enter each digit clearly in the allotted space, as this data goes directly to Computer Data Bank via Scope Input. Identify the letter I as "I"; numberic 1 as "1"; the letter O as "Ø"; numberic zero as "0"; the letter S as "S"; the letter U as "U"; the letter Z as "Z"; the letter J as "J"; and capitalize all other letters. Do not enter any more letters or digits than a block allows or use any codes not authorized by this procedure. Enter only the data in each block for which information is available using the codes contained in the code tables. If a code is not available, enter the information in Block 36. Enter in these blocks:

Block No.	Block Title	Explanation
6	PROJ.	Project code (See codes – Block 6).
7	FAIL DATE	Date failure was detected.
8	CABINET TYPE	Sperry Univac cabinet type number.
9	CAB S/N	Sperry Univac Manufacturing serial number.
10	E.T.M. (HOURS)	Elapsed Time Meter reading to nearest hour.
11	REPAIR MIN	Time to repair in minutes – isolate, repair and verify – no logistics
12	TYPE REPORT	Type of report code (See codes if not preprinted.)
13	TYPE OF FAILURE	Check applicable block.
14	CHASSIS TYPE	Chassis type designation or code (See codes – Block 14).
15	CHASSIS S/N	Sperry Univac Manufacturing serial number.
16	SUBA TYPE	Subassembly type code (See codes – Block 16).
17	SUBA S/N	Sperry Univac Manufacturing serial number.
18	SUBA REF.	Reference designation (position) from which failed subassembly was removed.
19	SUBASSEMBLY PART NUMBER	Sperry Univac part number of failed subassembly.
20	DASH	Sperry Univac dash number of failed subassembly.
21	REPL S/N	Serial Number of the replacement item.
22	REF DOC NO.	Associated FMR/FR/FCO/EIR, Etc.
24	COMP. TYPE	Component or part type code when component or part is removed (See codes – Block 24).
25	COMP. REF.	Component or part references designation (position) of failed component or part.
26	COMPONENT	Sperry Univac part number of failed component or part when component or part is removed.
27	DASH	Sperry Univac dash number of failed component or part.
28	VEND. CODE	Fill in vendor name in Block 36 if applicable.
29	DATE CODE	Vendor date code as applicable when components or parts are removed.
32	REPORTED BY	Employee number of person originating FMR.
33	LOCATION OR SITE	Name of location or site where failure occurred.
38	CONTRACT NUMBER	Contract number covering unit on which maintenance or testing is performed.
	EMPLOYEE NAME	Initials and last name of person originating FMR.

NOTES: 1. When Manufacturing serial or type numbers are not available, enter customer nomenclature and serial number in Block 36.
2. Originator does not make entries in Blocks 3, 4, 5, 28, 30, 31, and 35. Make entries in Blocks 24 through 29 only when repairs occur at the component/part level.

(2) WHAT WAS THE TROUBLE SECTION

A. **Failure Description** – Fill in a brief description of the symptoms of failure, operation routine, test and debugging procedure, errors noted, or other failure conditions observed. Give sufficient facts about the failure to adequately reconstruct the failure conditions for each level of assembly.

B. **Action Taken** – Fill in what was done to isolate this failure/malfunction and to repace or adjust the equipment to remove the problem. Trouble shooting notes such as switching of subassemblies, running diagnostic routines, testing for open or shorted pins, etc., are extremely helpful.

C. **Effect of Action** – Fill in what tests were run following the replacement of a failed part indicating the equipment is again operational. Also note part or assembly disposition, e.g., scrap, returned for analysis and/or repair with FMR.

D. **Maintenance Problems** – Enter problems which were encountered during this maintenance action. Notes as to availability of spares, replacements, damage, inadequate tools, and troubles in disassembling are helpful for future design considerations.

Appendix A.4. Field Failure Report Forms

SPERRY UNIVAC

EQUIPMENT MALFUNCTION REPORT

0 EQUIP NAME	33 SITE/LOCATION	1 EMR NUMBER L05855

3 PR	4 CL R N	5 SITE	6 PROJ	7 FAIL DATE Y Y M M D D	8 CABINET TYPE	9 EQUIP S/N	10 ETM HOURS	11 REPAIR MIN.	12 REPAIR TYP EM PM FC IC	13 TYPE OF FAILURE PRI SEC

14 MOD/CHAS TYP	15 MOD/CHAS S/N	16 SUBA TYPE	17 SUBA S/N	18 SUBA REF	19 SUBASSEMBLY PART NUMBER	20 DASH	21 REPLACEMENT S/N

22 RELATED EMR	38 PART TYPE	39 PART NUMBER	40 DASH	32 NAME

36 PROBLEM COMMENTS:

CHECK (√) IF YES

- ☐ DIAG DETECT
- ☐ DIAG ISOLATE
- ☐ LOAD FAILURE
- ☐ HEAT SENSITIVE
- ☐ SHOCK SENSITIVE
- ☐ INTERMITTENT
- ☐
- ☐

FAILURE ANALYSIS DATA

2 CI	24 COMP TYPE	25 COMP REF	26 COMPONENT PART NO.	27 DASH	28 VEND CODE	29 DATE CODE Y Y W W	30 FAIL CD	31 RES	37 ANALYST EMPL NO.	

35 ADDITIONAL DATA

FAILURE ANALYSIS

DETAILED INSTRUCTIONS

EMR INSTRUCTIONS

COMPLETE ALL OPEN BLOCKS AS FOLLOWS (FRONT SIDE ONLY)

BLK. NO.	BLK TYPE	EXPLANATION
0	EQUIP NAME	Enter the equipment name, e.g., UYK-20, UYK-7, CP901, etc.
1	EMR NO.	Equipment Malfunction Report Number.
3	PR	Part Returned Y for YES, N for NO.
5	SITE CODE	Site Code – Enter the unique number for each site which can be obtained from Sperry Univac, STP
7	FAIL DATE	Enter the date of the failure.
9	EQUIPMENT S/N	Equipment Serial Number – Enter the complete customer serial number from the equipment nameplate.
10	ETM HRS	Module Elapse Time Meter – Enter the ETM readings of the module in which the failure occurred. If there is only one ETM, enter that reading, e.g., UYK-20.
11	REPAIR TIME	Enter the actual time to effect the repair, in minutes, NOT inclding parts acquisition.
12	REPAIR TYPE	Check one of the blocks. EM – Emergency Maint., PM – Preventive Maint., FC – Field Change Order, IC – Installation and Checkout.
13	TYPE OF FAILURE	Check one for the type of failure. PRI – Primary Failure, SEC – Secondary Failure.
14	MOD/CHASSIS TYPE	Chassis Type. CPU – Central Processor Unit, IOC – Input/Output Controller, IOA – Input/Output Adapter, MEM – Memory, DDM – Double Density Memory, CAB – Cabinet, TS – Test Set, PS – Power Supply, MP – Maintenance Panel, ROCU – Remote Operator Console Unit.
15	MOD/CHASSIS S/N	Chassis Serial Number – Enter the serial number of the module the failure occurred in.
16	SUBA TYPE	Enter subassembly type, i.e., PC.
17	SUBASSY S/N	Enter Serial Number of the failed SUBASSY.
18	SUBASSY REF	Enter the location of the failed SUBASSY, e.g., J32C.
19	SUBASSY PART NO.	Enter the Univac part number for the failed major assembly not including dash number.
20	DASH	Enter the dash number of the failed item in Block 19.
21	REPLACEMENT S/N	Enter the replacement Part/Assy Serial No.
22	RELATED EMR NO.	Use only if secondary failure.
32	NAME	Name of the individual making this report. If feedback is desired include mailing address on the reverse side of the first copy.
33	SITE/LOCATION	Enter the name of the site and geographic location.
36	PROBLEM COMMENTS	Use this space for a narrative description of the failure to include problem description, how the problem was isolated (diagnostics, etc.), corrective action, and any difficulties in isolating the malfunction. If FCO or ECP installation, include the change type and number or any other unusual circumstances.
38	PART TYPE	Enter part type, e.g., RES for Resistor, IC for Integrated Circuit.
39	PART NO.	Enter the part number of the failed part (component) entered in Block 38.
40	DASH NO.	Enter a 3-digit dash number.

APPENDIX B.1

FAILURE DATA ACCORDING TO UNITS

	Intermittent			Potentially Intermittent			Total		
	0-2000	0-5000	0-10000	0-2000	0-5000	0-10000	0-2000	0-5000	0-10000
250	5	2	2	12	5	1	30	15	9
500	4	2	2	11	9	4	44	36	15
750	4	3	0	6	4	2	20	16	5
1000	6	3	0	16	14	4	39	29	6
1250	4	1	1	6	5	0	38	25	10
1500	6	5	1	3	3	3	21	18	7
1750	7	2	0	5	4	3	36	21	15
2000	5	2	3	7	6	5	27	18	15
2250		2	0		8	4		26	9
2500		2	1		3	0		17	2
2750		4	2		9	4		19	8
3000		3	2		2	0		13	6
3250		2	0		6	3		25	13
3500		2	1		4	1		26	11
3750		2	0		3	1		38	1
4000		2	2		4	0		11	5
4250		4	0		3	0		16	3
4500		2	1		1	0		8	2
4750		4	1		3	0		13	3
5000		1	1		5	0		11	7
5250			2			3			10
5500			2			5			17
5750			0			3			5
6000			0			3			5
6250			0			3			5
6500			0			1			6
6750			1			1			8
7000			2			0			6
7250			2			2			11
7500			1			2			10
7750			0			2			4
8000			1			0			2
8250			0			1			5
8500			0			4			12
8750			0			5			11
9000			0			2			6
9250			0			0			4
9500			0			4			7
9750			0			0			6
10000			0			2			3

APPENDIX B.2

FAILURE TOTALS BY CATEGORY

	0 - 2000	2000 - 5000	5000 - 10000	Total
Intermittent	41	30	11	82
Potentially Intermittent	66	51	43	160
Hard	148	142	89	379
Totals	255	223	143	621

APPENDIX B.3
Confidence Intervals of Parameters of Table 16

Description	90% C.I.	95% C.I.
Intermittent Failures 0-2000 hour	(6287 , 11193)	(6014, 11829)
Intermittent Failures 0-5000 hour	(9184, 14885)	(8767, 15630)
Potentially Intermittent (0-5000 hr)	(4873, 6830)	(4778, 7070)
Potentially Intermittent 0-10,000 hours		
0- 5,000 hours	(5302, 9277)	(5051, 9846)
5000 - 8250	(4478, 8562)	(4227, 9186)
8250 - 10000	(3373, 7479)	(3157, 8172)

Potentially Intermittent n = 169
0 – 2000 hr.

Time	5% Rank	95% Rank
250	.0408	.119
500	.0947	.1807
750	.1234	.2208
1000	.2105	.3229
1250	.2245	.3622
1500	.2578	.3815
1750	.288	.413
2000	.3263	.4567

Intermittent Failures n = 48

0 - 10,000

Time	5% Rank	95% Rank
250	.01	.09
500	.03	.15
750	.03	.15
1000	.03	.15
1250	.04	.18
1500	.06	.21
1750	.06	.21
2000	. 1	.28
2250	. 1	.28
2500	.12	. 3
2750	.15	.35
3000	.19	.39
3250	.19	.39
3750	.20	.42
4000	.24	.46
4250	.24	.46
4500	.26	.48
4750	.27	. 5
5000	.29	.52
5250	.33	.56
5500	.37	.61
5750	.37	.61
6000	.37	.61
6250	.37	.61
6500	.37	.61
6750	.39	.62
7000	.43	.66
7250	.47	. 7
7500	.49	.72
8000	.51	.74
8250	.51	.74
8500	.51	.74
8750	.51	.74
9000	.51	.74
9250	.51	.74
9500	.51	.74
9750	.51	.74
10,000	.51	.74

APPENDIX C.1
COMPARISON OF DISTRIBUTONS

TIME FAIL	OBSV. RELIABILITY	WEIBULL RELIABILITY	EXPONENTIAL RELIABILITY	OBSV. SURVIVORS	WEIBULL SURVIVORS	EXPONENTIAL SURVIVORS
			0-2000 I			
100	.99999871	.99999901	.99999964	1552647	1552647.4	1552648.4
289	806	814	897	46	46.1	47.4
497	742	742	823	45	44.9	46.3
616	678	706	781	44	44.4	45.6
1017	613	603	639	43	42.8	43.4
1375	549	524	512	42	41.6	41.4
1450	484	508	486	41	41.3	41
1843	420	432	347	40	40.1	38.8
1938	355	414	313	39	39.9	38.3
1983	291	406	297	38	39.7	38
			0-5000 I			
100	.99999823	.99999881	.99999952	1131979	1131979.6	1131980.4
289	734	744	862	78	78.1	79.4
455	646	644	782	77	76.9	78.5
497	558	620	762	76	76.7	78.3
616	469	556	706	75	75.9	77.6
1017	381	361	514	74	73.7	75.5
1375	293	204	344	73	72	73.5
1843	204	016	120	72	69.8	71.0
1938	116	.99998979	075	71	69.4	70.5
1983	028	962	054	70	69.2	70.2
2268	.99998939	855	.99998918	69	68	68.7
2520	851	764	797	68	67	67.3
2622	763	728	749	67	66.6	66.8
2799	674	666	664	66	65.9	65.8
2802	586	665	663	65	65.8	65.8
3165	498	542	490	64	64.5	63.9
3428	409	455	364	63	63.5	62.4
3911	321	299	134	62	61.7	59.8
3949	233	287	116	61	61.6	59.6
4037	144	260	074	60	61.3	59.2
4142	056	227	024	59	60.9	58.6
4561	.99997968	098	.99997824	58	59.4	56.3
4603	879	086	804	57	59.3	56.1
4835	791	016	693	56	58.5	54.8
4840	703	015	691	55	58.5	54.8
4992	761	.99997969	618	54	58	54
			0-10000 I			
1017	.99999810	.99999858	.99999846	528576	528576.2	76.1
1938	621	601	706	75	74.9	75.4
1983	432	586	699	74	74.8	75.4
2622	243	353	603	73	73.5	74.9
2799	054	282	576	72	73.2	74.7
3911	.99998864	.99998773	408	71	70.5	73.8
3949	675	753	402	70	70.4	73.8
4603	486	407	303	69	68.5	73.3

0-2000 II

TIME FAIL	OBSV. RELIABILITY	WEIBULL RELIABILITY	EXPONENTIAL RELIABILITY	OBSV. SURVIVORS	WEIBULL SURVIVORS	EXPONENTIAL SURVIVORS
186	.99999935	.99999894	.99999964	1552648	1552647.3	1552648.4
195	806	890	962	46	47.3	48.4
291	742	855	943	45	46.7	48.1
919	677	677	822	44	43.9	46.2
952	613	669	816	43	43.8	46.1
1698	549	503	671	42	41.2	43.9

0-5000 II

TIME FAIL	OBSV. RELIABILITY	WEIBULL RELIABILITY	EXPONENTIAL RELIABILITY	OBSV. SURVIVORS	WEIBULL SURVIVORS	EXPONENTIAL SURVIVORS
186	.99999911	.99999848	.99999967	1131980	1131979.2	1131980.6
195	734	844	965	78	79.2	80.6
291	646	800	485	77	78.7	80.4
919	558	593	837	76	76.3	79.1
952	469	584	831	75	76.2	79
1698	381	405	700	74	74.2	77.6
2729	293	203	517	73	71.9	75.5
2730	204	203	517	72	71.9	75.5
3149	116	129	443	71	71.1	74.4

0-10000 II

TIME FAIL	OBSV. RELIABILITY	WEIBULL RELIABILITY	EXPONENTIAL RELIABILITY	OBSV. SURVIVORS	WEIBULL SURVIVORS	EXPONENTIAL SURVIVORS
291	.99999810	.99999871	.99999955	528576	528576.3	528576.7
952	621	663	855	75	75.2	76.2
1698	432	461	743	74	74.1	75.6
2729	243	209	586	73	72.8	74.8
2730	054	208	586	72	72.8	74.8
3149	.99998864	111	523	71	72.3	74.4
5320	675	.99998641	194	70	69.8	72.7
5960	486	509	097	69	69.1	72.2

0-2000 III

TIME FAIL	OBSV. RELIABILITY	WEIBULL RELIABILITY	EXPONENTIAL RELIABILITY	OBSV. SURVIVORS	WEIBULL SURVIVORS	EXPONENTIAL SURVIVORS
287	.99999935	.99999770	.99999759	1552648	1552645.4	1552645.2
295	871	762	753	47	45.3	45.1
299	806	758	749	46	45.2	45.1
306	742	749	743	45	45.1	45
333	677	725	721	44	44.7	44.6
341	613	717	714	43	44.6	44.5
352	549	706	705	42	44.4	44.4
412	484	644	655	41	43.4	43.6
423	420	632	645	40	43.2	43.5
437	355	617	634	39	43	43.3
465	291	587	610	38	42.6	42.9
531	227	515	555	37	41.4	42
573	162	468	520	36	40.7	41.5
646	098	385	459	35	39.4	40.6
926	033	048	224	34	34.2	36.9
1000	.99998969	.99998955	162	33	32.7	36
1014	905	937	151	32	32.5	35.8
1020	840	929	145	31	32.3	35.7
1117	776	804	064	30	30.4	34.4
1162	711	746	027	29	29.5	33.8
1245	647	636	.99998957	28	27.8	32.8
1277	583	593	930	27	27.1	32.3
1620	518	122	643	26	19.8	27.9
1630	454	108	635	25	19.6	27.8
1698	389	012	578	24	18.1	26.9
1853	325	.99997789	448	23	14.6	24.9

0-5000 III

FAIL TIME	OBSV. RELIABILITY	WEIBULL RELIABILITY	EXPONENTIAL RELIABILITY	OBSV. SURVIVORS	WEIBULL SURVIVORS	EXPONENTIAL SURVIVORS
295	.99999911	.99999691	.99999753	1131980	1131977.5	1131978.2
299	823	687	749	79	77.4	78.1
306	734	680	743	78	77.3	78.1
341	646	644	714	77	76.9	77.7
352	558	633	705	76	76.8	77.6
373	469	612	687	75	76.6	77.4
423	381	562	645	74	76	76.9
437	293	548	634	73	75.8	76.8
465	204	521	610	72	75.5	76.5
573	116	414	520	71	74.3	75.5
646	028	342	459	70	73.5	74.8
926	.99998939	069	224	69	70.4	72.2
1000	851	.99998998	162	68	69.6	71.5
1014	763	984	151	67	69.5	71.4
1020	674	978	145	66	69.4	71.3
1117	586	885	064	65	68.3	70.4
1162	498	841	027	64	67.8	69.9
1277	409	731	.99998930	63	66.6	68.8
1620	321	404	643	62	62.9	65.6
1630	233	395	635	61	62.8	65.5
1698	144	330	578	60	62.1	64.9
1853	056	184	448	59	60.4	63.4
2032	.99998968	015	298	58	58.5	61.7
2065	879	.99997984	271	57	58.1	61.4
2333	791	732	046	56	55.3	58.8
2750	703	343	.99997697	55	50.9	54.9
2799	610	297	656	54	50.4	54.4
2843	526	256	619	53	49.9	54
2910	438	194	563	52	49.2	53.4
2971	349	137	512	51	48.5	52.8
3021	261	091	470	50	48	52.3
3032	173	080	461	49	47.9	52.2
3055	084	059	442	48	47.7	52
3116	.99996996	002	391	47	47	51.4
3146	908	.99996975	365	46	46.7	51.1
3426	819	716	131	45	43.8	48.5
3430	731	712	128	44	43.7	48.5
3561	643	591	018	43	42.4	47.2
3658	554	501	.99996937	42	41.4	46.3
4015	466	173	383	41	37.6	42.9
4218	378	.99995987	468	40	35.5	41
4342	289	873	364	39	34.2	39.8
4545	201	687	194	38	32.1	37.9
4736	113	513	034	37	30.2	36.1

0-10000 III

FAIL TIME	OBSV. RELIABILITY	WEIBULL RELIABILITY	EXPONENTIAL RELIABILITY	OBSV. SURVIVORS	WEIBULL SURVIVORS	EXPONENTIAL SURVIVORS
295	.99999810	.99999545	.99999804	528576	528574.5	528575.9
299	621	540	802	75	74.5	75.9
341	432	486	774	74	74.2	75.8
423	243	383	719	73	73.7	75.5
437	054	366	710	72	73.6	75.4
646	.99998864	118	572	71	72.3	74.7
952	675	.99998777	369	70	70.5	73.6
1020	486	703	324	69	70.1	73.4
1117	297	600	260	68	69.6	73
1277	108	432	154	67	68.7	72.5
1620	.99997918	083	.99998927	66	66.8	71.3
1630	729	073	920	65	66.8	71.2
1698	540	006	875	64	66.4	71
1853	351	.99997853	773	63	65.6	70.5
2065	162	647	632	62	64.5	69.7
2729	.99996973	022	192	61	61.2	67.4
2730	838	021	192	60	61.2	67.4
2786	594	.99996970	155	59	60.9	67.2
2843	405	917	117	58	60.7	67
3021	216	755	.99997999	57	59.8	66.4
3032	027	745	992	56	59.7	66.3
3149	.99995837	639	914	55	59.2	65.9
3426	648	391	731	54	57.9	65
3430	459	387	728	53	57.9	65
4218	270	.99995698	207	52	54.2	62.2
4342	081	591	124	51	53.6	61.8
4736	.99994891	255	.99996864	50	51.9	60.4
5405	702	.99994695	421	49	48.9	58.1
6269	513	.99993987	.99995849	48	45.2	55
7444	324	047	071	47	40.2	50.9
7709	135	.99992838	.99994895	46	39.1	50.0
8645	.99993946	110	275	45	35.2	46.7
9542	756	.99991424	.99993681	44	31.6	43.6
9610	567	372	636	43	31.4	43.3
9659	378	335	604	42	31.2	43.1

APPENDIX C.2 Proportion Breakdown of Microcircuit Types by Vendor

The 18 microcircuit types that were previously analyzed for pdfs of time to failure and which determined a study population of 1552649 relate to the vendor as follows:

PROPORTION BREAKDOWN BY VENDOR

VENDOR	Proportion of Population	Qty of Intermittent and Potentially Intermittent Failures	Proportion of Intermittent and Potentially Intermittent Failures
1	.2733	8	.205
2	.2933	3	.077
3	.3653	2	.051
4	.04	0	0
5	.0166	26	.667
25	.0075	0	0
78	.004	0	0

	Total Qty in Population	Proportion of Total Population	Proportion by Vendor					Failures by Vendor 0-2000 hr.					Failures by Vendor 2000-5000 hr.					Failures by Vendor 5000-10000 hr				
Vendor			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Microcircuit																						
1	272492	.1755	.206	.322	.472			1	0	0			3	0	0			0	0	0		
2	1055481	.6797	.276	.317	.407			1	3	0			0	0	0			0	0	0		
3	59011	.038	.546	.376			.078	2	0			9	0	0			10	0	0			1
4	69646	.045	.296	.141	.380		.183	0	0	0		3	0	0	1		3	1	0	1		

The remaining 14 part types had no failures of an intermittent and Potentially Intermittent nature and made up 6.19% of the population.

APPENDIX C.3

Quantity of Digital Microcircuits per Chassis

	IC Per Single Chassis	Total IC Population
Power Supply	7	1372
Input Output Controller	2544	432480
Input Output Adapter	246	57737
Central Processing Unit	3658	588938
Core Memory	781	412368
Film Memory	866	59754
TOTALS	8102	1552649

Grid of Microcircuit Failure by Chassis Function

	Intermittent	Potentially Intermittent	Hard
Power Supply	0	0	0
Input Output Controller	14	5	15
Input Output Adapter	0	0	13
Central Processor Unit	8	1	13
Core Memory	6	8	11
Film Memory	0	0	12

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA CR-159268		

4. Title and Subtitle	5. Report Date
Study of Intermittent Field Hardware Failure Data in Digital Electronics	June 1980
	6. Performing Organization Code
7. Author(s) Edward J. O'Neill and James R. Halverson	8. Performing Organization Report No.
	10. Work Unit No.
9. Performing Organization Name and Address Sperry Univac Univac Park P. O. Box 3525 St. Paul, Minnesota 55165	11. Contract or Grant No. NAS1-15574
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546	13. Type of Report and Period Covered Contractor Report
	14. Sponsoring Agency Code

15. Supplementary Notes

NASA Project Engineer, Salvatore Bavuso, Langley Research Center, Hampton, Virginia 23665

16. Abstract

This study involved the collection and analysis of data concerning intermittent failures in digital devices. The study was made using data from a computer which was designed for shipboard usage. The failure data consisted of actual field failures which were classified by failure mechanisms and their likelihood of having been intermittent, potentially intermittent, or hard. Each class was studied with respect to computer operation in the ranges of 0-2,000 hours, 0-5,000 hours and 0-10,000 hours. The study was done at the computer level as well as the microcircuit level (SSI Technology).

Results indicate that as age increases, the quasi-intermittent failure rate increases and the mean time to failure decreases.

17. Key Words (Suggested by Author(s))	18. Distribution Statement *
Intermittent failures Reliability Field Failure Data	Unclassified - Unlimited STAR Category 38

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	66	

End of Document