OPERATIONAL RELIABILITY OF KUIAMA SATELLITE EARTH STATION (1989-1995)

BY

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OCTOBER, 1996

CERTIFICATION

This thesis entitled "Operational Reliability of Kujama Satellite Earth Station" by Saidu Gorebe Abdullahi meets the regulations governing the award of the degree of Master of Science (Electronics and Telecommunications Engineering) of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DECLARATION

I, **Saidu Gorebe Abdullahi**, hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been presented in any previous application for a higher degree.

All quotations and sources of information as seen in this thesis are specifically acknowledged by means of references.

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DEDICATION

To The MAHANTA, the Living ECK Master. For teaching me that soul lives because of God's love for soul and as souls we are immortal beings.

ACKNOWLEDGMENTS

The first recognition must be given to Dr. (Engr.) B.G. Ishaku, my supervisor and academic grandfather. His invaluable suggestions, constructive criticism, corrections, and financial aids in turbulent moments, are deeply appreciated.

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ABSTRACT

The strategic status of Kujama Barth Station (KES) as the only international gateway in Northern part of Nigeria cannot be over emphasised, as any failure will result in interruption of communications, but also the partial isolation of a large part of the country from the "Global Village".

This thesis is concerned with the assessment of operational reliability of KES. Since reliability studies lean heavily on probabilty theorems, a compendium of relevant probability theorems were presented.

Outage data for KES were obtained and the operation of the earth station was modelled as a discrete state, continuous-time Markov process. Based on this model, a structured computer program was developed in Turbo Pascal and reliability parameters of the entire KES system and its major sub-systems were generated from the program for the period 1989 to 1995.

The results obtained were discussed and observations were made on operational reliability. The results were also persented in tabular forms and graphs, which establish the chronological trends in operational reliability of KES over the period under study. The optimum availability occurred in 1993 and the lowest availability in 1995.

Based on these observations and the conclusions arrived at, recommendations were presented including the failure event and action form suggested by the author.

It is hoped that the adoption of these recommendatios will help to improve the operational reliability of KES and ensure corporate perpetuity of NITEL Plc.

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LIST OF ACRONYMS

KES	Kujama (Satellite) Earth Station
AGREE	Advisory Group on Reliability of Electronic Equipment
1-out-n: G	The system is good if and only if at least 1 of its n elements are good.
IFRA	Increasing Failure Rate Average
MTTF	Mean time to failure
MTTR	Mean time to repair
MTBF	Mean time between failure
BB	Baseband
IEEE	Institute of Electrical and Electronics Engineers.
ITT	International Telephone and Telegraph (inc)
NITEL plc	Nigerian Telecommunications plc
BITE	Built - In Test Equipment
HPA	High Power Amplifier
LNA	Low Noise Amplifier
IMC	International Monitoring Centre.
INTELSAT	International Telecommunications Satellite Consortium.
CCIR	International Radio Consulltative Committee.

LIST OF SYMBOLS

Symbol	Equation or Table	Meaning
f(t)	3.1	Failure Probability Density function
Z(t)	3.1	Hazard rate.
R(t)	3.1	Reliability
λ	3.6	Failure rate
M(t)	3.9	Maintainability
μ	3.10	Repair rate
α	3.28	Availability
$\bar{\alpha}$		Unvailability
$W_1 \cup W_2$		Sum or union of events W_1 and W_2.
$W_1 \cap W_2$		Intersection of events W_1 and W_2.
$\varnothing$		Empty event
P(E)	A2	Probability of Occurrence of the event E
A>B		A is greater than B
Δ (δ)		Small increment
Σ		Summation
%		Percent

CHAPTER ONE

INTRODUCTION AND MOTIVATION

1.1 Introduction

Satellite Communication facilitates the closing of communications gap in rural areas of developing countries. There are many developing countries that have benefited from satellite communication, including Brazil, Indonesia and Mexico.

Natural and physical features in each of these countries created a great deal of problems in the establishment of telecommunications network. Brazil has an enormous territorial area, mostly jungle, making the installation of terrestrial links very difficult. Indonesia, a country consisting of thousands of islands scattered over a wide area in the Pacific Ocean, faces similar obstacles in the installation of terrestrial and submarine communications lines. Mexico has a variety of terrains, including mountains, jungles and deserts.

With the installation satellite communication however, these physical barriers no longer became problems and those countries are now enjoying an effective and reliablecommunication system. NITEL Plc. has a great interest in bringing telephone service to rural communities in Nigeria for both social and economic reasons. The extension of telecommunications infrastructures remote areas can be achieved easily via satellite communications.

Therefore satellite communication has created a quantum leap forward in long-distance communication, of which the earth station forms an essential part for a reliable and high-quality communication.

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Kujama Earth Station (KES) is the only international gateway to the Northern part of Nigeria. It is located in Chikun local government area of Kaduna state. Therefore failure of KES results in traffic interruption, which is tantamount to partial isolation of a large part of the country from the Global Village.

To avoid such a catastrophic situation, reliability assessment of KES is imperative. Also, such assessment is required because it:

(i) establishes chronological trends in reliability performance;

(ii) identifies weak subsystems needing immediate reinforcement;

(iii) establishes reliability indices which serve as a guide for future reliability assessments;

(iv) enables previous predictions to be compared with actual operating experience thereby facilitating reliability growth; and

(v) measures the effectiveness of current maintenance policy.

1.2 Thesis Motivation

Since the discussions in 1991 on the Global Information Infrastructures at the International Telecommunication Union plenipotentiary conference in Kyoto, Japan, the phrase *"information superhighway"* has come to stay. *Information superhighway* will hopefully bring the different people of the world closer by offering them, the ability to communicate easily. To derive optimum benefit from the *information superhighway*, highly reliable earth stations are required; which corroborates the need for reliability assessment.

Several studies on reliability evaluation of power systems have been carried out in the Department of Electrical Engineering, Ahmadu Bello University, Zaria [1,2,3], but no such work

has been done on long-distance communication. This thesis is therefore the first attempt in the department to undertake such a study in the area of telecommunications.

1.3 Problem Definition And Methodology

This investigation is concerned with the assessment of the operational reliability of Kujama Satellite Earth Station covering the period 1989 to 1995. Reliability indices such as MTTF, MTTR, MTBF, A, $\bar{A}$, etc are to be computed.

The objective of this thesis is achieved via the following sub-goals:

(i) collection of outage data from KES;

(ii) development of a computer program to process the data collected;

(iii) determination of the reliability indices for each year; and

(iv) the use of some reliability indices to plot bar charts and curves for visual representation of results.

1.4 Thesis Outline

The rest of the thesis is organised as follows

Chapter two reviews some important literature in reliability engineering and highlights reliability concepts and parameters. Hazard models are also presented.

Chapter three provides an abridged survey for the modus operandi of KES and program development using Turbo Pascal.

The results obtained are discussed in chapter four. Graphical illustrations of the results are presented.

Chapter five is devoted to conclusion and recommendations.

Reliability mathematics, Markov processes, and the program are attached as appendices.

CHAPTER TWO

RELIABILITY CONCEPTS AND PARAMETERS

Reliability engineering grew out of the demands of modern technology and particularly out of experiences in World War II with complex military systems. One of the first areas of reliability to be approached with mathematical sophistication was the area of machine maintenance,[4,5]. The techniques used to solve these maintenance problems grew out of successful experiences of A.K. Erlang, C. Palm and others in solving telephone trunking problems as reported by Baslow [39]. Erlang and Palm presented heuristic arguments to support the Poisson distribution as a limiting distribution for telephone calls [39], and finally Khintchine [6] and Ososkov [7] established rigorous mathematical proofs and provided necessary and sufficient conditions.

Applications of renewal theory to replacement problems were discussed as early as 1939 by Lotka [8]. Campbel [9] in 1941 also approached replacement problems using renewal theory techniques. Feller [10] is generally credited with developing renewal theory as a mathematical discipline.

In the late 1930s the subject of fatigue life in materials and the related subject of extreme value theory were being studied by Weibull [11], Gumbel [12], and Epstein [13]. In 1939 Weibull, a professor at the Royal Institute of Technology in Sweden, proposed the Weibull distribution, as an appropriate distribution to describe the breaking strength of materials. Later, Daniels [14], Birnbaum and Saunders [15] developed mathematical models that justified the assumptions made in respect of the normal and gamma distribution families respectively.

2.2 *The Formative Years*

The developmental period of reliability engineering for electronics applications began on 7th December, 1950 with the establishment of the Ad Hoc Group on Reliability of Electronic Equipment by the United States Air Force. The group was charged with the responsibility of increasing equipment reliability and reducing maintenance schedules. By late 1952 the United States Department of Defense had established the Advisory Group on Reliability of Electronic Equipment (AGREE). On 4th June, 1957, AGREE published its first report on reliability [16].

In 1951 Epstein and Sobel began work in the field of life testing which was to result in a long stream of important and influencial papers [17]. This work marked the beginning of the widespread assumption of the exponential distribution in life testing research. They justified their choice of the exponential distribution with the following short explanation [17].

"After some consideration and after discussion with electronics experts..... we decided to turn out initial efforts to ordered observations drawn from non-normal distributions. Specifically, we decided to study the case where the characteristic X being investigated has an exponential distribution with a density f (χ, θ) of the form

$$f(\chi,\theta) = (1/\theta)\ \exp(-\chi/\theta)\ \theta>0,\ \chi \geq 0" \quad [17]$$

Also, in 1951, W. Weibull published a paper [18] on the wide applicability of statistical distribution. Epstein and Sobel [17] contributed a paper on truncated life tests and Epstein followed it with another paper[19] on the same subject. This paper was the basis of the standard sequential reliability tests still in use. It also sets a precedence for mathematical sophistication which become a standard in reliability engineering.

The mathematically important paper of Moore and Shannon appeared in 1956 [20]. This paper was concerned with relay network reliability. Moore and Shannon derived impetus from

Von Neumann's attempt at describing certain operations of the human brain and the high reliability that has been attained by complex biological organisms. In the same year, a military handbook on reliability titled "Reliability Factors for Ground Electronic Equipment" was published by McGraw-Hill under the sponsorship of the Rome Air Development Centre (RADC). The mathematical section contained the bathtub shaped hazard-rate curve and a derivation of the familiar exponential function $R=\exp(-\lambda t)$ for reliability as a probability of survival with time when the hazard-rate is constant. It presented curves for computing the reliability of a redundant system for the simple case of *1-out-n:G* with no repair. Also in 1957, Weiss [21] introduced the use of semi-Markov processes to solve system maintainability problems.

In 1958 an elegant summation of the known mathematical results in renewal theory was presented by Smith [22]. Due to vibration problems encountered in new commercial jet aircraft, Birnbaum and Sauders [15] developed an ingenious statistical model for life lengths of structures under dynamic loading.

In 1961 research on coherent structures began with the paper by Birnbaum et al [23]. The publication "Mathematical Theory of Reliability" by Barlow and Proschan [24] stimulated much university research and was the first to treat the subject at a graduate level.

The Russian text on reliability by Gnedenko et al [25] was published in English translation in 1969. The emphasis was on maintenance and repair models using limiting probability techniques from queueing theory. The Moscow School of reliability under Prof. B.V. Gnedenko has consistently emphasized the connection between queueing theory and reliability application.

Also worthy of note is the book authored by Bazovsky "Reliability Theory and Practice" published by Prentice-Hall, New-York (1961) which is acknowledged for its good blend of theories and practice.

2.3 Reliability Emphasis Of The 1970S

The new engineering reliability emphasis in the 1970s was directed toward fault-tree analysis. This was motivated by nuclear power reactor safety considerations. The Fussel and Vesely paper [26] concerning the minimum cut-set algorithm, marked the beginning of efforts to avoid Monte Carlo methods for finding minimum cut-sets.

Reliability assessment was highly elucidated in a publication by Billinton, R and Allan, R.N, [27].

A line of shock model research began in 1973 with the publication of a paper titled "Shock Models and Wear Processes" by Esavay et al. This paper gave additional justification for theoretical interest in the class of life distributions referred to as Increasing Failure Rate Average (IFRA).

In 1974 Singh and Billinton [28] suggested methods of determining the frequency of failures of complex systems.

An excellent graduate textbook, "Statistical Theory of Reliability and Life Testing" by Barlow and Proschan was published in 1975. This book emphasized coherent systems and their reliability.

Of the many papers concerned with maintenance and replacement policies, two of the best are "A proof of Optimality for Age Replacement Policies" by Berg and "On the Optimality of Stationary Replacement Strategies" by Bergman.

Recently a great deal of work has been carried out at Cornell University led by Howard Taylor and Lee Phoenix concerning probability models for the strength of composite materials earlier developed by Daniels [14].

2.4 Reliability Emphasis Of The 1980S

The 1980s brought in the era of network reliability, primarily due to the importance of computer and computer network reliability. This period marked the beginning of a sophisticated, graph-theory oriented line of research in system-reliability calculation.

A significant growth has been achieved in this area in recognition of the usefulness of the Bayesian approach to inductive inference.

2.5 Current Reliability Emphasis

The current trend in reliability engineering is concerned with operational readiness of systems, which is an aid in planning and design improvements. Emphasis is also on development of computer aided design (CAD) databases that will be capable of providing reliability predictions, failure modes and effects analysis, etc.

2.6 Derivation Of Reliability Function

Quality is the conformance to specification. Reliability is therefore the extension of quality into time domain and may be paraphrased as the probability of non-failure in a given period. A more rigorous definition of reliability is as follows: *Reliability of a system is the probability that a system will perform a required function, under stated conditions, for a stated period of time [29].*

Consider the probability of an equipment failing in the time interval between t and t+dt. This can be described in two ways:

Firstly, it can be described as the probability of failure in the time interval t to t+dt given that it has survived until time t. i.e.

$$Z(t)\,dt$$

where Z(t) is the hazard rate.

And secondly, as the probability of failure in the internal t to t+dt unconditionally i.e.

$$f(t)dt$$

where f (t) is the failure probability density function.

The probability of survival to time t is defined as the reliability, R(t). Thus

$$Z(t)\,dt = \frac{f(t)dt}{R(t)}$$

$$\Rightarrow Z(t) = \frac{f(t)}{R(t)} \qquad (2.1)$$

However, if f(t) is the probability of failure in the internal dt then: the probability of failure in the interval 0 to t = $\int_o f(t)dt = 1 - R(t)$

$$\text{i.e} \qquad \int_o f(t)dt = 1 - R(t) \qquad (2.2)$$

Differentiating both sides of equation (2.2) yields

$$f(t) = -\frac{dR(t)}{dt} \qquad (2.3)$$

Substituting (2.3) into (2.1) we have

$$- Z(t) = \frac{dR(t)}{dt} \; x \; \frac{1}{R(t)} \tag{2.4}$$

Integrating both sides of equation (2.4) gives

$$-\int_o Z(t)dt = \int_1^{R(t)} \frac{d\,R(t)}{R(t)} = \log_e R(t) - \log_e 1$$

$$= \log_e R(t)$$

$$\therefore \; R(t) = \exp[-\int_o Z(\tau)dt] \tag{2.5}$$

where τ is a dummy variable for the failure rate λ being a constant

$$R(t) = \exp[-\int_o \lambda dt] = e^{-\lambda t} \tag{2.6}$$

2.7 *Mean Time To Failure (MTTF)*

MTTF is defined as the mathematical expectation of the variate T describing the time failure of system.

$$\therefore \quad \text{MTTF} = E[T] = \int_o^\infty tf(t)dt \tag{2.7}$$

$$\text{Since } f(t) = \frac{dF(t)}{dt} = \frac{-dR(t)}{dt}$$

where F(t) is probability of failure

$$\text{Hence MTTF} = -\int_o^\infty tdR(t) = \int_o^\infty R(t)dt \tag{2.8}$$

2.8 *Maintainability Function*

Maintainability is an index associated with a system under repair. It is the probability that the failed system will be restored to operational effectiveness within a given period of time (t hours) when the repair is performed in accordance with prescribed procedures. If T is a variate representing the repair time, then maintainability is defined as

$$M(t) = P(T \leq t) \tag{2.9}$$

If the repair time is exponentially distributed with the parameter μ, then the repair density function is given by

$$g(t) = \mu e^{-\mu t} \tag{2.10}$$

$$\text{whence} \quad P(T \leq t) = \int_o^t \mu e^{-\mu t}$$

$$= \quad 1 - e^{-\mu t} \tag{2.11}$$

Hence the maintainability equation is expressed as

$$M(t) = 1 - e^{-\mu t} \tag{2.12}$$

The expected value of repair -time is known as the mean time to repair (MTTR) and is given by

$$\text{MTTR} = \int_o^\infty t\, g(t)\, dt$$

$$\text{whence:} \qquad \text{MTTR} = \frac{1}{\mu} \tag{2.13}$$

The sum of MTTF and MTTR yields mean time between failures (MTBF).

$$\therefore \qquad \text{MTBF} = \text{MTTF} + \text{MTTR} \tag{2.14}$$

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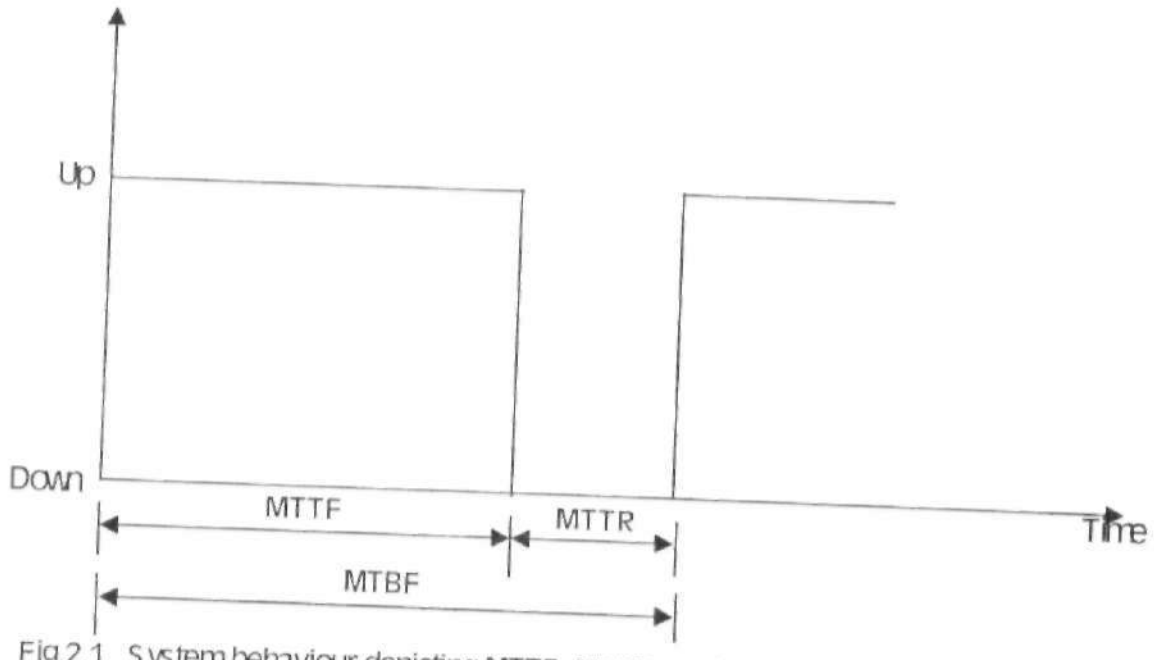


Fig.2.1. System behaviour depicting MTTF, MTTR, and MTBF.

Equation. 2.24 is illustrated by Fig. 2.1

2.9 *Hazard Models*

2.9.1 Constant-Hazard Model

The constant-hazard model takes the form

$$Z(t) = \lambda \tag{2.15}$$

Where λ is a constant and is independent of time. Constant-hazard rate is associated with the useful life of the bathtub curve of an electronic system.

The reliability of a system with constant hazard rate is given by equation (2.6) and its associated function is expressed as

$$f(t) = \lambda e^{-\lambda t} \tag{2.16}$$

Whence the MTTF = $\int_o^\infty e^{-\lambda t}\, dt = \frac{1}{\lambda}$ (2.17)

2.9.2 Linear-Hazard Model

Many electromechanical systems fail due to wear-out. The hazard rate of such systems increases with time. Thus the linear-hazard model is given by

$$Z(t) = bt, \quad t > o \tag{2.18}$$

where b is a constant.

$$\therefore \qquad R(t) = \exp\left[-\int_o^\infty bt\, dt\right] = \exp\left(\frac{-bt^2}{2}\right) \tag{2.19}$$

and

$$\text{MTTF} = \int_o^\infty e^{\frac{-bt^2}{2}} dt \tag{2.20}$$

2.9.3 Nonlinear-Hazard Model

The hazard rate is not always a linearly increasing function of time. Hence it is necessary to have a more general form of the hazard model which can be expressed as

$$Z(t) = at^b$$

Where a and b are constants.

This yields

$$R(t) = \exp\left[-at^{b+1}/(b+1)\right] \tag{2.21}$$

2.10 Availability Function

The availability function can be obtained using the Markov model. Stochastic failure and constant repair rate are assumed. The Markov graph for the availability of a system is shown in Fig. 2.2. The repair commences immediately the system fails and λ is the failure rate and μ the

repair rate.

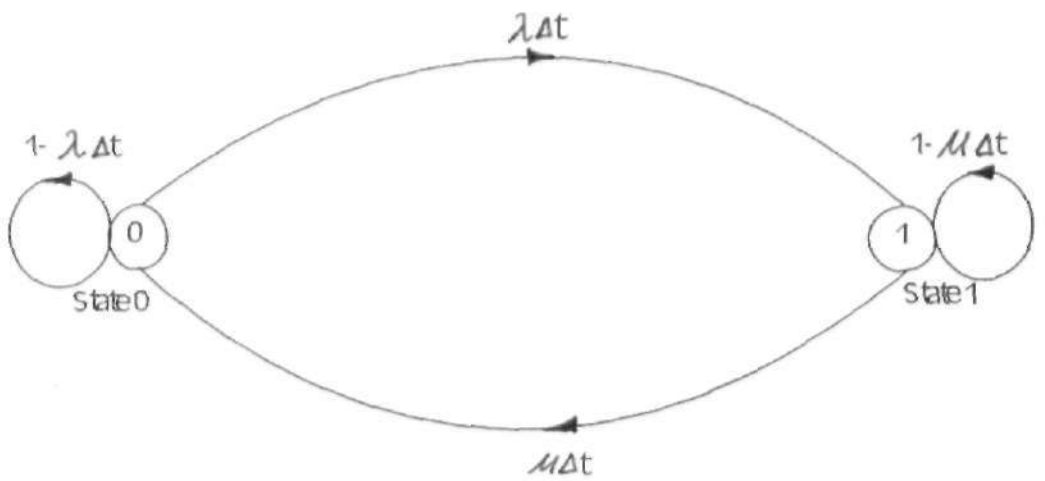


Fig. 2.2 Markov Graph for Availability

State 0 denotes that no failure has occurred and state 1 denotes that a failure has occurred. From the graph, the probability that the system will be in state 0 at time t+Δt is

$$P_o(t+\Delta t) = P_o(t)\ (1-\lambda\Delta t) + P_1(t)\,\mu\Delta t \qquad (2.22)$$

Similarly, the probability that the system will be in state 1 at time t+ Δt is

$$P_1(t+\Delta t) = P_1(t)\ (1-\mu\Delta t) + P_o(t)\,\lambda\Delta t \qquad (2.23)$$

$$\frac{Po(t+\Delta t)-Po(t)}{\Delta t} = -P_o(t)\,\lambda + P_1(t)\,\mu$$

The resultant differential equations are

$$\frac{dP_o(t)}{dt} = -P_o(t)\lambda + P_1(t)\ \mu \qquad (2.24)$$

$$\frac{dP_1(t)}{dt} = P_o(t)\ \lambda - P_1(t)\ \mu \qquad (2.25)$$

At time t = 0

$$P_o(o) = 1 \text{ and } P_1(t) = 0$$

Computing the state transition matrix, the solutions to these differential equation are given by

$$P_o(t) = \frac{\mu}{\lambda + \mu} + \frac{\lambda}{\lambda + \mu} e^{-(\lambda+\mu)t}$$

$$P_1(t) = \frac{\lambda}{\lambda + \mu} - \frac{\lambda}{\lambda + \mu} e^{-(\lambda+\mu)t} \qquad (2.26)$$

Since availability function, A (t) is the probability that the system is operating at time t,

$$\Rightarrow A(t) = P_o(t) = \frac{\mu}{\lambda + \mu} + \frac{\lambda}{\lambda + \mu} e^{-(\lambda+\mu)t}$$

As $t \rightarrow \infty$, A (t) reaches some steady-state value. The long-term availability of the system is

$$A = A(\infty) = \frac{\mu}{\lambda + \mu} \qquad (2.27)$$

This equation can be modified as

$$A = \frac{1/\lambda}{1/\lambda + 1/\lambda} = \frac{MTTF}{MTTF + MTTR}$$

$$= \frac{MTTF}{MTBF} \qquad (2.28)$$

CHAPTER THREE

PROGRAM DEVELOPMENT

3.1 Introduction

Program development is essential for a tangible reliability assessment, and the kernel of program development is the mathematical model of the system under study. The formulation of the mathematical model requires a sound engineering knowledge of the system. Hence an abridged survey of the operation of Kujama Satellite Earth Station is presented. Furthermore, the program requires the outage data to generate reliability parameters. Topical items in the fault catalogue are therefore also presented.

3.2 Kujama Satellite Earth Station

The concept of effective global communications hinges on satellite and its associated ground communications equipment (GCE). A communications satellite functions as a microwave link repeater in the sky which receives signals from an earth station, amplifies them, and translates their frequencies to prevent interference between uplink and downlink.

The communications equipment at Kujama Standard 'A' Satellite Earth Station are categorized into two, namely, the Receive equipment and the Transmit equipment. The station utilizes two 500 MHz bands ; receiving via the downlink in the 3.725 - 4.225 GHz band and transmitting in the 5.925 - 6.425 GHz band.

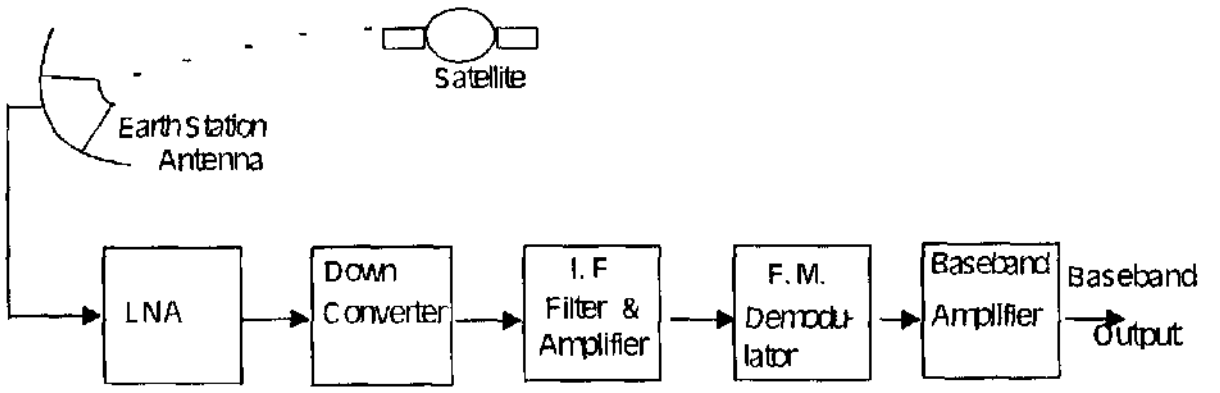


Fig. 3.1 Basic Layout of Kujama Earth Station Receive Equipment

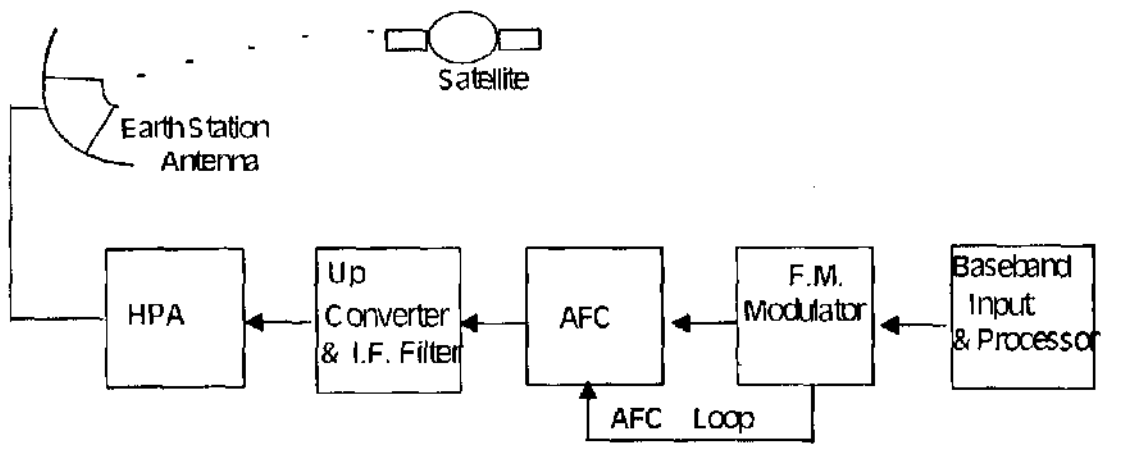


Fig.3.2 Basic Layout of Kujama Earth Station Transmit Equipment

3.2.1 Antenna System

The primary reflector surface is made of light-weight aluminium and supported by an 11m diameter ring girder. The reflector surface is treated with a special solar - reflective paint. This reflector has a diameter of 32 m and focal length of 11 m.

Elevation rotation is provided by two bearing assemblies and the entire rotating assembly is supported by the Azimuth axis wheel. Azimuth and Elevation electrical drive is provided by a dual A.C. servo system with anti-backlash features.

Cassegrain designs employing dual reflector surfaces are used at Kujama Earth Station. To achieve the desired collimation characteristics, the main reflector is a paraboloid and the sub-reflector a hyperboloid. In cassegrain design, the transmitting and receiving equipment are placed behind the main reflector. Thus making the system relatively more accessible for maintenance. The Cassegrain feed system is shown in fig. 3.3.

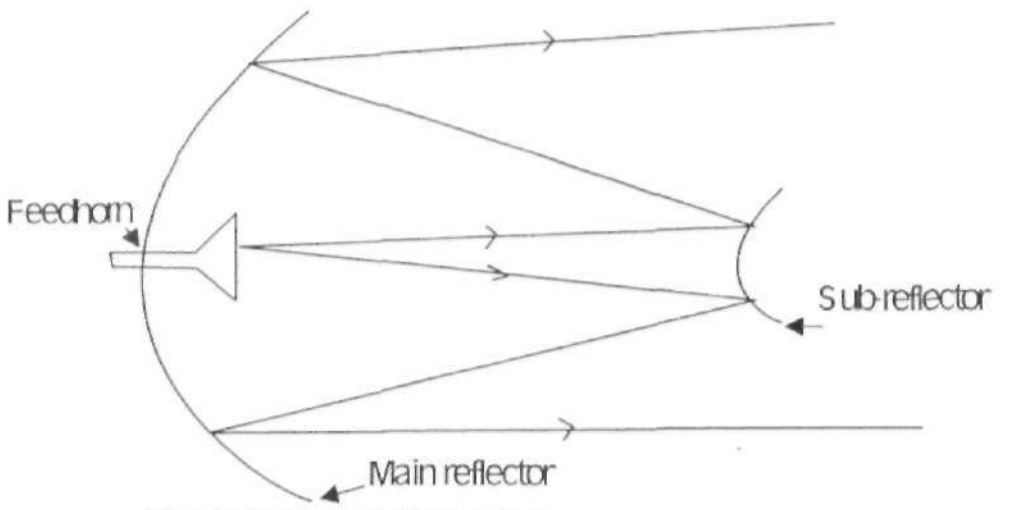


Fig. 3.3 Cassegrain feed system

3.2.1.1 Tracking System

The satellite is not quite geostationary. It performs a 20 km figure eight trip daily. Hence it is imperative for an earth station antenna to track the satellite to minimize signal level degradation resulting from antenna gain roll-off. The steptrack tracking method is employed.

The operational concept of the steptrack tracking system is to acquire the satellite beacon signal through the communications feed. Then the antenna is commanded to make an initial

angular move, and comparison of the received beacon level before and after the move is effected. Hence the direction of the next move is decided for optimum beacon level. The Digital Antenna Control Unit (DACU) makes the decision regarding the optimization of the beacon signal level.

3.2.2 Low Noise Amplifier (LNA)

The LNA is an extremely sensitive high frequency transistor circuit which amplifies the weak signals received from the satellite, without swamping them with excessive noise.

KES is equipped with two LNAs. Hence the secondary LNA is automatically substituted when the primary LNA fails. The output of the LNA feeds the down converters.

3.2.3 Low Noise Receiver (Down Converter)

The task of the receiver is to select the required FM.- carrier in the down-link frequency range and convert it to an intermediate frequency of 70 MHz. It also allows for manual selection of frequencies in incremental steps of 125 KHz by means of switches on the panel.

3.2.4 Intermediate Frequency Filter

The I.F. Filter determines the pre-detection bandwidth which must be of proper size for the carrier selected. The filter is set at I.F bandwidths of 1.25 MHz - 36 MHz which conforms to International Telecommunications Satellite consortium (INTELSAT) and International Radio Consultative committee (CCIR) specifications. The I.F. filter also establishes receiver threshold and reduces adjacent channel interference.

3.2.5 Intermediate Frequency Amplifier

The I.F Amplifier basically contains an AGC amplifier, that maintains a stabilized signal level of +10 dB ± 1.0 dB to the demodulator.

3.2.6 Demodulator

The FM feedback demodulator is designed to accommodate channel capacities from 12 through 1332. It contains a limiter to remove unwanted amplitude changes in the incoming signal. The signal is then demodulated in a discriminator to obtain the baseband signal.

3.2.7 Baseband Amplifier

The demodulated baseband signal is feed into the baseband amplifier where it is amplified and conditioned. The baseband amplifier has a net gain of 5 dB and a flat response within ± 0.25 dB from 12 KHz to 10 MHz. The de-emphasis networks effect channel capacity assignments. The output of the baseband amplifier feeds the Baseband output for final signal processing.

3.2.8 Baseband Input

The baseband input is to provide +20 dB/channel output baseband to the message processor. There is an additional provision for internal gain selectors of +30 dB/channel and +40 dB/channel. Also the gain can be adjusted from the front panel.

3.2.9 Message Processor

It has a unity gain, provides automatic gain control, and removes unwanted signal frequencies.

3.2.10 Modulator

The modulator receives a base band input of +20 dB/channel and gives an I.F. 70 MHz at +5dBm. The modulation is effected such that second - order nonlinearities are cancelled.

3.2.11 Automatic Frequency Control (AFC)

The 70 MHz +5 dBm signal from the modulator is sampled at a rate of 10 MHz by the AFC. The AFC provides stability of the 70 MHz carrier at a level of 0 dBm.

3.2.12 Intermediate Frequency Filter (IF Filter)

The IF filter attenuates adjacent channel radiations and minimizes delay distortion. Due to the 20 dB insertion loss introduced by the filter, IF carrier is delivered to the up-converter at a level of -20 dBm.

3.2.13 Upconverter

The 70 MHz IF signal is first translated to a frequency of 1.1125 GHz. Then it passes through a band pass filter to a mixer for a final frequency translation to 6 GHz.

The overall frequency translation process amplifies the IF signal to +30 dBm at 6GHz.

3.2.14 High Power Amplifier (HPA)

The HPA subsystem consists of two traveling wave tube amplifiers (TWTA) with switching and combining circuits. While one of the amplifiers is in use, the other is on standby. The HPA and antenna, wholly determine the terminal Effective Isentropically Radiated Power (EIRP). The output of the HPA feeds the antenna.

3.3 DATA COLLECTION

The fault catalogue of KES has the following topical items.

(i) Date: The date that a failure occurs is recorded.

(ii) Time: Outage start time is entered into this column.

(iii) Outage Minutes: The time duration in minutes for which KES is not open to traffic is recorded. This is the down-time of the system.

(iv) Causes of Outage: Factors that precipitates failure are recorded e.g. Tracking problem, power failure, etc.

The recommended format for the Failure Report and Action Form is given in fig. 3.3.

KES FAILURE REPORT AND ACTION FORM									
1	REPORT NUMBER: REPORT DATE: REPORT COMPLETED BY:								
2	EVENT DATE START Month: Day: Local time:			END Month: Day: Local time:					
3	EQUIPMENT								
4	PROBLEM	Catastrophic		Degraded		Incipient			
5	MANNER OF DETECTION	BITE		PM					
		INTELSAT							
6	PRECIPITATING FACTOR(S)								
7	CONTRIBUTING FACTOR (S)	Aging		Stochastic Failure		Systematic		Human Factor	
8	LOGISTIC TIME	Hour				Minutes			
9	DISPOSITION	Replace module		Repair		Modific-ation			
Details of Action taken:									

Fig 3.3: Recommended Format for Failure Report and Action Form

The topical items in fig 3.3 are elucidated below:

(i) Event Date: This contains two columns for recording outage start time and outage end time respectively. For each column, the month (0 - 12), day (1 - 31) and local time are recorded.

(ii) Equipment: The failed equipment is uniquely identified.

(iii) Problem: An abridged description of the failure is entered. The failure mode types (catastrophic, degraded, and incipient) are given so that the appropriate one can be ticked.

(iv) Manner of Detection: The means by which an outage is detected is recorded. Some means of detection given in the format are explained below:

(a) Built - in test equipment (BITE) are used to diagnose faults and initiate alarms.

(b) Preventive Maintenance (PM) consists of periodic inspection and measurements of key parameters, aimed at detecting whether they are drifting toward the limit.

(c) INTELSAT: Sometimes an earth station may fail without the operators realising it. INTELSAT headquarters in Washington detects the failure and communicate it to the earth station concerned.

(v) Precipitating Factor(s): A single factor precipitating a failure is recorded. When more than one factor each recording is preceded by? And an assessment is carried out later in other to determine the dominant factor.

(vi) Contributing Factor(s): A single or multiples of the following contributing factors are recorded:

(a) Aging indicates that the useful life of the equipment has been exceeded.

(b) Stochastic Failure means random or chance failure which implies that the equipment is in its useful life period.

(c) Systematic implies that design, manufacturing process and environmental conditions contributed to the failure.

vii. Logistic Time:Is the time used in sourcing spares and consumables before the commencement of corrective maintenance.

Viii. Disposition: This is the immediate corrective action taken to restore the system to normal condition. The appropriate action effected is ticked followed by a detailed description of the action taken.

A comprehensive outage data was obtained for a period of seven years from 1989 to 1995. The reliability indices for each year were then computed for KES.

Fig. 3.4 through fig. 3.10 gives bar charts illustrating number of failures versus failure events respectively, for 1989 to 1995.

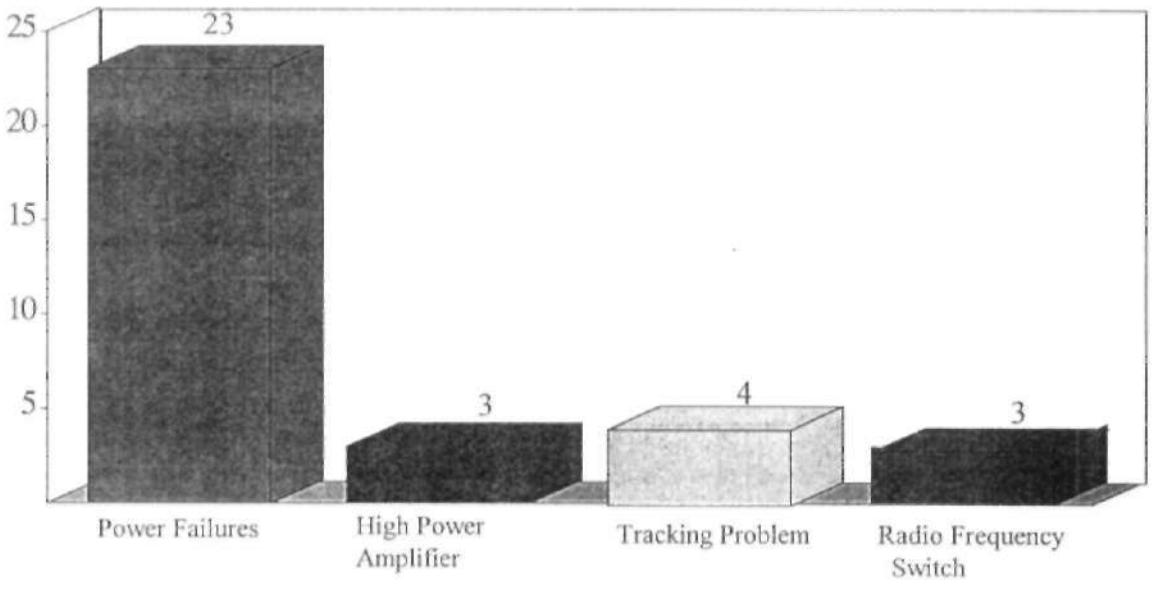


Fig. 3.4 No of Outages versus Events (1989)

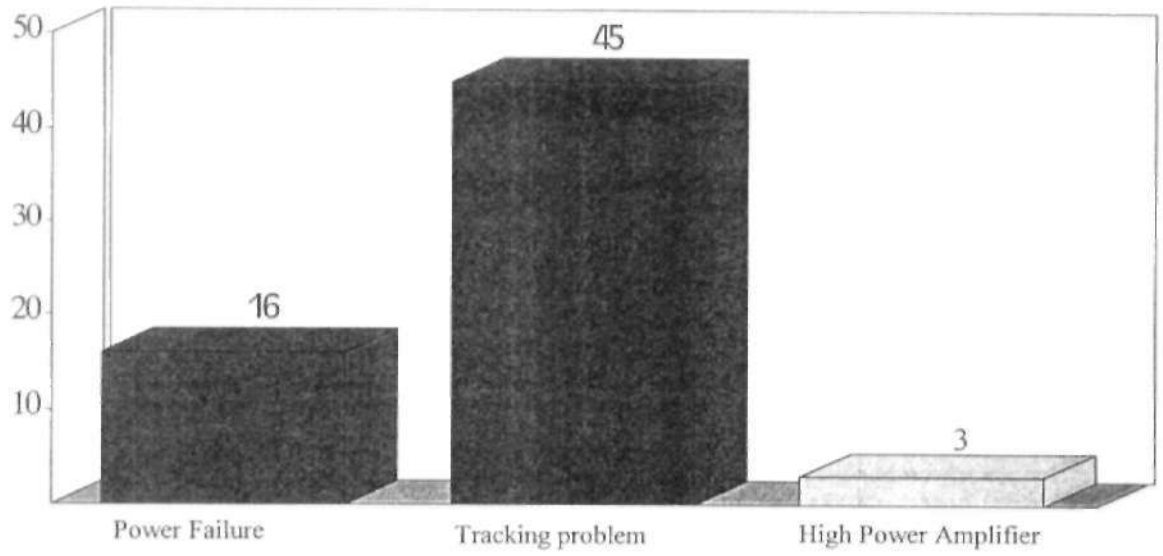


Fig. 3.5 No of Outages versus Events (1990)

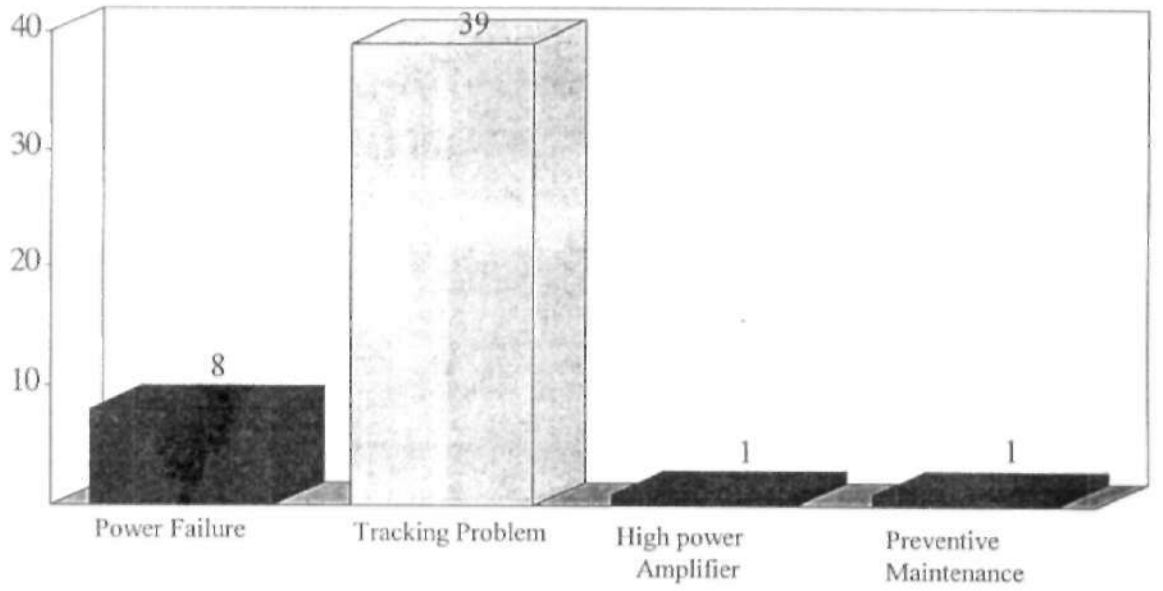


Fig 3.6 No of Outages versus Events (1991)

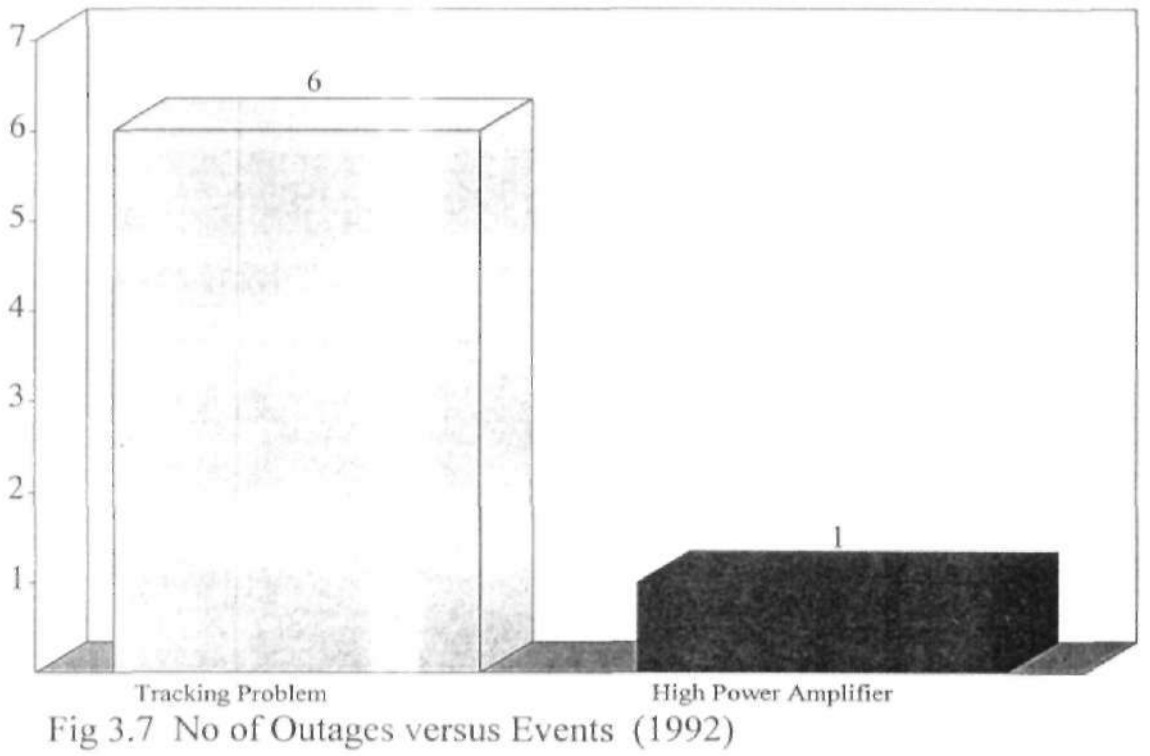


Fig 3.7 No of Outages versus Events (1992)

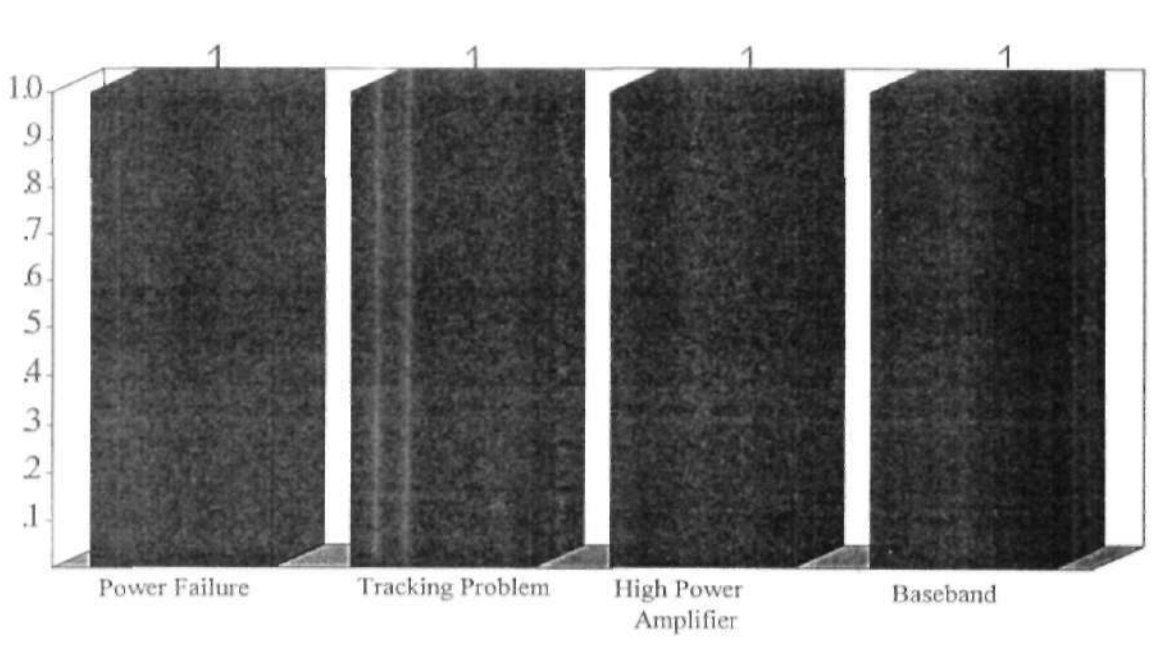


Fig.3.8 No of Outages versus Events (1993)

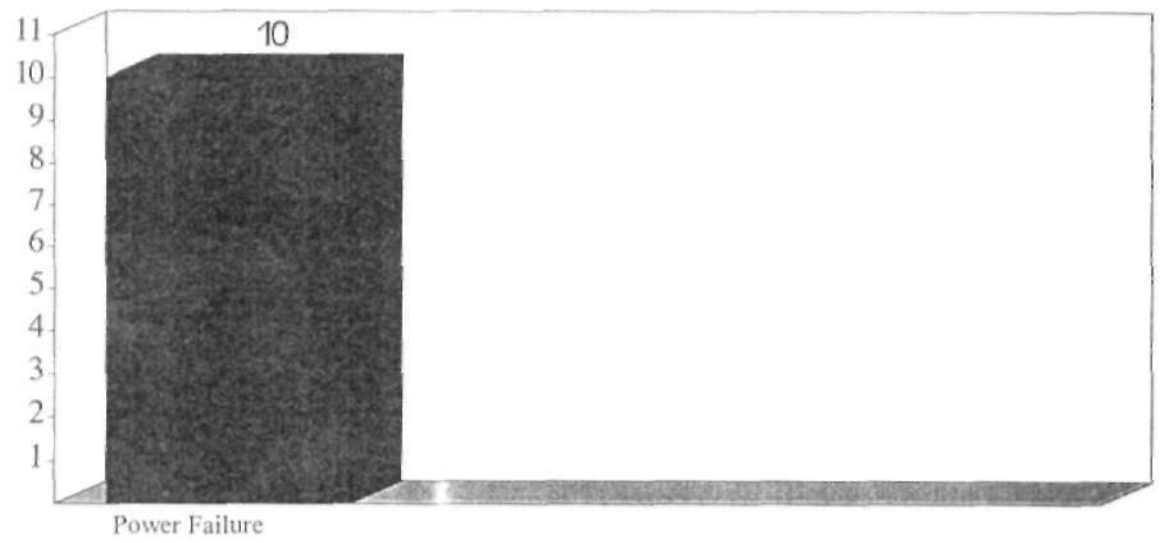


Fig. 3.9 No of Outages versus Events (1994)

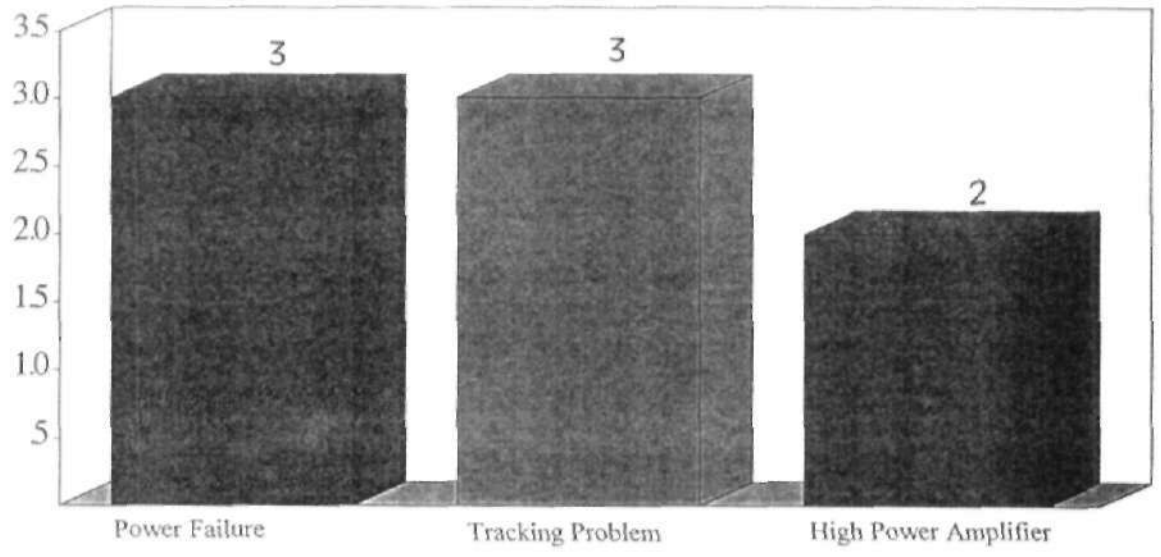


Fig 3.10 No of Outages versus Events (1995)

3.4 Computation Of Reliability Parameters

The performance of the KES system was modeled as a discrete state, continuous time Markov process. The system is either in failed or operating state and transition from one state to another can occur anytime. More explanation on Markov processes is offered in appendix B. The following formulae and conditions [30] were used to compute the reliability parameters.

$$\text{MTTF} = \frac{Uptime}{Number\ of\ failures}$$

$$\text{MTTR} = \frac{Downtime}{Number\ of\ failures}$$

$$\text{MTBF} = \text{MTTF} + \text{MTTR}$$

$$\lambda = \frac{1}{MTTF}$$

$$\mu = \frac{1}{MTTR}$$

$$N = \sum_{i=1}^{12} n_i$$

where n_i is the number of failures in a month i

$$a = \frac{MTTF}{MTBF}$$

$$\bar{a} = 1 - a$$

If a = 1.000, then R = A

If $0.9996 \leq a \leq 0.999999$, the R=B

If $0.999 \leq a \leq 0.999599$, then R=C

If $a \leq 0.99900$, then R=D.

where A,B,C, and D are the INTELSAT's ranking of on availabilities from the best when a = 1.0000, to worst when a $\leq$ 0.99900.

3.4.1 Program Development

The structured programming approach was used in developing the program. This is due to the inherent advantages of structured programming. Some of thes advantages are as follows:

i. the self- documenting nature of structured programming makes programs easier to read, maintain and change;

ii. structure programming facilitates transfer of programming experience derived from other high-level languages;

iii. the clarity and modularity of structured programming makes it easier to test and debug.

The objective of structured programming is to decompose a problem into smaller separate units. A solution for a separate unit is called a procedure. Thus the synergistic interaction between the procedures in a programm is the hallmark of a well-designed structured program.

Turbo Pascal was primarily developed to facilitate structured programming; hence the source program for this project was written in Turbo Pascal. Furthermore, Turbo Pascal allows the compilation of the source program into executable file, which facilitates running the program from Disk Operating System (DOS) prompt, thereby eliminating the need for a compiler.

The Text and Graphic facilities of Turbo Pascal was utilized to give a captivating graphic effects, in order to sustain the interest of the user. The program is user friendly and highly flexible. Also, random bipping pixels were used to stimulate screen blanker to prevent burning patterns into the cathode ray tube (CRT).

For brevity, only the main screen of the program is discussed. At the onset, the program beeps the title of the project " Operational Reliability of Kujama Earth Station" three times. Then it displays the main screen, containing the menu items as shown in fig. 3.11

Operational Reliability of Kujama Earth Station		
ADD	DISPLAY	MODIFY
PRINT	QUIT	

(Use ↑↓→← or ADMPQ to highlight the option, then press <ENTER> to complete the selection.)

Fig. 3.11 Main Program Screen.

The program allows the user to append (or add) new records; view or (display) old records and revise (or modify) old records. These is also a provision for printing the reliability parameters for each year and quitting the program in a friendly manner using the QUIT menu item. Furthermore, the interactive nature of this program is illustrated by the message under the window of the menu items.

The source program is made up of a main program, a function and several procedures. A hardcopy of this program is given in appendix C. The main program transfers control to procedures and function depending on the menu chosen by the user. After choosing a menu item, there are messages in each module to guide the user.

Due to the fact that flowcharts consume space the algorithm for the main program, procedures, and function are given below:

Main program

1. Initialize graphic mode
2. Display initial graphic effects
3. Close graphic mode
4. Call openfiles procedure
5. Are all files opened successfully?
6. If False, terminate
7. If True, initialize menu
8. Respond to menu selection until Quit is selected
9. If Quit is selected, Initialize graphic mode
10. Display closing graphic effects
11. Close graphic mode and terminate.

Procedure Reversevideo

1. Read the status of text to be displayed as a parameter
2. If False, set text colour to green and background colour to white. Then terminate.
3. If True, set text colour to yellow and background colour to red. Then terminate.

Procedure continue

1. Pass in the row and column number as parameter
2. Position cursor at the appropriate position
3. Display message
4. Read a key
5. Is it a spacebar?

6. If True, terminate

7. If False, repeat step 4 in this module.

Procedure Highlightselection

1. Call Reversevideo procedure with status TRUE

2. Write the appropriate menu item in capital letters.

3. Call Reversevideo procedure with status FALSE and terminate.

Procedure Initialzemenu

1. Display the menu screen

2. Display the message information

3. Display the menu item on screen

4. Place the highlight initially on the first item and terminate.

Function searchindex

1. Pass in the item to search for as parameter.

2. Use binary search algorithm to locate item

3. Is item found?

4. If False return (-1)

5. If True return record number and terminate

Procedure Sortindex

1. Pass in the number of records as a parameter

2. Use sorting algorithm to handle sorting process and terminate.

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Procedure Statusline

1. Pass in message as a parameter
2. Display the message close to the bottom of the screen and terminate.

Procedure Waittogo

1. Is any Key pressed?
2. If False repeat step 1 in this module
3. If True, clear the screen and terminate

Procedure Putpixelplay

1. Call status line procedure to display a message on the screen
2. Display pixel randomly in random colours across the screen
3. Display another message at the centre of the screen and terminate.

Procedure Addrecord

1. Is maximum number of records exceeded?
2. If False, terminate
3. If True, enter the year
4. Is year a leap year?
5. If True, number of days is 366 and goto step 7.
6. If False, number of days is 365.
7. Continue
8. Enter the number of failures and downtime from January to December.
9. Calculate the total number of failures and total downtime.
10. Calculate uptime, MTTF, MTTR, MTBF, λ, μ, A, $\overline{A}$, R and N.
11. Should record be saved?

12. If False, abandon record and go to step 14.

13. If True, Save record

14. Continue

15. Input another record?

16. If False, terminate

17. Call procedure Addrecord recursively and terminate

Procedure Getmember

1. Enter the year

2. Call searchindex function to search for the year's record.

3. Is the record found?

4. If False, terminate

5. If True, return record number and terminate.

Procedure Showrecord

1. Call procedure Getmember to locate the year's record

2. Is it found?

3. If False, terminate

4. If True, display the reliability parameters for the year and terminate.

Procedure Modifyrecord

1. Call procedure Getmember to locate the year's record

2. Is it found?

3. If False, terminate

4. If True, display original values of number of failures and downtime.

5. Want to change these values?

6. If False, terminate

7. If True, enter new values for number of failures and downtime from January to December

8. Recalculate all reliability parameters.

9. Save revision?

10. If False, terminate

11. If True, save the modified values and parameters, then terminate.

Procedure Printrecord

1. Assign device names to printer a file

2. Enter the year

3. Is there any error?

4. If True, terminate

5. If False, call procedure search index to search for the year's record.

6. Is the record found?

7. If False, terminate

8. If True, send the reliability parameters and their values to the printer and file

9. Close the file and off the printer, then terminate.

Procedure Removehighlight

1. Write the menu item without highlight and terminate.

Procedure selectnextactivity

1. Remove highlight from the current item
2. Place highlight on the next item
3. Allow highlight to wrap from last item to the first and terminate.

Procedure Selectpreviousactivity

1. Remove highlight from current item
2. Place highlight on previous item
3. Allow highlight to wrap form first item to the last and terminate.

Procedure Selectupper activity

1. Remove highlight from current item
2. Place highlight on the item on top of the current item (if any) and terminate.

Procedure Selectloweractivity

1. Remove highlight from current item
2. Place highlight on the item below the current item (if any) and terminate.

Procedure GetSelection

1. Read the key pressed
2. Depending on whether A, D, M, P,.Q, ↑, ↓, →, ←, or ENTER is pressed, the appropriate response is give
3. Is Quit is chosen?
4. If False, go to step 1, in this module
5. If True, terminate.

Procedure Openfiles

1. Attempt opening all files
2. Is there any error?
3. If True, terminate.
4. Get the file length (number of records) of main files and record all the keys and record number in index file
5. Close index file and terminate.

Procedure Saveindex

1. Open index file
2. Save the key and record number of each record in the index file.
3. Close index file and terminate.

Finally, the program is user friendly and highly flexible. It displays a menu that allows the user to Add, Display, and Modify records. Also there is a provision for printing the reliability parameters for each year. The user can quit the program from the menu. A hardcopy of this program is given in appendix C.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

The program developed in chapter three was used to process the outage data. The results obtained will be presented and elucidated in this chapter.

4.2 Presentation Of Results

The results of computation of the reliability parameters for each year, starting from 1989 to 1995 are summarized in Table I. Furthermore Table II through Table VIII give the reliability parameters for the failure events from 1989 to 1995. All tables consist of the following parameters:

(i) MTTF: Mean time to failure; computed in hours,

(ii) MTTR: Mean time to repair; computed in hours,

(iii) MTBF: Mean time between failures; computed in hours,

(iv) λ constant failure rate; is computed in per hour,

(v) μ, the repair rate; computed in per hour

(vi) a: Availability, which is dimensionless,

(viii) $\bar{a}$: Unavailability, which is also dimensionless,

(viii) R: Ranking of an earth station by INTELSAT for grading the performance of an earth station. Ranking depends on availability.

Table I

RELIABILITY PARAMETERs	1989	1990	1991	1992	1993	1994	1995
MTTF	265.024747	136.450260	178.227211	1,250.85	2189.491667	875.246667	1088.7583333
MTTR	0.429798	0.424740	0.548299	0.583333	0.508333	0.753333	6.241667
MTBF	265.450000	136.87500	178.775510	1251.428571	2190.000000	876.000000	1095.0000
γ	0.003773	0.007329	0.005611	0.000799	0.000457	0.001143	0.000918
μ	2.326675	2.354384	1.823821	1.714286	1.967213	1.327434	1.967213
α	0.998381	0.996897	0.996933	0.999534	0.999768	0.999140	0.994300
$\bar{\alpha}$	0.001619	0.003103	0.003067	0.000466	0.000232	0.000860	0.005700
R	D	D	D	C	B	C	D
N	33	64	49	7	4	10	8

Table II

1989	TRACKING PROPLEM	HPA	POWER FAILURE	RFS
MTTF	2189.454250	2918.0194444	380.605783	2919.8111111
MTTR	0.545750	1.805556	0.263783	0.188889
MTBF	2190.000000	2920.000000	380.869566	2920.000000
γ	0.000457	0.000343	0.002627	0.000342
μ	1.832341	0.553846	3.790995	5.294117
α	0.999751	0.999382	0.999307	0.999935
$\bar{\alpha}$	0.000249	0.000618	0.000693	0.000065
R	B	C	C	B
N	4	3	23	3

Table III

1990	TRACKING PROBLEM	HPA	POWER FAILURE
MTTF	194.247407	2919.088889	625.329762
MTTR	0.419259	0.911111	0.384524
MTBF	194.666667	2920.00000	625.714286
γ	0.005148	0.000343	0.0015.99
μ	2.385159	1.097561	2.600619
α	0.997846	0.999688	0.999385
$\bar{\alpha}$	0.002154	0.000312	0.000615
R	D	B	C
N	45	3	14

Table IV

1991	TRACKING PROBLEM	HPA	POWER FAILURE	PREVENTIVE MAINTENANCE
MTTF	223.988034	8759.500000	1094.768750	8759.950000
MTTR	0.627350	0.500000	0.231250	0.050000
MTBF	224.615385	8760.000000	1095.000000	8760.000000
γ	0.004465	0.000114	0.000913	0.00114
μ	1.594005	2.000000	4.324324	20.000000
α	0.002793	0.999943	0.999789	0.999994
$\bar{\alpha}$	D	0.000057	0.000211	0.000006
R	39	B	B	B
N		1	8	1

Table V

1992	TRACKING PROBLEM	HPA
MTTF	1459.68333	8758.616667
MTTR	0.316667	1.383333
MTBF	1460.000000	8760.000000
γ	0.000685	0.000114
μ	3.157895	0.722892
α	0.999783	0.999842
$\bar{\alpha}$	0.000217	0.000158
R	B	B
N	6	I

Table VI

1993	TRACKING PROPLEM	HPA	POWER FAILURE	LOSS OF BASEBAND
MTTF	8759.533333	8759.966667	8759.933333	8758.500000
MTTR	0.466667	0.033333	0.066667	1.500000
MTBF	8760.000000	8760.000000	8760.000000	8760.000000
γ	0.000114	0.000114155	0.000114	0.000114
μ	2.142857	30.000300	15.000000	0.666667
α	0.999947	0.999996	0.999992	0.999829
$\bar{\alpha}$	0.000053	0.000004	0.000008	0.000171
R	B	B	B	B
N	1	1	1	1

Table VII

1994	POWER FAILURE
MTTF	875.246667
MTTR	0.753333
MTBF	876.000000
γ	0.001143
μ	1.327434
α	0.999140
$\bar{\alpha}$	0.000860
R	C
N	10

Table VIII

1995	TRACKING PROPLEM	HPA	POWER FAILURE
MTTF	2913.183333	4378.116667	2911.427778
MTTR	6.816667	1.883333	8.572222
MTBF	2920.000000	4380.000000	2920.000000
γ	0.000343	0.000228	0.000343
μ	0.146699	0.530973	0.116656
α	0.997666	0.999570	0.997064
$\bar{\alpha}$	0.002334	0.000430	0.002936
R	D	C	D
N	3	2	3

A visual representation of availability (a) and unavailability ($\bar{a}$) of KES from 1989 to 1995 is depicted using bar charts in fig 4.1.

Fig. 4.2 through fig. 4.8 give curves illustrating the variation of the respective reliability parameters over the period understudy. Furthermore, fig 4.9 through fig. 4.14 give curves depicting the variation of some reliability parameters for dominant failure events.

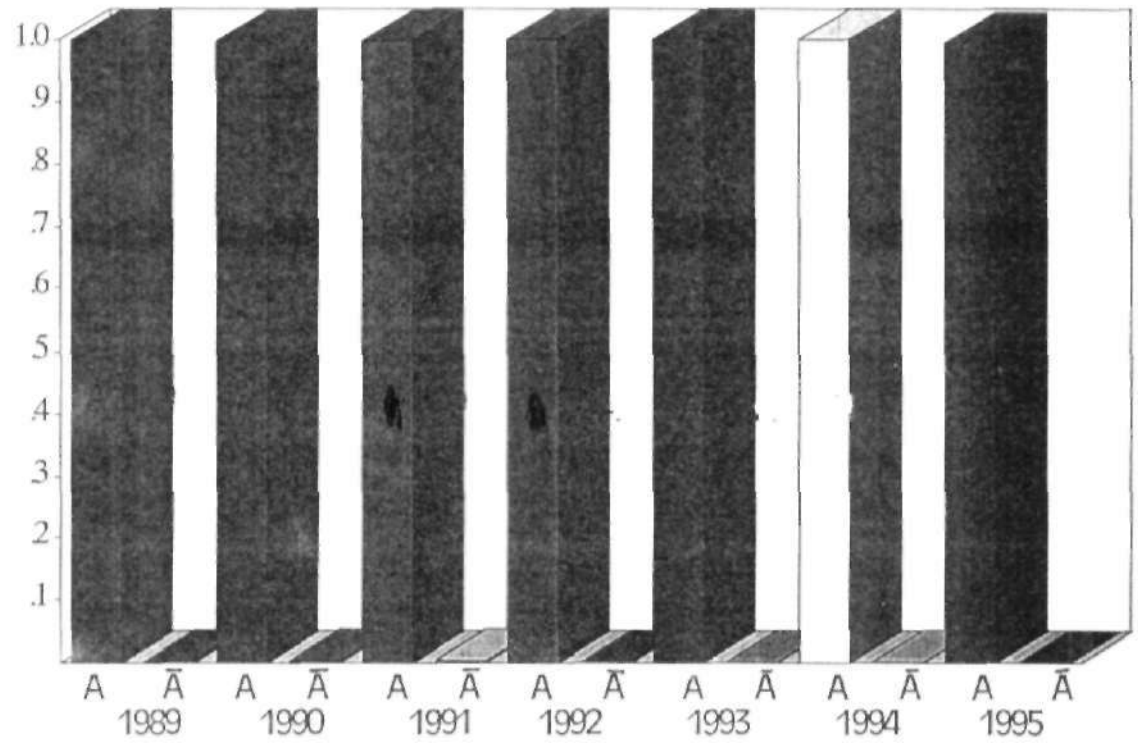


Fig. 4.1 Availabilty & Unavailability versus Years

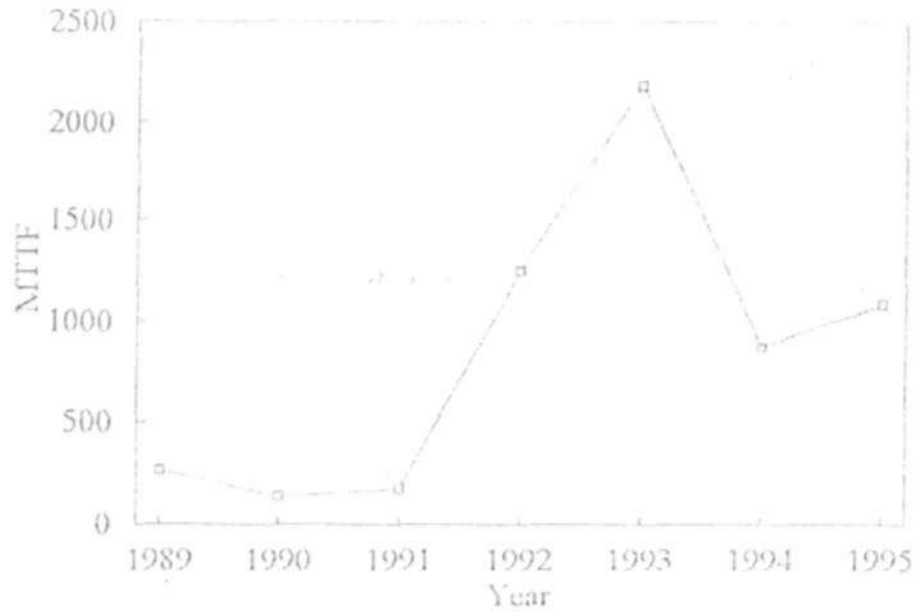


Fig. 4.2 Mean Time To Failure versus Year

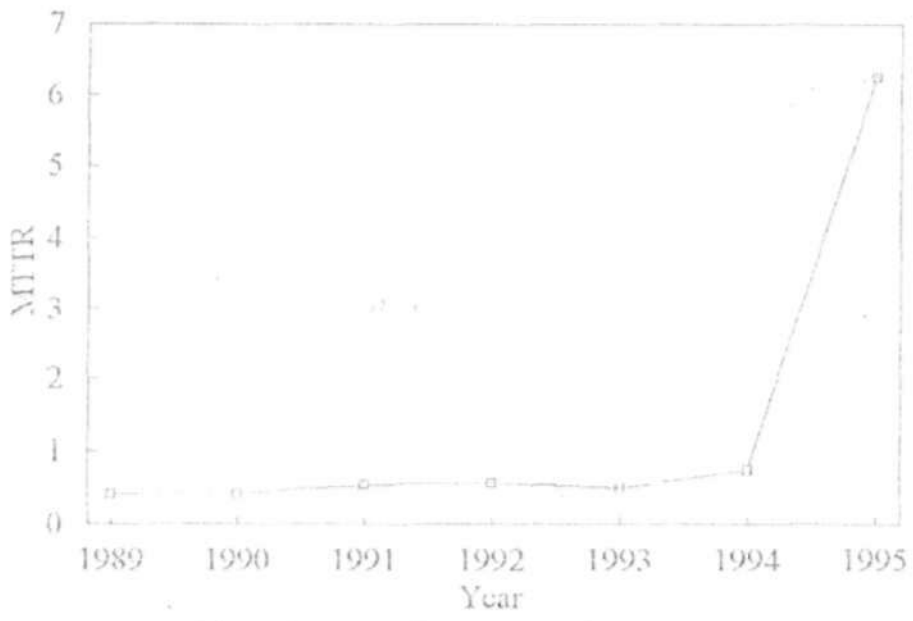


Fig. 4.3 Mean Time To Repair versus Year

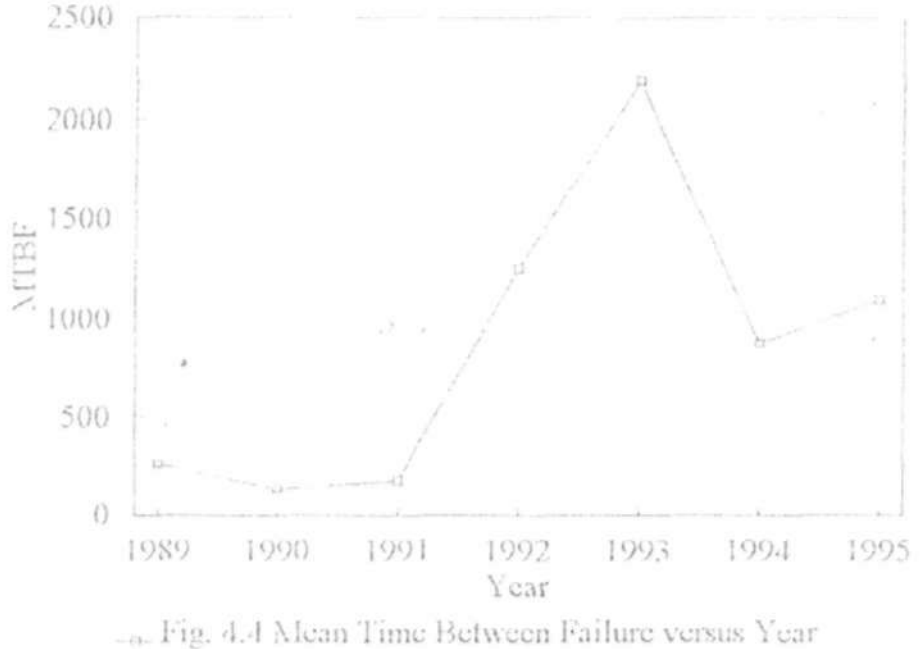


Fig. 4.4 Mean Time Between Failure versus Year

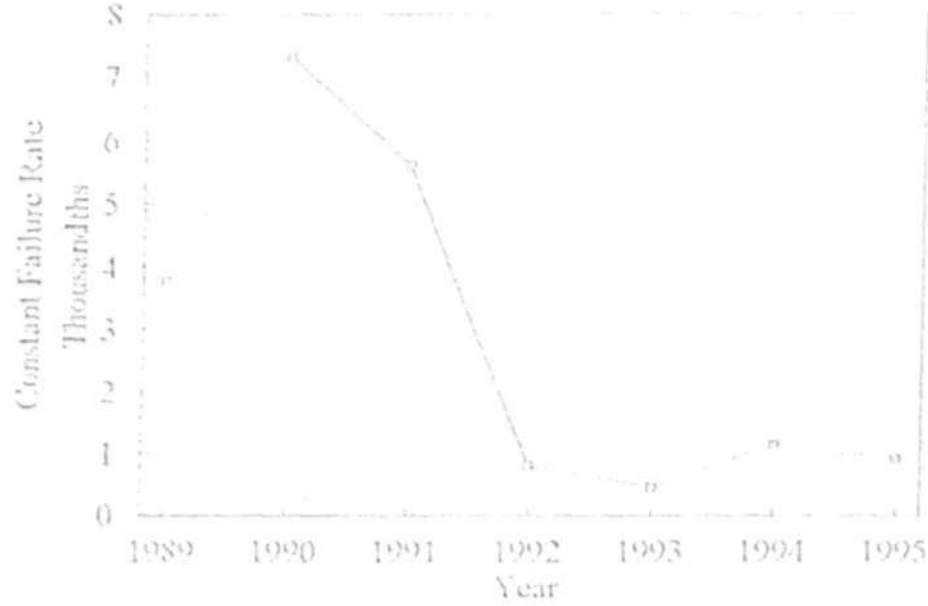


Fig.4.5 Failure Rate versus Year

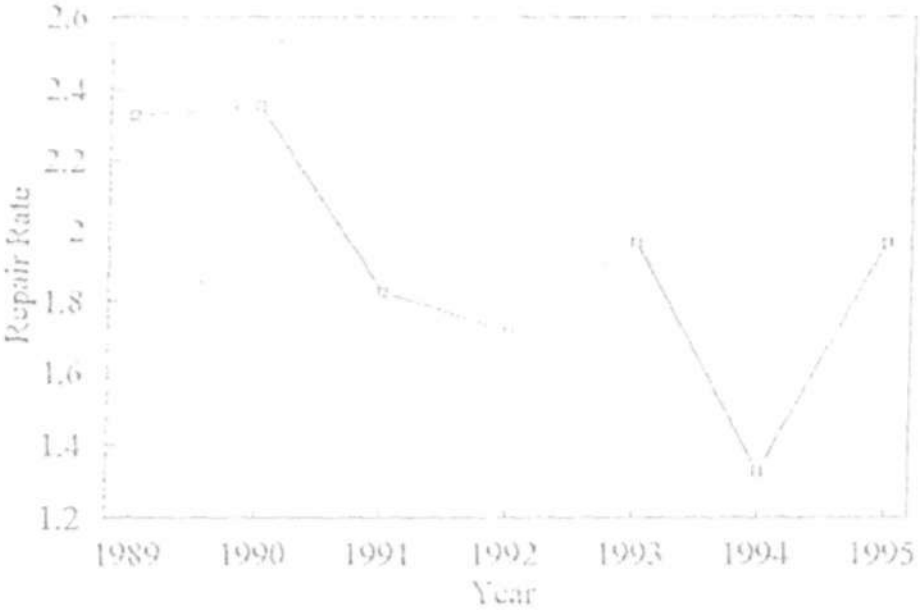


Fig. 4.6 Repair Rate versus Year

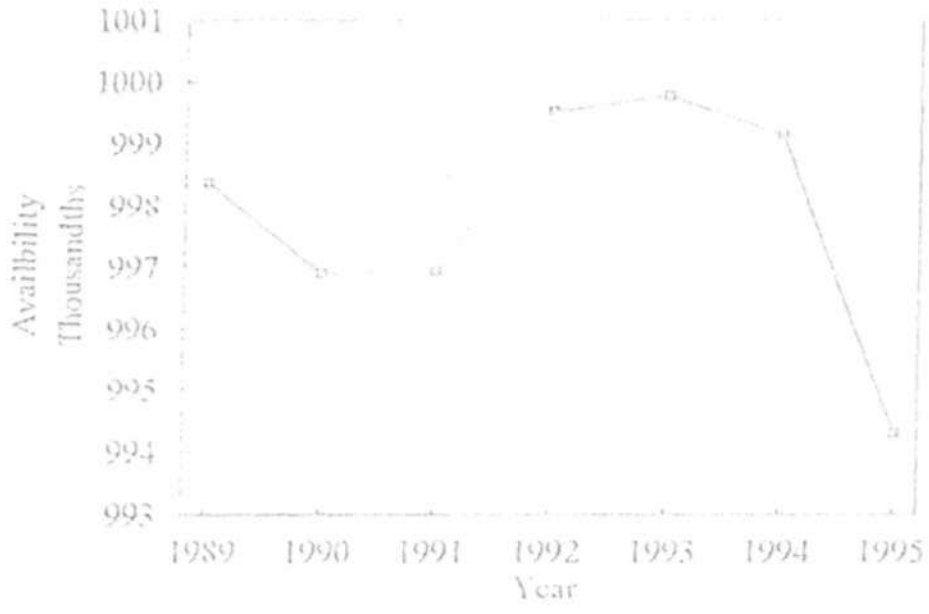


Fig. 4.7 Availability versus Year

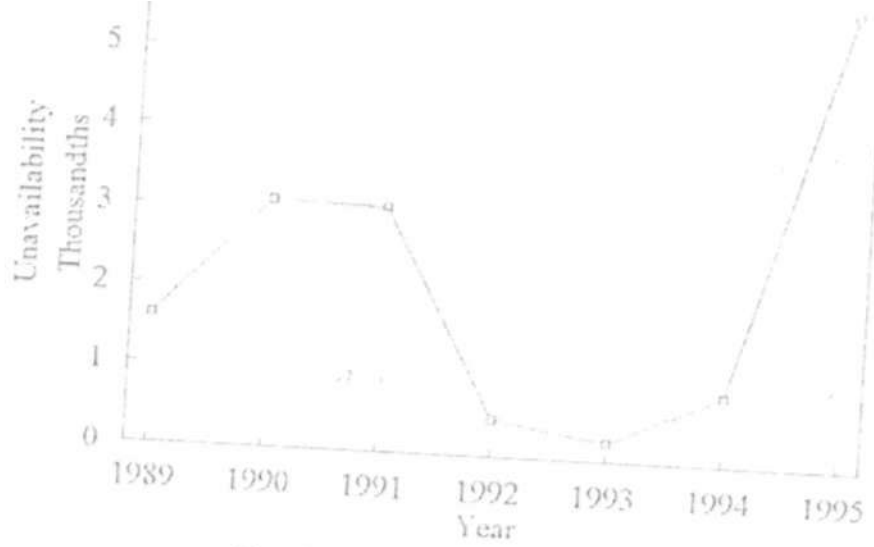


Fig. 4.8 Unavailability versus Year

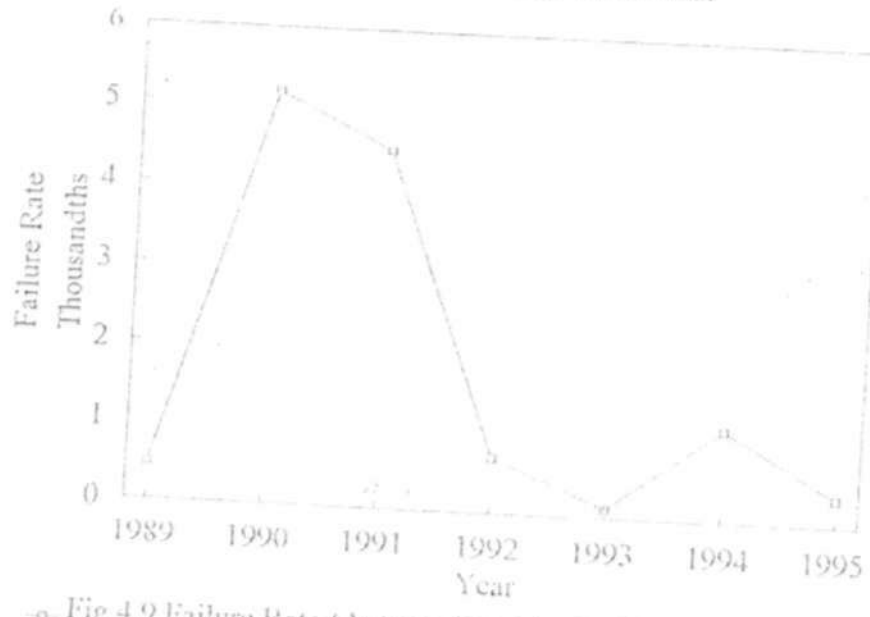


Fig 4.9 Failure Rate (Antenna Tracking Problem) versus Year

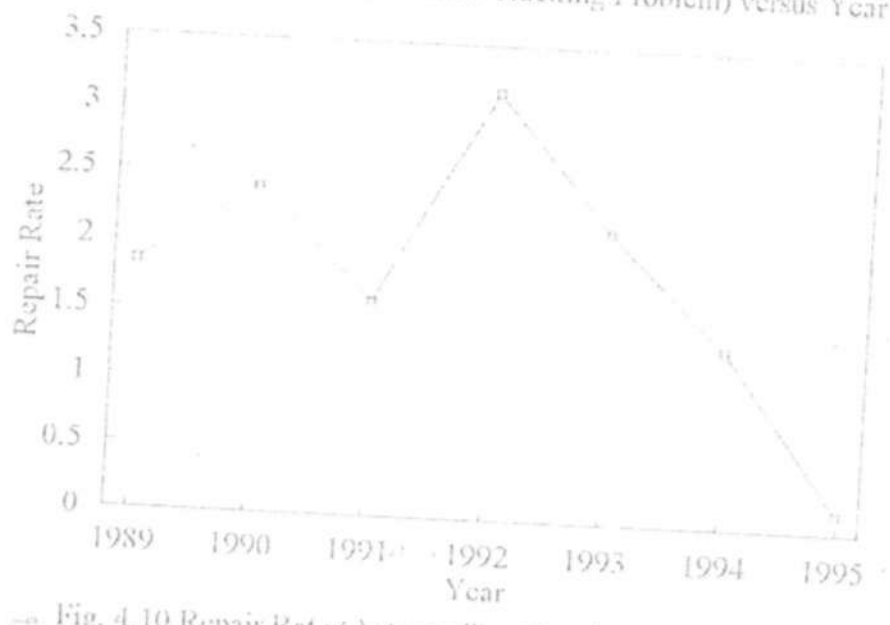


Fig. 4.10 Repair Rate (Antenna Tracking Problem) versus Year

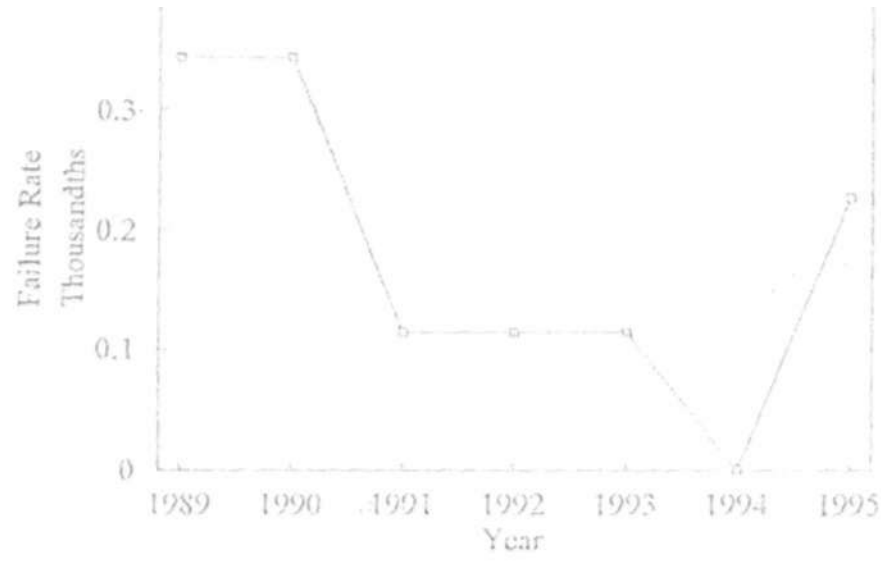


Fig. 4.11 Failure Rate (HPA) versus Year

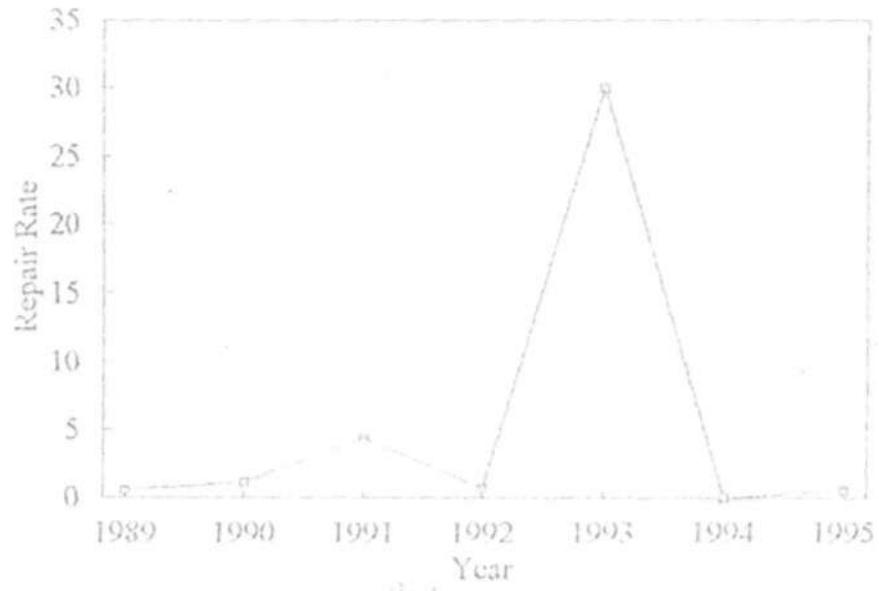


Fig 4.12 Repair Rate (HPA) versus Year

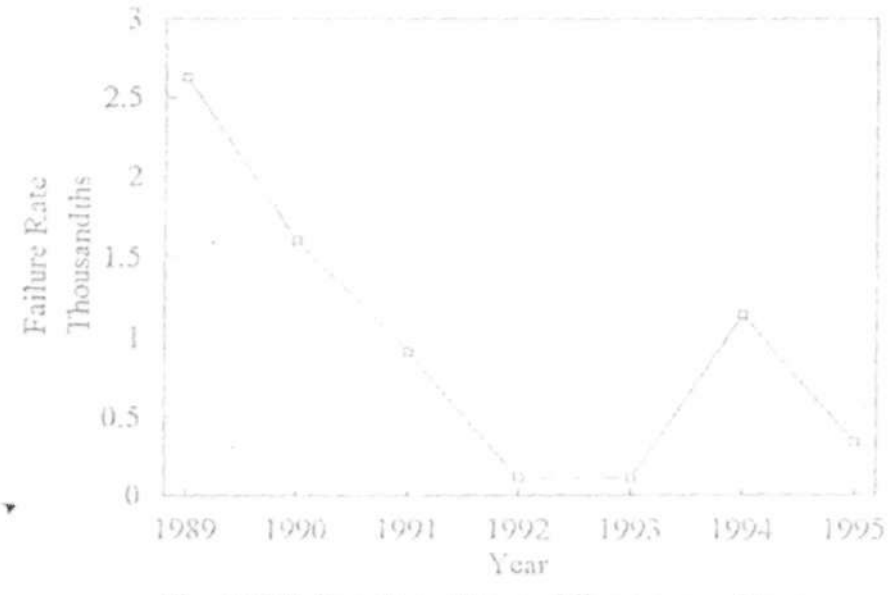


Fig. 4.13 Failure Rate (Power failure) versus Year

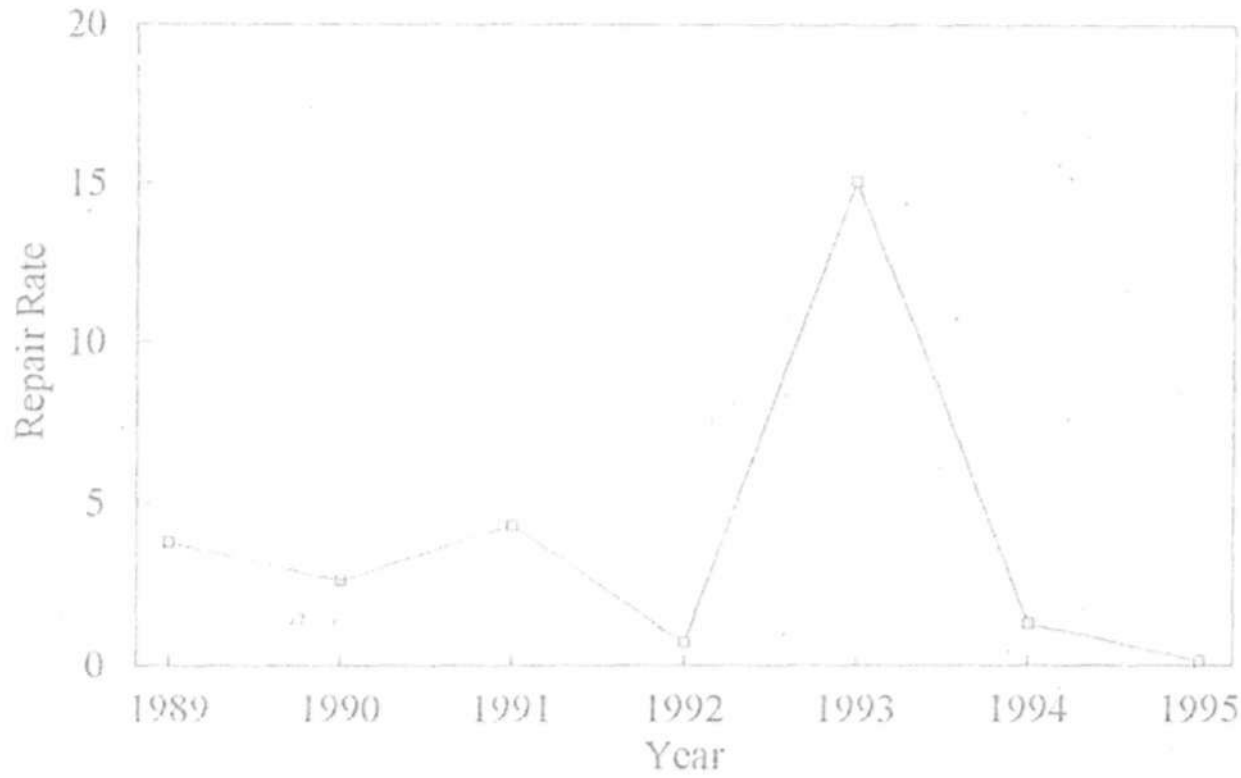


Fig. 4.14 Repair Rate (Power failure) versus Year

4.3 Discussion Of Results

For 1989 the MTTR was 0.43 hours (about 26 mins) which is much greater than the INTELSAT's recommended MTTR of 3 minutes. This indicates that the system spent excess time in down state.

The availability of 99.8381% indicates poor performance by INTELSAT standards and the ranking "D" buttresses this point. From fig 3.4, it is obvious that the major failure event in 1989 was power failure which contributed to the down time of 6.067 hours.

In 1990, the availability was 99.6897% which also yields a ranking "D". In fig 3.5, the tracking problem caused the highest number of outages and the downtime due to this event is about 66% of the total downtime for the year.

The availability for 1991 is 99.6933% which corresponds to a ranking "D". The MTTR increased to 0.5483 hours compared to the MTTR for 1990. This implies that more time was spent on repairs.

Also worthy of note, is the fact that the only preventive maintenance for the period under study was carried out in 1991 and it lasted for 3 minutes. Fig 5.4 shows that the tracking problem constituted the major failure event leading to a downtime of about 91.09% of the total downtime.

In 1992, the MTTR is 0.5933 hours but the MTTF has considerably increased to 1250.8452 hours, when compared with other values of MTTF for the previous years. This development, improved the ranking to "C". The availability for 1992 is 99.9534%.

The dominant failure event for 1992 was the tracking problem which contributed to a downtime of 2.7 hours out of the total downtime of 4.0833 hours.

The availability for 1993 was 99.976% which yields a rank of "B". This is the optimum operational reliability for the period under study as indicated by the MTTF of about 2189.5 hours. The aforementioned value of MTTF implies that there was no interruption of telephone traffic for an average of about 91 days.

Furthermore, an unusual failure event occurred, that is the loss of baseband signal from International Monitoring Centre (IMC). This is an outage of the line - of - sight microwave subsystem between IMC and KES; and the downtime due to the events is about 73.8% of the total downtime for 1993.

The availability for 1994 is 99.914% which corresponds to a ranking "C". And the only failure event was power failure.

The year 1995, KES has an availability of 99.43% which yields a ranking "D". The MTTR is 6.241667 hours this is the largest time spent on repairs for the period under study. Hence it is not surprising that KES was highly unreliable in 1995.

Though the frequency of occurrence of power failure and HPA failure are the same, but the downtime due to each event is respectively 51.5% and 41% of the total downtime for 1995.

Hence it is obvious that KES had its peak availability in 1993 and the lowest availability in 1995.

CHAPTER FIVE

CONCLUSIONS

5.1 Introduction

A system with optimum operational reliability is not achieved by accident. But through adoption of recommendations, effective maintenance policy, high intentions, sincere effort and skillful execution. To enhance the reliability of Kujama Earth Station (KES) salient recommendations were synthesized from the results and the author's experience. Thus conclusions and recommendations are presented in this chapter.

5.2 Conclusions

The implication of the results is, that reliable and unreliable subsystems in KES have been identified. Thus the following modifications and reinforcements are proffered with a view to improving the operational reliability of KES.

More redundancy should be introduced at the HPA subsystems so that when one HPA is in operation, the remaining two, will be on standby. This will arrest the perennial problem of both HPAs being in downstate simultaneously.

The current power supply subsystem is unsuitable because it necessitated the full-time use of diesel generators. The poor performance of these generators is due to perpetual inadequate supply of fuel and spare parts. Therefore, it is essential to supply electricity to earth stations via NEPA plc, powerlines.

The cost of extending powerlines to earth stations can be minimized if they are located very close to the IMC. This proximity to the IMC can abate loss of basedband signals.

Therefore eliminating the transmission of baseband signal via the line-of-sight microwave subsystem.

Recently, there was a catastrophic failure of both the long-distance microwave radio link and coaxial cable link between Lagos and Kaduna. This failure would have completely disrupted communication between the Southern and Northern parts of Nigeria, if not for the availability of earth stations at Kujama and Victoria Island Lagos. Therefore considering the unreliable nature of NITEL plc network, it is necessary for NITEL plc to vote at least 5% of its total investment for maintenance of earth stations in Nigeria.

By the year 2000, Nigeria telecommunications industry may be liberalized. Thus NITEL plc will no longer enjoy monopoly of the industry and will face aggressive competition from private firms. Thus NITEL plc must strive to satisfy its customers for corporate perpetuity.

It is sufficiently evident that the operational reliability of KES is poor by INTELSAT standards. And it is impossible to satisfy customers without reliable earth stations. Because frequent and unpleasant inconveniences resulting from unreliability, will bring customer dissatisfaction and loss of business. Thus it is imperative for NITEL plc to improve the reliability of earth stations and its entire network.

Though it is often asserted that an availability of 100% cannot be expected when unmotivated staff are used for maintenance, this unreliability can be arrested, if NITEL plc, adopts and skillfully executes some or all the recommendations enumerated below.

5.3 Recommendations

Currently, KES uses fault catalogue (note book) for recording outage data. But a formal failure - reporting document is necessary in order to ensure that the data is consistent and

narrative. The recording of outage is effected by people, hence it is subject to errors, omissions and misinterpretation.

To alleviate the aforementioned problem, a conglomeration of Institute of Electrical and Electronics Engineers (IEEE) recommended format of failure event record and International Telephone and Telegraph (ITT) Europe (inc) failure report form, shown in fig 3.3, should be adopted. As a corollary, KES and other earth stations should be equipped with modern computers, to automate data collection using the recommended format. And this will facilitate regular reliability assessment which is required for effective planning.

Proficiency in carrying out corrective maintanance is achieved by a combination of knowledge and diagnostic skill. Though knowledge can be acquired by direct teaching methods, skill can be gained only from experience. Therefore, the adoption of the recommended format for failure report and action form, will facilitate the acquisation of skill because it also allows in-dept recording of previous maintenance actions.

Furthermore, the adoption of the recommended format will enhance reliability assessment, because reliability indices such as mean time between replacement (MTBR) of an equipment and mean active maintenance time (MAMT) can be computed.

Equipment failure rates form the basis for manpower scheduling. Hence effort should be increased from two to three technicians charged with the responsibilty of maintenance of an equipment that shows increasing failure rate. This specialisation and concentration of efforts will reduce the MTTR of the equipment and improve availabilty of the system.

Currently, the stock in KES is continually replenished either by repairing failed components or by ordering new spares. In either case, the repair time or lead time should be minimized so that the probability of a stockout causing system failure will be very low.

The minimum spares levels can be calculated from the equipment failure rate and ordering time. Therefore, NITEL should employ figuires 4.9, 4.11, and 4.13 to obtain the minmum spares levels for the components of the respective equipment. Furthermore, a computer program for inventory control, should be developed.

For cost - effective and uninterrupted power supply, KES power supply subsystem should be reinforced with National Electric Power Authority (NEPA) lines. This will require a 500 kVA SF_6 transformer.

Since only two generators out of the four generators are functional, maintenance action should be carried out on generators that are out of use to ensure a continuous power supply.

During adverse weather conditions, the tracking of the satellite should be effected carefully to avoid antenna runaway.

NITEL should adhere strictly to the requirement of doing preventive replacement on the high power amplifier at two years interval.

With the high pace of digitalisation in telecommunication industry, KES being an analog earth station may soon become obsolete. Currently, African countries are spending up to $400 million per year [31] for obligatory routing of intra-African telephone traffic through Europe; and to circumvent this, NITEL should look into the possibility of using KES for intra-African communication.

NITEL should insist that only engineers that are highly conscious of reliability should manage earth stations.

KES should be treated as an isolated location, thus more incentive should be given to the staff. This will motivate them to improve their performance.

A recent World Bank Study on the entire NITEL communication network, reveals that the network is poorly maintained. And sound maintenance is the bedrock of an effective communication system. Thus NITEL should improve on its maintenance policy and create reliability consciousness in the staff. This policy should be vigorously pursued and woven seamlessly with other organisational goals.

Preventive maintenance should be effected regularly on built-in test equipment (BITE) to minimize the incidence of false alarms or incorrect diagnosis. This will aid timely correction of incipient faults before they degenerate to catastrophic failure.

Similar work should be carried out on other earth stations to assess their reliability.

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APPENDICES

APPENDIX A

RELIABILITY MATHEMATICS

A.1 INTRODUCTION

Reliability science is concerned with problems that involve uncertainties. Thus it leans heavily on probability theory. Hence the rudiments of probability theory are imperative for a good study of reliability problems.

A.2 RANDOM EXPERIMENTS

A.2.1 Definitions

In reliability problems the information by which a conclusion or decision must be based is invariably the result of an experiment or observation. An experiment in which the result of it's repeated performance under identical conditions yields different results is called a random experiment. That is the outcome of the experiment is not certain *a-priori*.

A.2.2 Sample Space

The inevitable step in the construction of a mathematical model of a random experiment is the choice of a suitable representation for each possible outcome of the experiment. Each of such representations is called an element and the set of all possible elements is termed the sample space of the experiment. It is often denoted by S.

A.2.3 Events

A set of outcomes that is of interest to an experimenter is described as an event, usually denoted by E. An event is uniquely determined by its constituent elements.

In some applications we are concerned with general related events rather than just one event. It then becomes imperative to combine them in some specified way to arrive at new events that are of interest. Union and intersection are the basic operations involved in this combination process.

i. The union of events W_1 and W_2 is a third event Z. Event Z contains all the elements or points that are either inW_1 or in W_2 or in both W_1 and W_2. Symbolically,

$$Z = W_1 \cup W_2 = \bigcup_{i=1}^{2} W_i$$

Consider events

$$W_1 = [S, U, G, M, A, D]$$

$$W_2 = [M, A, H, O, N, T, U]$$

then $Z = [S, U, G, M, A, D, H, O, N, T]$

ii. The intersection of events W_1 and W_2 is another event H whose elements belong to both W_1 and W_2. Viz:

$$H = W_1 \cap W_2 = \bigcap_{i=1}^{2} W_i$$

Using the preceding W_1 and W_2 in the illustration above

$$H = [U, M, A]$$

If events W_1 and W_2 are disjoint events,

then $W_1 \cap W_2 = \phi$

where ϕ denoted an empty event.

A.3 PROBABILITY

It is obvious that when we perform a random experiment, the occurrence of its outcome cannot be expressed with absolute certainty. It is however, useful to know the chances of the event occurring. Probability is a tool used to measure this chance. It gives a quantitative estimate of the possibility of occurrence of an event.

A.3.1 Classification

Myriads of definitions of mathematical probability have been offered by many authors. These definitions can be classified into three groups:

(i) *a-priori* definition,

(ii) empirical definition, and

(iii) axiomatic definition.

A.3.2 a-priori definition

If there are U exhaustive, mutually exclusive, and equally likely events and H of them are sample points of an event E, then the probability of occurrence of event E is defined as

$$P(E) = \frac{H}{U} \tag{A.1}$$

A.3.3 Empirical definition

If we denote the number of occurrences of an event E by H in U independent trials, it is obvious that the frequency ratio $\frac{H}{U}$ for sufficiently large U will be almost constant. This implies that the experiment will show statistical regularity. The probability of occurrence of the event E is thus defined as

$$P(E) = \lim_{U \to \infty} \frac{H}{U} \tag{A.2}$$

Provided the limit is finite and unique

A.3.4 Axiomatic Probability

The axiomatic approach starts with the statement of the following three fundamental axioms of probability.

Axiom 1: The probability that an event E occurs is a number between zero and one, inclusive:
$0 \leq P(E) \leq 1$

Axiom 2: The probability of the entire sample space is unity.
$P(S) = 1$

Axiom 3: The probability of the union of two mutually exclusive events is sum of the individual probabilities:

$P(E_1 \cup E_2) = P(E_1) + P(E_2)$

These axioms are consistent with intuitive ideas of how probabilities behave.

A.4. VARIATE AND DISTRIBUTION FUNCTIONS

A.4.1 Variates

A variable quantity which denotes the result of a given random experiment is called a variate. The quantification of the outcomes of a random experiment in such a way that each outcome is represented by exactly one numerical value involves the notion of a variate. A variate X, then, is a rule by which every outcome y in the sample space S of the random experiment is assigned a number X (y), called the value of the variate X for the outcome y. We may view a variate as being a coding whereby every outcome y is given a numerical code X (y). Mathematically, a variate is a function that assigns a real number X (y) to each outcome y in the sample space S.

The diversity of a variate is extremely great. In order to specify the probabilities of the value of the variate that are so identified, the concept of a distribution function is introduced to enable us specify them in a uniform way.

A.4.2 Binomial Distribution

Binomial distribution is involved when we are interested in a variate X which denotes the number of times the given event occurs in a set of trials. This distribution is constrained by the following assumptions.

1. Only two possible outcomes, success or failure, for each trial are allowed.
2. The probability of success is constant for all trials
3. If there are m trials, they must be independent.

The probability of getting exactly k successes in m trials is given by

$P(m,k) = \binom{m}{k} P^k (1 - P)^{m-k}$ k=0, 1, 2, ..., n,

This probability function is called the binomial density function.

A.4.3 Poisson Distribution

In reliability engineering we often come across problems that consist of observing discrete events in a continuos interval. Such problems are handled using the Poission distribution if it satisfies the following conditions.

1. For each small interval of time Δt, the probability of occurrence of one event is $\lambda \Delta t$, where λ is a constant.
2. The probability of two or more occurrences in the interval Δt is negligible.
3. Each occurrence is independent of all other occurrences.

If X is the number of occurrences and satisfies the above conditions, then it is a Poisson variate.

Suppose there are n intervals of time Δt in a time interval of t. We can think of the n intervals as forming a sequence of n independent trials with a probability of success equal to $\lambda \Delta t$.

Then X is approximately a binomial variate and therefore the binomial probability is

$$P(n, \chi) = \binom{n}{\chi} (\lambda \Delta t)^{\chi} (1 - \lambda \Delta t)^{n-\chi} \quad \chi = 1, 2, ..., n \qquad \text{A.3}$$

$= 0$, otherwise

The limit approached by the above probability when $t \to 0$ is the desired probability of getting χ occurrences in time t. Substituting t/n for Δt in equation A.3

$$P(n, \chi) = \frac{n!}{\chi!\,(n-\chi)!} \left(\frac{\lambda t}{n}\right)^{\chi} \left(1 - \frac{\lambda t}{n}\right)^{n-\chi}$$

$$= \frac{(\lambda t)^{\chi}}{\chi!} \left(1 - \frac{\lambda t}{n}\right)^{(n-\chi)} \left[\frac{n(n-1) \ldots (n-\chi+1)}{n^{\chi}}\right]$$

$$= \frac{(\lambda t)^{\chi}}{\chi!} \left(1 - \frac{\lambda t}{n}\right)^{(n-\chi)} \left(\frac{n^{\chi}}{n^{\chi}}\right) \left(1 - \frac{1}{n}\right) \ldots \left(1 - \frac{\chi - 1}{n}\right)$$

as $n \to \infty$,

$$\left(1 - \frac{1}{n}\right)\left(1 - \frac{2}{n}\right) \ldots \left(1 - \frac{\chi - 1}{n}\right) \to 1 \quad \text{and} \quad \left(1 - \frac{\lambda t}{n}\right)^{n-\chi} = \left(1 - \frac{\lambda t}{n}\right)^{n} \left(1 - \right.$$

Thus the binomial probability approaches

$$f(\chi) = \frac{(\lambda t)^{\chi}}{\chi!} e^{-\lambda t}, \qquad \chi = 0, \quad 1 \ldots\ldots, n$$

Substituting $\lambda t = \mu$,

$$f(\chi) = e^{-\mu} \frac{\mu^{\chi}}{\chi!}, \quad \chi = 0, 1, 2, \ldots\ldots$$

$f(\chi)$ is the poisson probability density function.

A.4.5 Weibull Distribution

The Weibull distribution's density function is given by

$$f(\chi) = \beta\chi^{(\beta-1)} \exp[-(\chi/\alpha)^{\beta}] \qquad \text{A. 4}$$

Where α is the location parameter and β is the shape parameter.

The reliability of a system can be computed in regions I and III of the bath-tub curve shown in fig A.1 using Weibul Distribution. Where

$\beta < 1$ represents a decreasing hazard rate;
$\beta = 1$ represents a constant hazard-rate; and
$\beta < 1$ represents an increasing hazard-rate.

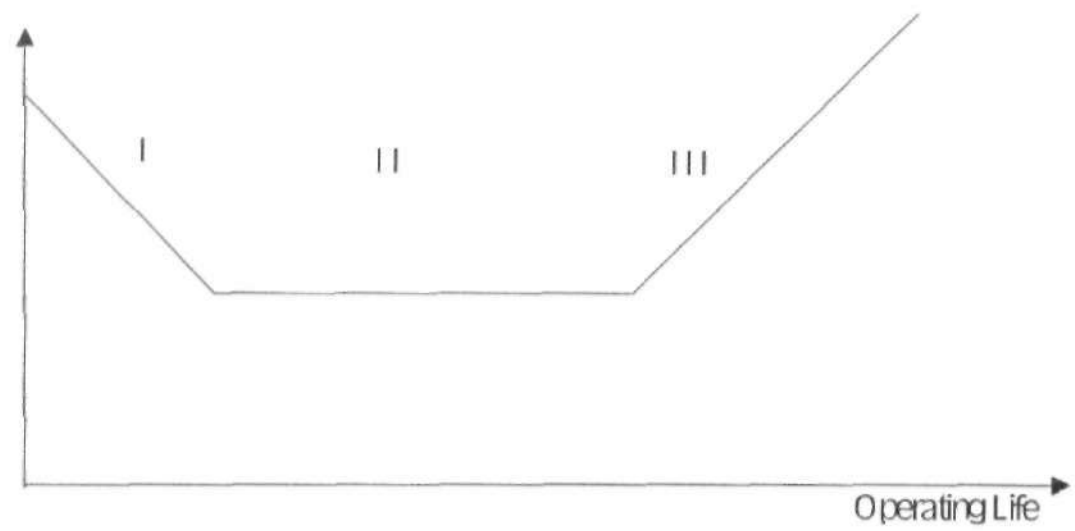


Fig. A.1 Conventional Bath-tub Curve (Hazard Rate versus Operating Time)

A.4.6 Gamma Distribution

A gamma distribution density function is defined by

$$f(\chi) = C\chi^{(a-1)}\ e^{-b\chi},\quad \chi \geq 0 \qquad \text{A.5}$$

where a and b are positive constants and

$$C = \frac{b^a}{\sqrt{(a)}}$$

where $\sqrt{(a)} = \int_o^\infty U^{a-1}\ e^{-u} du$

is known as the gamma function.

A.5. NUMERICAL CHARACTERISTICS OF VARIATES

A.5.1 Mathematical Expectation

If X is a discrete variate with the probability density function $f(\chi_i)$, then the mathematical expectation of X is defined by

$$E[X] = \sum_{i=1}^{n} \chi_i \, f(\chi_i) \qquad \text{A.6}$$

where $\chi_1, \chi_2, \ldots, \chi_n$ are the values of X.

If X is a continuous variate over the orange

$a \leq \chi \leq b$, then

$$E[X] = \int_a^b \chi f(\chi) \, d\chi \qquad \text{A.7}$$

where f(x) is the probability density function.

A.5.2 Variance

The variance of a variate X is defined as the expectation of the square of the deviation of X from E [X]. It is defined as

$$V[X] = \int_{\infty}^{\infty} \{\chi - E[X]\}^2 \, f(\chi) \, d\chi \qquad \text{A.8}$$

variance measures the dispersion of the value of a variate about the expectation.

APPENDIX B

BASIC CONCEPTS OF MARKOV PROCESSES

The Markov process is a mathematical model dealing with the various states in which a process can reside and the state transitions with the constraints that the next state to which the process can pass is a function of the present state only. If transitions occur at random-time intervals, then the system is a continous-time process, and transition rates are of interest.

System Models: The set of all equipment in KES is called a system. Each equipment may be in either of two states at any time, thus the system is either available (up) or in repair (down) and can be characterized by its mean behaviour.

A transition from up to down state is called a failure and a transition from down to up state is called a repair. And the respective transition rates are called failure rate (λ) and repair rate (μ). It is assumed that repair and failure rates are constant. It is further assumed that MTTR and MTTF are finite. These assumptions imply that the availability (A) or fraction of time the system will be in Up state , is a number greater than zero and less than one.

Consider the case of two identical equipments in parallel, each having failure rate λ and repairs rate μ. The subsytem can be in three possible states.

State (0) Both equipment operating.

State (1) One equipment operating, the other having failed.

State (2) Both equipment failed.

Let $P_i(t)$ be the probability that the subsytem is in state (i) at time t and assume that the initial state is (0).

Therefore $P_o(0) = 1$ and $P_1(0) = P_2(0) = 0$.(B1)

$\Rightarrow P_o(t) + P_1(t) + P_2(t) = 1$ (B2)

The subsytem will be in state (0) at time $t+\delta t$ if:

a. the subsytem was in state (0) at time t and no failure occurred in either equipment during the interval δt, or,

b. the subsytem was in state (1) at time t, no further failure occurred during δt, and the failed equipment was repaired during δt.

The probability of only one failure occurring in one equipment during the interval is simply $\lambda\ \delta t$ (δt is very small). Consequently $(1-\lambda\delta t)$ is the probability that no failure will occur in one equipment during the interval. The probability that both equipment will be failure-free during the interval is, therefore,

$$(1-\lambda\delta t)^2 \sim 1 - 2\lambda\delta t \qquad \text{(B3)}$$

The probability that one failed equipment will be repaired within δt is μdt. This leads to the equation:

$$P_o(t+\delta t) = P_o(t).\ (1-2\lambda\delta t) + P_1(t).(1-\lambda\delta t).\ \mu\delta t \qquad \text{(B4)}$$

Similarly for state 1 and 2:

$$P_1(t+\delta t) = P_o(t).\ (-2\lambda\delta t) + P_1(t).\ (1-\lambda\delta t).\ (1-\mu\delta t) \qquad \text{(B5)}$$

$$P_2(t+\delta t) = P_1(t).\ \lambda\delta t + P_2(t) \qquad \text{(B6)}$$

Since $\lim_{\delta t \to 0} \dfrac{P_i(t+\delta t) - P_i(t)}{\delta t}$ *is* $\dfrac{dP_i(t)}{dt} = \dot{P}_i(t$;

Hence equations B4, B5 and B6 yield:

$$\dot{P}_o(t) = -2\lambda P_o(t) + \mu P_1(t) \qquad \text{(B7)}$$

$$\dot{P}_1(t) = 2\lambda P_o(t) - (\lambda + \mu) P_1(t) \qquad \text{(B8)}$$

$$\dot{P}_2(t) = P_1(t)\lambda \qquad \text{(B9)}$$

Writing equations B7, B8 and B9 in matrix form;

$$\begin{bmatrix} \dot{P}_0(t) \\ \dot{P}_1(t) \\ \dot{P}_2(t) \end{bmatrix} = \begin{bmatrix} -2\lambda & \mu & 0 \\ 2\lambda & -(\lambda+\mu) & 0 \\ 0 & \lambda & 0 \end{bmatrix} \begin{bmatrix} P_0(t) \\ P_1(t) \\ P_2(t) \end{bmatrix} \qquad \text{(B10)}$$

The state space diagram for the subsytem is given in fig B2.

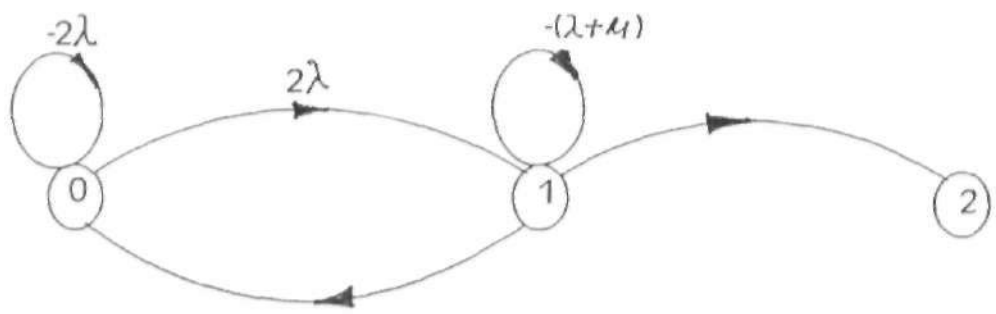


Fig B2: State space diagram for two idenitical equipment connected in parallel.

The MTTF for this subsystem can be found by integrating reliability function over the range 0 to ∞

$$MTTF = \int_o^\infty R(t)dt \quad (B11)$$

$$= \int_o^\infty P_o(t)dt + \int_o^\infty P_1(t)dt \quad (B12)$$

$$= T_o + T_1 \quad (B13)$$

The values of T_o and T_1 can be found by solving the following:

$$\int_0^\infty \begin{bmatrix} \dot{P}_0(t) \\ \dot{P}_1(t) \\ \dot{P}_2(t) \end{bmatrix} dt = \begin{bmatrix} -2\lambda & \mu & 0 \\ 2\lambda & -(\lambda+\mu) & 0 \\ 0 & \lambda & 0 \end{bmatrix} \int_0^\infty \begin{bmatrix} P_0(t) \\ P_1(t) \\ P_2(t) \end{bmatrix} dt \quad (B14)$$

$$\begin{bmatrix} P_0(\infty) - P_0(0) \\ P_1(\infty) - P_1(0) \\ P_2(\infty) - P_2(0) \end{bmatrix} \begin{bmatrix} -2\lambda & \mu & 0 \\ 2\lambda & -(\lambda+\mu) & 0 \\ 0 & \lambda & 0 \end{bmatrix} \begin{bmatrix} T_0 \\ T_1 \\ T_2 \end{bmatrix} \quad (B15)$$

Since $P_o(0) = 1$; $P_1(0) = P_2(0) = 0$ and $P_o(\infty) = P_1(\infty) = 0$; $P_2(\infty) = 1$

Hence equation (B15) reduces to

$$\begin{bmatrix} -1 \\ 0 \\ 1 \end{bmatrix} = \begin{bmatrix} -2\lambda & \mu & 0 \\ 2\lambda & -(\lambda+\mu) & 0 \\ 0 & \lambda & 0 \end{bmatrix} \begin{bmatrix} T_0 \\ T_1 \\ T_2 \end{bmatrix} \qquad \text{(B16)}$$

Using Cramer's rule to solve for T_o and T_1 yields:

$$T_0 = \frac{\lambda+\mu}{2\lambda^2} \quad \textit{and} \quad T_1 = \frac{1}{\lambda}$$

So that

$$\text{MTTF} = \frac{1}{\lambda} + \frac{\lambda + \mu}{2\lambda^2} = \frac{3\lambda + \mu}{2\lambda^2}$$

$$\therefore \quad \text{MTTF} = \frac{3\lambda + \mu}{2\lambda^2}$$

APPENDIX C

PROGRAM Project;

```
USES CRT,CHRNUNIT,STRUNIT,INUNIT,DOS,GRAPH;
TYPE
 namestring=STRING[4];
 profilerecord=RECORD
         year: INTEGER;
         n:ARRAY[1..12] OF INTEGER;
         downtime:ARRAY[1..12] OF REAL;
         dtime,uptime,mttf,mttr,mtbf,lamb,miu,a,abar:REAL;
         nt,leaporclear:INTEGER;
         r:CHAR;
 END;
 indexrecord=RECORD
         key:STRING[4];
         recordnumber:INTEGER
 END;
 activities=(add,display,revise,prin,quit);
 activityrange=add..quit;
 activityrecord=RECORD
         row,column:BYTE;
         menustring:STRING[25]
 END;

CONST
maxrecords=1200; rowpos1=6; rowpos2=9; optiondisplay=' A D M P Q ';
profilename='NEW.DAT'; indexfilename='GOOD.NDX';
activity:ARRAY[activityrange] OF activityrecord=
 ((row:rowpos1;column:20;menustring:'Add'),
  (row:rowpos1;column:35;menustring:'Display'),
  (row:rowpos1;column:53;menustring:'Modify'),
  (row:rowpos2;column:20;menustring:'Print'),
  (row:rowpos2;column:35;menustring:'Quit'));
nullchar=#0; enter=#13; bell=#7;
uparrow=#72; leftarrow=#75; rightarrow=#77;
downarrow=#80;
menuchars:SET OF CHAR =['A','D','M','P','Q',nullchar,enter];
cursorscancodes:SET OF
CHAR=[uparrow,leftarrow,rightarrow,downarrow];

VAR
profile:profilerecord;index:ARRAY[1..maxrecords] of indexrecord;
```

```
profilefile:FILE OF profilerecord; indexfile:TEXT; filelength:INTEGER;
done,ready :BOOLEAN; currentselection:activities;
drivervar,randcolor,color,modevar,i,j:INTEGER;
maxcolor:INTEGER;
PROCEDURE reversevideo(status:BOOLEAN);
BEGIN
 IF status THEN
  BEGIN
  TEXTCOLOR(YELLOW);
  TEXTBACKGROUND(RED)
 END
 ELSE
  BEGIN
  TEXTCOLOR(GREEN);
  TEXTBACKGROUND(WHITE)
  END
END;

PROCEDURE continue(l,m:INTEGER);
VAR
  inspace:CHAR;
BEGIN
  GOTOXY(l,m);
  WRITE('Press the space bar to continue');
  REPEAT
   inspace:=READKEY;
  UNTIL inspace=' '
END;

PROCEDURE highlightselection;
BEGIN
 reversevideo(TRUE);
 WITH activity[currentselection] DO
  BEGIN
   GOTOXY(column,row);
   WRITELN(uppercase(menustring))
  END;
 reversevideo(FALSE);
 GOTOXY(80,25)
END;

PROCEDURE initializemenu;
VAR
 option:activities;
 I:INTEGER;
```

```
BEGIN
 TEXTBACKGROUND(LIGHTGRAY);
 WINDOW(1,1,80,25);
 CLRSCR;
 TEXTCOLOR(BLUE);
 GOTOXY(1,4);
 WRITELN(',stringofchars(',78),');
 GOTOXY(1,5); WRITELN(',spaces(78),');
 GOTOXY(1,6); WRITELN(',spaces(78),');
 GOTOXY(1,7); WRITELN(',spaces(78),');
 GOTOXY(1,8); WRITELN(',spaces(78),');
 GOTOXY(1,9); WRITELN(',spaces(78),');
 GOTOXY(1,10); WRITELN(',spaces(78),');
 GOTOXY(1,11);
 WRITELN(',  ');
 GOTOXY(1,23);
 WRITELN(',  ');
 reversevideo(TRUE);
 GOTOXY(5,3);
 WRITELN(stringofchars(#5,12),' OPERATIONAL RELIABILITY',
 'OF KUJAMA EARTHSTATION ',stringofchars(#5,12));
 reversevideo(FALSE); GOTOXY(20,rowpos1+12);
 WRITE('(Use '); reversevideo(TRUE);
 WRITE(#24,' ',#25,' ',#26,' ',#27);
 reversevideo(FALSE); WRITE('  or  ');
 reversevideo(TRUE); WRITELN(optiondisplay); reversevideo(FALSE);
 GOTOXY(20,rowpos1+13); WRITE('to highlight the option, ');
 GOTOXY(20,rowpos1+14);
 WRITE('then press <Enter> to complete the selection.)');
 FOR option := add TO quit DO
  WITH activity[option] DO
  BEGIN
    GOTOXY(column,row);
    initialhigh(menustring)
  END;
 TEXTCOLOR(RED+BLINK);
 GOTOXY(15,24);
 WRITE('(Currently ', filelength);
 IF filelength=1 THEN
  WRITE(' record out of ',maxrecords,' records ')
 ELSE
  WRITE(' records out of ',maxrecords,' records');
  WRITELN(' in database.)');
  currentselection:=add;
  highlightselection;
```

```
 END;

FUNCTION searchindex(targetname:namestring):INTEGER;
VAR
found,notthere:BOOLEAN; first,last,midpoint,targetrecord:INTEGER;
BEGIN
found:=FALSE; notthere:=FALSE; first:=1;
last:=filelength; targetrecord:=-1;
REPEAT
 midpoint:=(first+last) DIV 2;
 WITH index[midpoint] DO
  BEGIN
   IF key=targetname THEN
    BEGIN
     found:=TRUE;
          targetrecord:=recordnumber
    END
   ELSE
    BEGIN
     IF key<targetname THEN
     first:=midpoint+1
    ELSE
     last:=midpoint-1
    END
   END;
 notthere:=(last<first)
UNTIL (found OR notthere);
searchindex:=targetrecord
END;

PROCEDURE sortindex(sortlength:BYTE);
VAR
 listjump,i,j:BYTE; sortcomplete:BOOLEAN; saverecord:indexrecord;
BEGIN
listjump:=1;
WHILE listjump<=sortlength DO
 listjump:=listjump*2;
WHILE listjump>1 DO
 BEGIN
  listjump:=(listjump-1) DIV 2;
   REPEAT
    sortcomplete:=TRUE;
         FOR j:=1 TO sortlength-listjump DO
          BEGIN
           i:=j+listjump;
```

```
            IF index[j].key>index[i].key THEN
             BEGIN
              saverecord:=index[j]; index[j]:=index[i];
              index[i]:=saverecord;
              sortcomplete:=FALSE
             END
            END
    UNTIL sortcomplete
 END
END;

PROCEDURE statusline(message:STRING);
BEGIN
  SETTEXTJUSTIFY(CENTERTEXT,TOPTEXT);
  SETTEXTSTYLE(TRIPLEXFONT,HORIZDIR,3);
  OUTTEXTXY(GETMAXX DIV 2,GETMAXY-40,message)
END;

procedure WaitToGo;
VAR
 Ch : char;
BEGIN
 REPEAT UNTIL KEYPRESSED;
 Ch := READKEY;
 CLEARDEVICE;
END;


PROCEDURE PutPixelPlay(message:STRING);
CONST
 Seed   = 1962; NumPts = 2000; Esc    = #27;
VAR
 I : WORD; X, Y, Color : WORD; XMax, YMax  : INTEGER;
 ViewInfo    : ViewPortType;
BEGIN
 StatusLine('Press a key to continue...'); GetViewSettings(ViewInfo);
 WITH ViewInfo DO
 BEGIN
        XMax := (x2-x1-1); YMax := (y2-y1-1);
 END;
 WHILE NOT KEYPRESSED DO
 BEGIN
RandSeed := Seed; I := 0;
WHILE (NOT KEYPRESSED) AND (I < NumPts) DO
BEGIN
```

```
BEGIN
    INC(I);
    X := RANDOM(XMax)+1; Y := RANDOM(YMax)+1; Color := GETPIXEL(X, Y);
    IF Color = RandColor THEN
     PUTPIXEL(X, Y, 0);
END;
SETCOLOR(Randcolor+2); SETTEXTSTYLE(TRIPLEXFONT,HORIZDIR,3);
SETTEXTJUSTIFY(CENTERTEXT,CENTERTEXT);
OUTTEXTXY(GETMAXX DIV 2,GETMAXY DIV 2,message);
END;
WaitToGo;
END;

PROCEDURE addrecord;
VAR
 okrecord:BOOLEAN; answer:CHAR;
 yearstr:STRING[4];
 I:INTEGER;
BEGIN
 IF filelength>maxrecords THEN
 BEGIN
  WINDOW(1,1,80,25); TEXTBACKGROUND(LIGHTGRAY); CLRSCR; GOTOXY(17,12);
  TEXTCOLOR(RED+BLINK);
  WRITELN('You have entered the maximum number of records');
  TEXTCOLOR(MAGENTA); continue(25,25); initializemenu
 END;
  WINDOW(1,1,80,25); TEXTBACKGROUND(LIGHTBLUE); CLRSCR;GOTOXY(29,2);
  TEXTBACKGROUND(LIGHTRED); TEXTCOLOR(BLUE);
  HIGHVIDEO; WRITELN('ENTER A NEW SET OF DATA');
  GOTOXY(29,3); WRITELN('-');
  NORMVIDEO; TEXTBACKGROUND(LIGHTBLUE);
  TEXTCOLOR(YELLOW);
  WITH profile DO
  BEGIN
   REPEAT
    GOTOXY(5,5); CLREOL; year:=ininteger('Year of interest:          ');
    STR(year,yearstr)
   UNTIL (year>0) AND (year<9999);
   IF (year MOD 4=0) AND (year MOD 100=0) AND (year MOD 400<>0) THEN
        leaporclear:=366
   ELSE
        leaporclear:=365;
  IF (searchindex(yearstr)>=0) THEN
   BEGIN
    GOTOXY(22,24); TEXTBACKGROUND(LIGHTBLUE);
TEXTCOLOR(RED+BLINK);
```

```
 WRITELN('This record is already in the database');
 TEXTCOLOR(MAGENTA);
 continue(25,25);
 END
ELSE
 BEGIN
 GOTOXY(10,9); CLREOL;
 n[1]:=ininteger('Number of failures in January:   ');
 GOTOXY(10,10); CLREOL;
 n[2]:=ininteger('Number of failures in February:  ');
 GOTOXY(10,11); CLREOL;
 n[3]:=ininteger('Number of failures in March:     ');
 GOTOXY(10,12); CLREOL;
 n[4]:=ininteger('Number of failures in April:     ');
 GOTOXY(10,13); CLREOL;
 n[5]:=ininteger('Number of failures in May:       ');
 GOTOXY(10,14); CLREOL;
 n[6]:=ininteger('Number of failures in June:      ');
 GOTOXY(10,15); CLREOL;
 n[7]:=ininteger('Number of failures in July:      ');
 GOTOXY(10,16); CLREOL;
 n[8]:=ininteger('Number of failures in August:    ');
 GOTOXY(10,17); CLREOL;
 n[9]:=ininteger('Number of failures in September: ');
 GOTOXY(10,18); CLREOL;
 n[10]:=ininteger('Number of failures in October:  ');
 GOTOXY(10,19); CLREOL;
 n[11]:=ininteger('Number of failures in November: ');
 GOTOXY(10,20); CLREOL;
 n[12]:=ininteger('Number of failures in December: ');
 nt:=0;
 dtime:=0.0;
 FOR I:=1 TO 12 DO
     nt:=nt+n[i];
 FOR I:=1 TO 12 DO
  BEGIN
     GOTOXY(1,9+I);
     CLREOL
  END;
 GOTOXY(10,9); CLREOL;
 downtime[1]:=inreal('DOWN TIME (in minutes) in January:   ');
 GOTOXY(10,10); CLREOL;
 downtime[2]:=inreal('DOWN TIME (in minutes) in February:  ');
 GOTOXY(10,11); CLREOL;
 downtime[3]:=inreal('DOWN TIME (in minutes) in March:     ');
 GOTOXY(10,12); CLREOL;
```

```
downtime[4]:=inreal('DOWN TIME (in minutes) in April:     ');
GOTOXY(10,13); CLREOL;
downtime[5]:=inreal('DOWN TIME (in minutes) in May:       ');
GOTOXY(10,14); CLREOL;
downtime[6]:=inreal('DOWN TIME (in minutes) in June:      ');
GOTOXY(10,15); CLREOL;
downtime[7]:=inreal('DOWN TIME (in minutes) in July:      ');
GOTOXY(10,16); CLREOL;
downtime[8]:=inreal('DOWN TIME (in minutes) in August:    ');
GOTOXY(10,17); CLREOL;
downtime[9]:=inreal('DOWN TIME (in minutes) in September: ');
GOTOXY(10,18); CLREOL;
downtime[10]:=inreal('DOWN TIME (in minutes) in October:  ');
GOTOXY(10,19); CLREOL;
downtime[11]:=inreal('DOWN TIME (in minutes) in November: ');
GOTOXY(10,20); CLREOL;
downtime[12]:=inreal('DOWN TIME (in minutes) in December: ');
FOR I:=1 TO 12 DO
    dtime:=dtime+downtime[i];
dtime:=dtime/60;
uptime:=leaporclear*24-dtime;
mttf:=uptime/nt;
mttr:=dtime/nt;
mtbf:=mttf+mttr;
lamb:=1/mttf;
miu:=1/mttr;
a:=mttf/mtbf;
IF a=1.0000 THEN r:='A';
IF (a>=0.9996) AND (a<=0.999999) THEN r:='B';
IF (a>=0.999) AND (a<=0.999599) THEN r:='C';
IF a<0.999 THEN r:='D';
abar:=1-a;
REPEAT
    GOTOXY(27,23); CLREOL;
    answer:=UPCASE(inchar('Save this record (Y/N) ? '));
UNTIL (answer='y') OR (answer='Y') OR (answer='n') OR(answer='N');
okrecord:=(answer='Y'); WRITELN(answer);
IF okrecord THEN
 BEGIN
 WINDOW(20,10,60,15); TEXTBACKGROUND(WHITE); CLRSCR;
 TEXTCOLOR(RED+BLINK); SEEK(profilefile,filelength);
 INC(filelength);
 GOTOXY(5,3); WRITELN('Saving record # ',filelength);
 WRITE(profilefile,profile);
 WITH index[filelength] DO
     BEGIN
```

```
          key:=yearstr;
          recordnumber:=filelength-1
         END;
        sortindex(filelength); TEXTCOLOR(MAGENTA);
        continue(5,4)
    END
   ELSE
    BEGIN
        WINDOW(20,10,60,15); TEXTBACKGROUND(WHITE); CLRSCR;
        GOTOXY(5,3); TEXTCOLOR(RED+BLINK);
        WRITELN('Abandoning this record input....');
        TEXTCOLOR(MAGENTA);continue(5,4);
    END
  END
END;
WINDOW(20,10,60,15); TEXTBACKGROUND(WHITE); CLRSCR;
TEXTCOLOR(BLUE);
GOTOXY(5,3);
REPEAT
 answer:=UPCASE(inchar('Input another record (Y/N) ? '));
UNTIL (answer='y') OR (answer='Y') OR (answer='n') OR (answer='N');
okrecord:=(answer='Y'); WRITELN(answer);
IF okrecord THEN addrecord
END;

PROCEDURE getmember(VAR whichrecord:INTEGER);
VAR
 year:INTEGER;
 er:CHAR;
 yearstr:STRING[4];
BEGIN
REPEAT
 GOTOXY(5,5); CLREOL; year:=ininteger('Year of interest:          ');
 STR(year,yearstr)
UNTIL (year>0) AND (year<9999);
whichrecord:=searchindex(yearstr);
WINDOW(1,1,80,25); TEXTCOLOR(LIGHTBLUE); CLRSCR;
IF whichrecord>=0 THEN
 BEGIN
  SEEK(profilefile,whichrecord); READ(profilefile,profile);
  WITH profile DO
   BEGIN
    TEXTCOLOR(YELLOW); GOTOXY((80-LENGTH(yearstr)) DIV 2,3);
    WRITELN(yearstr);
    GOTOXY((80-LENGTH(yearstr)) DIV 2,4);
    WRITELN(stringofchars('',LENGTH(yearstr)));
```

```
  END
 END
  ELSE
   BEGIN
    GOTOXY(22,13); TEXTCOLOR(RED+BLINK);
    WRITELN('Can"t find this record in the database');
   END
 END;

PROCEDURE continueorquit;
VAR
  inspace:CHAR;
BEGIN
GOTOXY(15,18); CLREOL; WRITE('Press any key to continue, Esc to quit');
REPEAT
  inspace:=READKEY;
UNTIL inspace<>";
IF inspace=#27 THEN
  BEGIN
   initializemenu;
   EXIT;
  END;
GOTOXY(1,18); CLREOL;
END;

PROCEDURE showrecord;
VAR
      location:INTEGER;
        er,inspace:CHAR;
BEGIN
WINDOW(1,1,80,25); TEXTBACKGROUND(LIGHTGRAY); CLRSCR; GOTOXY(22,3);
TEXTBACKGROUND(LIGHTMAGENTA); TEXTCOLOR(BLUE); HIGHVIDEO;
WRITELN('Display the parameters for the year'); GOTOXY(22,4);
WRITELN('-'); NORMVIDEO;
GOTOXY(5,6); TEXTBACKGROUND(LIGHTGRAY); TEXTCOLOR(BLUE);
getmember(location);
IF location>=0 THEN
BEGIN
WITH profile DO
BEGIN
  GOTOXY(14,4); HIGHVIDEO; TEXTCOLOR(BLUE);
  WRITELN('   RELIABILITY PARAMETER          VALUE     ');
  WRITELN(SPACES(8),stringofchars('',60));
  WRITELN(SPACES(17),'MTTF
',SPACES(17),'',SPACES(5),mttf:12:6);
  WRITELN(SPACES(17),'MTTR      ',SPACES(17),'',SPACES(5),mttr:12:6);
```

```
  WRITELN(SPACES(17),'MTBF      ',SPACES(17),'',SPACES(5),mtbf:12:6);
  WRITELN(SPACES(17),'L         ',SPACES(17),'',SPACES(5),lamb:12:6);
  WRITELN(SPACES(17),'          ',SPACES(17),'',SPACES(5),miu:12:6);
  WRITELN(SPACES(17),'A         ',SPACES(17),'',SPACES(5),a:12:6);
  WRITELN(SPACES(17),'Å         ',SPACES(17),'',SPACES(5),abar:12:6);
  WRITELN(SPACES(17),'R         ',SPACES(17),'',SPACES(16),r);
  WRITELN(SPACES(17),'N         ',SPACES(17),'',SPACES(5),nt:12);
END;
END;
TEXTCOLOR(MAGENTA);
continue(25,25)
END;

PROCEDURE modifyrecord;
VAR
        location,i,k:INTEGER;
        resp,conf:CHAR;
BEGIN
WINDOW(1,1,80,25); TEXTBACKGROUND(LIGHTBLUE); CLRSCR; GOTOXY(22,3);
TEXTBACKGROUND(LIGHTRED); TEXTCOLOR(BLUE); HIGHVIDEO;
WRITELN('Revise the parameters for the year'); GOTOXY(22,4);
WRITELN('-'); NORMVIDEO; GOTOXY(5,6);
TEXTBACKGROUND(LIGHTBLUE); TEXTCOLOR(YELLOW); getmember(location);
TEXTCOLOR(MAGENTA);
GOTOXY(1,25); CLREOL;
IF location>=0 THEN
BEGIN
 WITH profile DO
 BEGIN
 TEXTCOLOR(RED);
 GOTOXY(20,9);
 WRITELN('ORIGINAL VALUES');
 GOTOXY(20,10);
 WRITELN('');
 TEXTCOLOR(BROWN);
 GOTOXY(11,11); WRITELN('Number of failures in January:  ',n[1]:8);
 GOTOXY(11,12); WRITELN('Number of failures in February: ',n[2]:8);
 GOTOXY(11,13); WRITELN('Number of failures in March:    ',n[3]:8);
 GOTOXY(11,14); WRITELN('Number of failures in April:    ',n[4]:8);
 GOTOXY(11,15); WRITELN('Number of failures in May:      ',n[5]:8);
 GOTOXY(11,16); WRITELN('Number of failures in June:     ',n[6]:8);
 GOTOXY(11,17); WRITELN('Number of failures in July:     ',n[7]:8);
 GOTOXY(11,18); WRITELN('Number of failures in August:   ',n[8]:8);
 GOTOXY(11,19); WRITELN('Number of failures in September:',n[9]:8);
 GOTOXY(11,20); WRITELN('Number of failures in October:  ',n[10]:8);
 GOTOXY(11,21); WRITELN('Number of failures in November: ',n[11]:8);
```

```
GOTOXY(11,22); WRITELN('Number of failures in December: ',n[12]:8);
TEXTCOLOR(RED);
GOTOXY(15,23); WRITELN('Press any key to continue...');
conf:=READKEY;
FOR I:=1 TO 13 DO
 BEGIN
        GOTOXY(1,10+I);
        CLREOL
 END;
TEXTCOLOR(BROWN);
GOTOXY(11,11);
WRITELN('DOWN TIME (in minutes) in January:  ',downtime[1]:8:2);
GOTOXY(11,12);
WRITELN('DOWN TIME (in minutes) in February: ',downtime[2]:8:2);
GOTOXY(11,13);
WRITELN('DOWN TIME (in minutes) in March:    ',downtime[3]:8:2);
GOTOXY(11,14);
WRITELN('DOWN TIME (in minutes) in April:    ',downtime[4]:8:2);
GOTOXY(11,15);
WRITELN('DOWN TIME (in minutes) in May:      ',downtime[5]:8:2);
GOTOXY(11,16);
WRITELN('DOWN TIME (in minutes) in June:     ',downtime[6]:8:2);
GOTOXY(11,17);
WRITELN('DOWN TIME (in minutes) in July:     ',downtime[7]:8:2);
GOTOXY(11,18);
WRITELN('DOWN TIME (in minutes) in August:   ',downtime[8]:8:2);
GOTOXY(11,19);
WRITELN('DOWN TIME (in minutes) in September:',downtime[9]:8:2);
GOTOXY(11,20);
WRITELN('DOWN TIME (in minutes) in October:  ',downtime[10]:8:2);
GOTOXY(11,21);
WRITELN('DOWN TIME (in minutes) in November: ',downtime[11]:8:2);
GOTOXY(11,22);
WRITELN('DOWN TIME (in minutes) in December: ',downtime[12]:8:2);
GOTOXY(15,23);
IF UPCASE(inchar('Change the values (Y/N) ? '))='Y' THEN
        BEGIN
        FOR I:=1 TO 14 DO
         BEGIN
          GOTOXY(1,8+I);
          CLREOL
         END;
        TEXTCOLOR(YELLOW);
        GOTOXY(10,9); CLREOL;
        n[1]:=ininteger('Number of failures in January:   ');
        GOTOXY(10,10); CLREOL;
```

```
n[2]:=ininteger('Number of failures in February:  ');
GOTOXY(10,11); CLREOL;
n[3]:=ininteger('Number of failures in March:     ');
GOTOXY(10,12); CLREOL;
n[4]:=ininteger('Number of failures in April:     ');
GOTOXY(10,13); CLREOL;
n[5]:=ininteger('Number of failures in May:       ');
GOTOXY(10,14); CLREOL;
n[6]:=ininteger('Number of failures in June:      ');
GOTOXY(10,15); CLREOL;
n[7]:=ininteger('Number of failures in July:      ');
GOTOXY(10,16); CLREOL;
n[8]:=ininteger('Number of failures in August:    ');
GOTOXY(10,17); CLREOL;
n[9]:=ininteger('Number of failures in September: ');
GOTOXY(10,18); CLREOL;
n[10]:=ininteger('Number of failures in October:  ');
GOTOXY(10,19); CLREOL;
n[11]:=ininteger('Number of failures in November: ');
GOTOXY(10,20); CLREOL;
n[12]:=ininteger('Number of failures in December: ');
TEXTCOLOR(RED);
GOTOXY(15,23); WRITELN('Press any key to continue...');
conf:=READKEY;
FOR I:=1 TO 13 DO
 BEGIN
  GOTOXY(1,10+I);
  CLREOL
 END;
TEXTCOLOR(YELLOW);
GOTOXY(10,9); CLREOL;
downtime[1]:=inreal('DOWN TIME (in minutes) in January:   ');
GOTOXY(10,10); CLREOL;
downtime[2]:=inreal('DOWN TIME (in minutes) in February:  ');
GOTOXY(10,11); CLREOL;
downtime[3]:=inreal('DOWN TIME (in minutes) in March:     ');
GOTOXY(10,12); CLREOL;
downtime[4]:=inreal('DOWN TIME (in minutes) in April:     ');
GOTOXY(10,13); CLREOL;
downtime[5]:=inreal('DOWN TIME (in minutes) in May:       ');
GOTOXY(10,14); CLREOL;
downtime[6]:=inreal('DOWN TIME (in minutes) in June:      ');
GOTOXY(10,15); CLREOL;
downtime[7]:=inreal('DOWN TIME (in minutes) in July:      ');
GOTOXY(10,16); CLREOL;
downtime[8]:=inreal('DOWN TIME (in minutes) in August:    ');
```

```
    GOTOXY(10,17); CLREOL;
    downtime[9]:=inreal('DOWN TIME (in minutes) in September: ');
    GOTOXY(10,18); CLREOL;
    downtime[10]:=inreal('DOWN TIME (in minutes) in October:   ');
    GOTOXY(10,19); CLREOL;
    downtime[11]:=inreal('DOWN TIME (in minutes) in November:  ');
    GOTOXY(10,20); CLREOL;
    downtime[12]:=inreal('DOWN TIME (in minutes) in December:  ');
    FOR I:=1 TO 12 DO
      dtime:=dtime+downtime[i];
    dtime:=dtime/60;
    uptime:=leaporclear*24-dtime;
    mttf:=uptime/nt;
mttr:=dtime/nt;
    mtbf:=mttf+mttr;
    lamb:=1/mttf;
    miu:=1/mttr;
    a:=mttf/mtbf;
    abar:=1-a;
    TEXTCOLOR(MAGENTA);
    GOTOXY(5,21);
    IF UPCASE(inchar('Save revised record (Y/N) ? '))='Y' THEN
     BEGIN
       GOTOXY(5,22); CLREOL; TEXTCOLOR(BLUE); WRITELN('Yes');
       DELAY(500);
       GOTOXY(5,22); CLREOL; TEXTCOLOR(RED+BLINK); GOTOXY(25,22);
       WRITELN('Saving the modified record....');
       SEEK(profilefile,location);
      WRITE(profilefile,profile); GOTOXY(5,24); CLREOL;
      END
     ELSE
      BEGIN
       TEXTCOLOR(BLUE); GOTOXY(5,22); WRITELN('No');
       DELAY(500); GOTOXY(5,22);
       CLREOL; GOTOXY(26,22); TEXTCOLOR(RED+BLINK);
       WRITELN('Abandoning the revision....');
       DELAY(500); GOTOXY(5,24); CLREOL
      END;
   END;
 END;
TEXTCOLOR(MAGENTA); continue(25,24);
 END
END;

PROCEDURE PRINTRECORD;
CONST
```

```
  null='';
 VAR
  year:INTEGER;
  er:CHAR;
  yearstr:STRING[4];
  location,whichrecord:INTEGER;
  inspace,inss:CHAR;
  stat:BOOLEAN;
  printer:TEXT;
  prinfile:TEXT;
 BEGIN
  ASSIGN(prinfile,'OUTFILE.PRN');
  REWRITE(prinfile);
 {$I-}
   ASSIGN(printer,'LPT1');
   REWRITE(printer);
 IF IORESULT=0 THEN
   BEGIN
   WINDOW(1,1,80,25); TEXTBACKGROUND(LIGHTGRAY); CLRSCR; GOTOXY(22,3);
   TEXTBACKGROUND(LIGHTMAGENTA); TEXTCOLOR(BLUE); HIGHVIDEO;
   WRITELN('Print the parameters for the year'); GOTOXY(22,4);
   WRITELN('-'); NORMVIDEO;
   GOTOXY(5,6); TEXTBACKGROUND(LIGHTGRAY); TEXTCOLOR(BLUE);
   REPEAT
   GOTOXY(5,5); CLREOL; year:=ininteger('Year of interest:              ');
   STR(year,yearstr)
 UNTIL (year>0) AND (year<9999);
 WRITELN(printer,null);
 IF IORESULT<>0 THEN
 BEGIN
 CLOSE(printer);
 WINDOW(1,1,80,25); TEXTBACKGROUND(LIGHTGRAY); CLRSCR; GOTOXY(10,10);
 TEXTCOLOR(BLUE+BLINK);
 WRITELN('PRINTER NOT READY!!!');
 GOTOXY(10,14);
 TEXTCOLOR(RED);
 WRITELN('Press any key to exit...');
 inss:=READKEY;
 EXIT;
 whichrecord:=searchindex(yearstr);
 IF whichrecord>=0 THEN
 BEGIN
  SEEK(profilefile,whichrecord); READ(profilefile,profile);
  WITH profile DO
   BEGIN
    WRITELN(printer,null);
```

```
    WRITELN(printer,null);
    WRITELN(printer,null);
    WRITELN(printer,null);
    WRITELN(printer,SPACES(36),yearstr);
    WRITELN(printer,SPACES(36),stringofchars('',4));
    WRITELN(printer,null);
    WRITELN(prinfile,null);
    WRITELN(prinfile,null);
    WRITELN(prinfile,null);
    WRITELN(prinfile,null);
    WRITELN(prinfile,SPACES(36),yearstr);
    WRITELN(prinfile,SPACES(36),stringofchars('',4));
    WRITELN(prinfile,null)
  END
 END
  ELSE
   BEGIN
    GOTOXY(22,13); TEXTCOLOR(RED+BLINK);
    WRITELN('Can''t find this record in the database');
    TEXTCOLOR(MAGENTA);
    CLOSE(printer);
     CLOSE(prinfile);
    continue(25,25);
    stat:=TRUE;
   END;
IF location>=0 THEN
BEGIN
IF stat=TRUE THEN EXIT;
WITH profile DO
BEGIN
  WRITE(printer,SPACES(16));
  WRITELN('  RELIABILITY PARAMETER          VALUE    ');
  WRITELN(printer,SPACES(8),stringofchars('',60));
  WRITE(printer,SPACES(17));
  WRITELN('MTTF     ',SPACES(17),'',SPACES(5),mttf:12:6);
  WRITE(printer,SPACES(17));
  WRITELN('MTTR     ',SPACES(17),'',SPACES(5),mttr:12:6);
  WRITE(printer,SPACES(17));
  WRITELN('MTBF     ',SPACES(17),'',SPACES(5),mtbf:12:6);
  WRITE(printer,SPACES(17));
  WRITELN('L        ',SPACES(17),'',SPACES(5),lamb:12:6);
  WRITE(printer,SPACES(17));
  WRITELN('         ',SPACES(17),'',SPACES(5),miu:12:6);
  WRITE(printer,SPACES(17));
  WRITELN('A        ',SPACES(17),'',SPACES(5),a:12:6);
  WRITE(printer,SPACES(17));
```

```
WRITELN('Å        ',SPACES(17),'',SPACES(5),abar:12:6);
WRITE(printer,SPACES(17));
WRITELN('R        ',SPACES(17),'',SPACES(16),r);
WRITE(printer,SPACES(17));
WRITELN('N        ',SPACES(17),'',SPACES(5),nt:12);
CLOSE(printer);
WRITE(prinfile,SPACES(16));
WRITELN('  RELIABILITY PARAMETER          VALUE    ');
WRITELN(prinfile,SPACES(8),stringofchars('',60));
WRITE(prinfile,SPACES(17));
WRITELN('MTTF     ',SPACES(17),'',SPACES(5),mttf:12:6);
WRITE(prinfile,SPACES(17));
WRITELN('MTTR     ',SPACES(17),'',SPACES(5),mttr:12:6);
WRITE(prinfile,SPACES(17));
WRITELN('MTBF     ',SPACES(17),'',SPACES(5),mtbf:12:6);
WRITE(prinfile,SPACES(17));
WRITELN('L        ',SPACES(17),'',SPACES(5),lamb:12:6);
WRITE(prinfile,SPACES(17));
WRITELN('         ',SPACES(17),'',SPACES(5),miu:12:6);
WRITE(prinfile,SPACES(17));
WRITELN('A        ',SPACES(17),'',SPACES(5),a:12:6);
WRITE(prinfile,SPACES(17));
WRITELN('Å        ',SPACES(17),'',SPACES(5),abar:12:6);
WRITE(prinfile,SPACES(17));
 WRITELN('R        ',SPACES(17),'',SPACES(16),r);
 WRITE(prinfile,SPACES(17));
 WRITELN('N        ',SPACES(17),'',SPACES(5),nt:12);
 CLOSE(prinfile);
 END;
 END;
 TEXTCOLOR(MAGENTA);
 continue(25,25);
 END;
END;
END;

PROCEDURE removehighlight;
BEGIN
 WITH activity[currentselection] DO
  BEGIN
   GOTOXY(column,row); initialhigh(menustring)
   END
  END;

PROCEDURE selectnextactivity;
BEGIN
```

```
 removehighlight;
 IF currentselection=quit THEN currentselection:=add
 ELSE
  currentselection:=SUCC(currentselection); highlightselection
 END;

PROCEDURE selectpreviousactivity;
BEGIN
 removehighlight;
 IF currentselection=add THEN currentselection:=quit
 ELSE
 currentselection:=PRED(currentselection);
 highlightselection
END;

PROCEDURE selectupperactivity;
BEGIN
 removehighlight;
 IF currentselection=prin THEN currentselection:=add;
 IF currentselection=quit THEN currentselection:=display;
 IF currentselection=revise THEN currentselection:=revise;
 highlightselection
 END;

PROCEDURE selectloweractivity;
BEGIN
 removehighlight;
 IF currentselection=add THEN currentselection:=prin;
 IF currentselection=display THEN currentselection:=quit;
 IF currentselection=revise THEN currentselection:=revise;
 highlightselection
END;

PROCEDURE getselection(VAR quitsignal :BOOLEAN);
CONST
options:ARRAY[1..5] OF activities=(add,display,revise,prin,quit);
        firstchars='ADMPQ';
VAR
inchar:CHAR;
drivervar,modevar:INTEGER;
BEGIN
drivervar:=0;
quitsignal:=FALSE;
REPEAT
 inchar:=UPCASE(READKEY);
 IF NOT (inchar IN menuchars) THEN
```

```
            WRITE(bell)
UNTIL (inchar IN menuchars);
CASE inchar OF
 'A','D','M','P','Q' :
 BEGIN
     removehighlight;
     currentselection:=options[POS(inchar,firstchars)];
     highlightselection
 END;

 nullchar :
 BEGIN
 inchar:=READKEY;
 IF inchar IN cursorscancodes THEN
  CASE inchar OF
  leftarrow:selectpreviousactivity;
  rightarrow:selectnextactivity;
  uparrow:selectupperactivity;
  downarrow:selectloweractivity
 END
ELSE
 WRITE(bell)
END;

  enter :
  BEGIN
  IF currentselection=quit THEN quitsignal:=TRUE
  ELSE
  BEGIN
  CLRSCR;
  CASE currentselection OF

add: BEGIN
drivervar:=0;
INITGRAPH(drivervar,modevar,'C:\TP\BGI');
putpixelplay('Get ready to enter a new set of data');
CLOSEGRAPH; addrecord
END;

display: IF filelength>0 THEN
BEGIN
drivervar:=0;
INITGRAPH(drivervar,modevar,'C:\TP\BGI');
putpixelplay('Get ready to display a set of data');
CLOSEGRAPH; showrecord
END
```

```
 ELSE
  BEGIN
  WINDOW(1,1,80,25); TEXTBACKGROUND(YELLOW);
  CLRSCR; TEXTCOLOR(RED);
  GOTOXY(33,12); WRITELN('No record yet!');
  continue(25,25);
  END;

revise:  IF filelength>0 THEN
  BEGIN
  drivervar:=0;
  INITGRAPH(drivervar,modevar,'C:\TP\BGI');
  putpixelplay('Get ready to revise the data');
  CLOSEGRAPH; modifyrecord
  END
  ELSE
  BEGIN
  WINDOW(1,1,80,25); TEXTBACKGROUND(YELLOW);
  CLRSCR; TEXTCOLOR(RED);
  GOTOXY(33,12); WRITELN('No record yet!');
  continue(25,25);
  END;

prin :  IF filelength>0 THEN
  BEGIN
  drivervar:=0;
  INITGRAPH(drivervar,modevar,'C:\TP\BGI');
  putpixelplay('Get ready to print the results');
  CLOSEGRAPH; printrecord
  END
  ELSE
  BEGIN
  WINDOW(1,1,80,25); TEXTBACKGROUND(YELLOW);
  CLRSCR; TEXTCOLOR(RED);
  GOTOXY(33,12); WRITELN('No record yet!');
  continue(25,25);
  END;
END;
CLRSCR; initializemenu
END
END
END
END;

PROCEDURE openfiles(VAR filcok:BOOLEAN);
VAR
```

```
        i:INTEGER;
BEGIN
ASSIGN(profilefile,profilename);
ASSIGN(indexfile,indexfilename); fileok:=TRUE;
{SI-}
 RESET(profilefile);
{SI+}
IF IORESULT<>0 THEN REWRITE(profilefile);
filelength:=FILESIZE(profilefile);
IF filelength>0 THEN
 BEGIN
        {SI-}
                RESET(indexfile);
        {SI+}
        IF IORESULT=0 THEN
                BEGIN
                 FOR i:=1 TO filelength DO
                        WITH index[i] DO
                                READLN(indexfile,key,recordnumber);
                 CLOSE(indexfile);
                END
        ELSE
                BEGIN
                 fileok:=FALSE; GOTOXY(20,12); TEXTCOLOR(MAGENTA);
                 WRITE('NEW.DAT exists, ');
                 WRITELN('but GOOD.NDX does not.');
                 GOTOXY(20,13); TEXTCOLOR(BLUE);
                 WRITELN('    .... Can"t continue.');
                 CLOSE(profilefile); DELAY(4000);
                 WINDOW(1,1,80,25); NORMVIDEO; TEXTBACKGROUND(BLACK);
                 TEXTCOLOR(WHITE);
                CLRSCR
                END
        END
END;



PROCEDURE saveindex;
VAR
        i:INTEGER;
BEGIN
REWRITE(indexfile);
FOR i:=1 TO filelength DO
        WITH index[i] DO
                WRITELN(indexfile,key,recordnumber);
        CLOSE(indexfile)
END;
```

```
BEGIN
 drivervar:=0; INITGRAPH(drivervar,modevar,'C:\TP\BGI');
 SETCOLOR(WHITE);
 FOR i:=0 TO GETMAXX DIV 2 DO
 RECTANGLE(GETMAXX DIV 2-I,GETMAXY DIV 2-I,
 GETMAXX DIV 2+I,GETMAXY DIV 2+I);
 SETCOLOR(BLUE);
 SETTEXTSTYLE(TRIPLEXFONT,HORIZDIR,5);
 SETTEXTJUSTIFY(CENTERTEXT,CENTERTEXT);
 OUTTEXTXY(GETMAXX DIV 2,GETMAXY DIV 3,'Operational Reliability');
 SETCOLOR(GREEN); SETTEXTSTYLE(SANSSERIFFONT,HORIZDIR,4);
 OUTTEXTXY(GETMAXX DIV 2,GETMAXY *2 DIV 3,'of');
 DELAY(1500); CLEARDEVICE;
 RECTANGLE(0,0,GETMAXX,GETMAXY);
 FLOODFILL(GETMAXX DIV 2,GETMAXY DIV 2,LIGHTBLUE);
 FOR I:=1 TO 4 DO
 BEGIN
 SETTEXTSTYLE(GOTHICFONT,HORIZDIR,8);  SETCOLOR(RED);
 OUTTEXTXY(GETMAXX DIV 2,GETMAXY DIV 3,'KUJAMA');
 SETCOLOR(YELLOW);
 SETTEXTSTYLE(SANSSERIFFONT,HORIZDIR,4);
 OUTTEXTXY(GETMAXX DIV 2,GETMAXY *2 DIV 3,'EARTHSTATION');
 DELAY(500);
 SETTEXTSTYLE(GOTHICFONT,HORIZDIR,8);  SETCOLOR(WHITE);
 OUTTEXTXY(GETMAXX DIV 2,GETMAXY DIV 3,'KUJAMA');
 SETCOLOR(WHITE);
 SETTEXTSTYLE(SANSSERIFFONT,HORIZDIR,4);
 OUTTEXTXY(GETMAXX DIV 2,GETMAXY *2 DIV 3,'EARTHSTATION');
 DELAY(500)
 END;
 DELAY(500);
 CLOSEGRAPH; WINDOW(1,1,80,25); TEXTCOLOR(LIGHTGRAY); CLRSCR;
 openfiles(ready);
 IF ready THEN
 BEGIN
 initializemenu;
 REPEAT
        getselection(done)
 UNTIL done;
 INITGRAPH(drivervar,modevar,'c:\tp\bgi');  SETCOLOR(CYAN);
 FOR i:=0 TO GETMAXY DIV 2 DO
 RECTANGLE(0,GETMAXY DIV 2-i,GETMAXX,GETMAXY DIV 2+i);
 SETCOLOR(WHITE); SETTEXTJUSTIFY(CENTERTEXT,CENTERTEXT);
 SETTEXTSTYLE(GOTHICFONT,HORIZDIR,8);
 OUTTEXTXY(GETMAXX DIV 2, GETMAXY DIV 2,'Bye for now');
 DELAY(4000); CLOSEGRAPH; CLRSCR; CLOSE(profilefile);
```

```
 IF filelength>0 THEN saveindex;
 WINDOW(1,1,80,25); NORMVIDEO; TEXTBACKGROUND(BLACK);
 TEXTCOLOR(WHITE);
 CLRSCR;
END
END.
```