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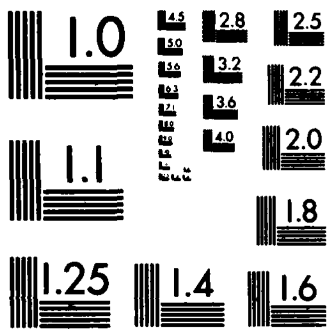

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A RELIABILITY AND FAILURE MODE
ANALYSIS OF CELESTIAL
TRAINING DEVICE MICROCOMPUTERS
EMPLOYED BY SAC AND MAC

George F. Nemeyer, Jr., Captain, USAF

LSSR 85-83

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
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Wright-Patterson Air Force Base, Ohio

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Although inexpensive, desk-top microcomputers offer the promise of improving productivity in many areas, their maintenance reliability must be considered when assessing their cost-effectiveness from a life-cycle cost viewpoint. This thesis set out to determine the reliability and frequency-of-repair of a typical microcomputer system, the Celestial Training Device (CTD), currently in the Air Force inventory. Owners of CTD systems were surveyed to determine system failure rates and which components were prone to failure. Existing repair procedures were evaluated for speed of response and, when possible, cost-effectiveness. The results of this study provide a picture of maintenance requirements for a typical microcomputer system which can be used by potential buyers of microcomputers as a basis for determining the most suitable maintenance procedure.

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A RELIABILITY AND FAILURE MODE ANALYSIS OF CELESTIAL TRAINING DEVICE MICROCOMPUTERS EMPLOYED BY SAC AND MAC

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Systems Management

By

George F. Nemeyer, Jr., BSEE
Captain, USAF

September 1983

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Captain George F. Nemeyer, Jr.

has been accepted by the the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN SYSTEMS MANAGEMENT

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CHAPTER 1

INTRODUCTION

The Air Force has recently begun buying small, desk-top microcomputers with the hope of improving people's productivity in areas ranging from clerical office work to aircrew training. Generally, these computer systems are commercial, off-the-shelf items purchased by individual agencies using unit operating funds (7).

These new computers have posed procurement and maintenance problems because established Government and Department of Defense procedures in these areas recognize only large, expensive computers which require special considerations for operator training and high equipment maintenance cost. Specifically, the Air Force 300-series regulations governing data automation equipment outline extensive requirements for acquisition, operation, and maintenance of computers. By the strictest interpretation of these regulations, the office microcomputers would be subject to the same requirements as large base-level computer systems (7). The cost of complying with these regulations could be many times the entire cost of a typical microcomputer system. The Operations Small Computer Conference, convened by the Air Staff Office of Plans and

Operations (XO-I) in January 1982, identified the need to revise the existing regulations to accommodate inexpensive microcomputers (7).

THE MAINTENANCE ISSUE

One problem area identified during this conference is maintenance. Frequently, agencies have purchased machines without serious consideration of the equipment maintenance which would be required (7). Although modern, solid-state electronic equipment is generally perceived to be "very reliable," failures do occur; and they must be accounted for when purchasing a system. Hetzel points out that the total cost of a system must include the cost of maintenance over its lifetime, whether that cost is an estimate of the actual cost of repairs which may be needed or the cost of fixed-rate maintenance under contract (4:p.1-2).

The possibilities for maintaining small computers range from repairs on an as-required basis, through on-call maintenance contracts, to keeping an entire system as a backup spare. Additional variations would include having maintenance performed by civilian or Air Force personnel. The optimum cost method to use would depend on the relative costs of the various methods versus the reliability and total cost of the computer system. For critical applications, the backup spare may be necessary, but for the typical office application, either contract maintenance or as-required maintenance may prove more cost effective.

Maintenance contracts can prove expensive relative to the cost of the system. For example, estimates obtained by the author for contract maintenance on a system which cost less than $4500 were on the order of $600 per system per year. This means that an agency employing eight of these systems could afford to replace an entire system for the cost of one year's maintenance contract. Thus, the maintenance contract would "pay for itself" only if the lack of reliability of the machines was such that an entire system would have to be replaced each year. If, on the other hand, the small machines prove reliable enough, such contracts could be eliminated and maintenance could be done on an as-required basis for less cost.

PROBLEM STATEMENT

Insufficient data exist in the government and private sector concerning the reliability and frequency of repair of off-the-shelf commercial microcomputers because they represent a new technology only recently enjoying wider distribution. Specific recommendations about the lowest cost maintenance procedure cannot be based either on facts or on simulations which have been validated. In order to provide decision-making information for small computer acquisition programs from a maintenance logistics and funding standpoint, their actual in-the-field reliability must be determined.

JUSTIFICATION FOR RESEARCH

An extensive search of the literature has revealed that no published system reliability studies have been done on the small, office-environment system. Literature sources investigated included Air Force Institute of Technology School of Systems and Logistics and School of Engineering library facilities, and Aeronautical Systems Division library facilities at Wright-Patterson AFB, the Defense Technical Information Center computerized information service, and the library facilities accessible through the Union List of Serials covering the Miami Valley, Cincinnati, and Northern Kentucky areas. Published studies have been confined to special microcomputers designed for high-reliability applications such as combat or other harsh environmental conditions. Conclusions reached from these studies of systems designed especially for high reliability would be inappropriate to the commercial, office environment system. This study provides information on such a system.

OBJECTIVE OF RESEARCH

The objective of the research is twofold. The first objective is to provide information on failure modes and the resultant level of reliability for the specific computer system under study; this information will provide a basis for evaluating the alternatives for the most cost effective maintenance program for that particular system. The second objective is to provide a picture of the types and amounts of maintenance required by an actual, in-the-field system consisting of typical microcomputer components which may be used as the basis for estimating reliability and maintenance needs of similar off-the-shelf systems under purchase consideration. In both cases, this information will permit a more realistic determination of system life-cycle cost by allowing an appreciation for the most cost effective maintenance plan to be employed in the acquisition strategy.

SCOPE OF RESEARCH

This thesis is restricted to assessing the reliability in terms of failure rates and failure modes of a typical system currently in the Air Force inventory. The system chosen for study is representative of a typical commercial microcomputer system. Although the research attempted to determine the maintenance methods used and the cost of maintenance actually performed on the computers under study, this thesis does not directly attempt to determine which of the alternative maintenance plans mentioned above would be most cost effective. However, considerations about the merits and relative effectiveness of existing maintenance methods made salient by information obtained from the study are discussed.

The system which was studied is the Celestial Training

Device (CTD) microcomputer system employed by units of the Strategic Air Command (SAC) and the Military Airlift Command (MAC). This microcomputer system, although acquired over several years, represents a relatively homogeneous system in terms of the types and brands of its components, which are typical of many commercial microcomputers. Additionally, it is a system which has been in use long enough to provide enough historical data to allow a valid assessment of reliability to be made.

GENERAL RESEARCH PLAN

Historical data was sought and analyzed to determine CTD computer system failure rates, failure modes, and maintenance actions performed. Because such data have not been kept as organized records, survey techniques were used to obtain sample data from individual agencies which have the computers. Appropriate statistical methods were then applied to the data to determine measures of reliability and maintenance needs.

CHAPTER 2

THE CTD SYSTEM

The purpose of this chapter is to familiarize the reader with the Celestial Training Device computer system. The history of the CTD is outlined along with an explanation of its functions and capabilities. Additionally, the computer hardware which makes up the CTD and the procedures currently employed for its maintenance are discussed.

CTD SYSTEM BACKGROUND

The Celestial Training Device system was conceived by two SAC navigators, Captains Doyle H. Gambrell, Jr. and Monty S. Hoffsommer, in 1978 (3:pp 18-19). The CTD is based on a microcomputer system consisting of a mainframe central processor containing memory, a clock, and one or more floppy disk drives. The mainframe is connected to a cathode-ray tube (CRT) terminal for user input and output display and a printer for hard-copy of mission results. A block diagram of the overall CTD system is shown below in Figure 1.

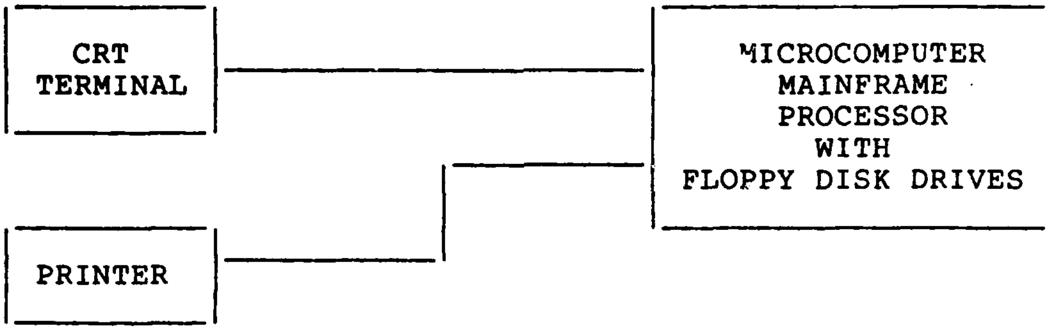

Figure 1. CTD System Configuration

In operation, the microcomputer is programmed to display simulated aircraft instrument readings on the CRT terminal. The instrument readings duplicate the information available at the navigator's station aboard a KC-135 tanker aircraft. Readouts include aircraft airspeed, Doppler drift and groundspeed, absolute altitude, pressure altitude, outside air temperature, magnetic or gyro compass heading, and time-of-day. The microcomputer contains a clock circuit which may be set for any date and time desired to start the simulated flight. Latitude and longitude of the starting point are also entered before the mission is begun. Once started, the computer program updates the display readouts according to the flight characteristics of the real aircraft, thus simulating an actual flight, in real-time, over any part of the world.

In addition, to displaying flight instrument readings, the computer maintains data on the locations of the sun, moon, and selected navigation stars and will compute and display simulated sextant readings for the navigator to use to "guide" the aircraft. The celestial information is computed for the actual bodies (sun, moon, stars) which would be visible at the time of day or night from the geographical location of the simulated aircraft. Thus, a navigator preparing for an actual mission may "pre-fly" the CTD on the same "day" as the proposed mission and obtain the same celestial information which will be available on the real trip. He then has an idea of what the results of celestial precomputations should be; and, therefore, he can avoid potential in-flight navigation errors due to computation mistakes.

The navigator uses the CTD instrument and sextant readings to determine his estimate of the location of the aircraft relative to the desired course exactly as he would when navigating the actual aircraft. Changes in in-flight wind speed and direction can be simulated, and bad weather may be simulated during the mission, just as may occur in an actual flight. To complicate the navigator's task, the computer may cause certain instruments to "fail" or give incorrect readings.

By inputting desired changes through the terminal keyboard, the navigator may alter the aircraft course, airspeed, and altitude while the computer keeps track of the location of the aircraft by latitude and longitude. Since the computer "knows" which displayed instrument readings are in error and the amount of error, it is able to track the aircraft accurately. At the end of the simulated flight, the navigator receives a printout showing the location of the aircraft at intervals throughout the mission. Using this printout, he may compare his navigation log and chart to the "actual" location of the aircraft at any time during the "flight."

Mission difficulty in terms of the number and severity of instrument errors, wind speed and direction volatility, sextant error, etc. may be pre-programmed by the navigator before the mission starts. Additionally, "canned" missions with pre-determined difficulty may be flown. Canned missions may be developed and stored for later use by others. This feature is especially valuable for training units because inexperienced navigators can fly increasingly difficult missions, with the mission difficulty parameters known beforehand only by the instructor.

Although the functions of the system are complex, the software programs, written by Captains Gambrell and Hoffsommer, run on an inexpensive microcomputer system which costs less than five thousand dollars. Because of the low cost of the system, SAC adopted the system and approved purchase of enough units to put one in each squadron having KC-135 navigators. Subsequent study showed the quality of training which the navigator received was comparable to that received by flying in the actual aircraft at a significant cost saving (6:p.421).

During 1980, Captain Titus Purdin and this author, both then in the Military Airlift Command, converted the KC-135 software programs to simulate the characteristics of the C-130 Hercules transport aircraft flown by MAC. Additionally, the display readouts were modified to be representative of the C-130 navigator's equipment. Demonstrations of the C-130 version to the Commander at Little Rock AFB, Arkansas led to the adoption of a pilot program to evaluate the CTD system for use by MAC navigators. The pilot program proved successful; and MAC, following SAC's lead, also approved purchase of one system per C-130 squadron worldwide and several additional units for the MAC C-130 navigator upgrade training school at Little Rock AFB. Further growth of the program included C-130 units of the National Guard and Air Force Reserve.

Currently there are 45 CTD computer systems under the SAC program and 32 under the MAC program. Because the CTD is a microcomputer which be programmed for tasks other than celestial navigation training, the system has found wide application. As a result, still more units are envisioned for the future.

CTD SYSTEM HARDWARE

The hardware on which the CTD system programs run is a typical microcomputer. It is made up of commercial components, and no special hardware or circuit modifications are required for it to perform as a celestial navigation trainer. Only the CTD program software is needed. The system's three main components are the computer mainframe, CRT terminal, and printer.

Computer Mainframe

The computer used in the CTD is a North Star Horizon manufactured by North Star Computers, Inc. (Although the name "North Star" may imply that it was designed for a "celestial" function, it is only a coincidence that the brand name is related to its function in this particular application.) The Horizon mainframe (the cabinet housing the processor, memory, power supply, etc.) supports between 48 and 64 kilobytes of memory, and one or two 5 1/4 inch floppy disk drives. Newer systems typically have more memory and two drives because decreasing component costs allowed the manufacturer to supply enhanced machines at the same (or lower) cost. The computer also contains a real-time clock circuit board which may be set and read under control of the software programs to provide the time of day.

Because the CTD navigator training software was originally written using the North Star BASIC language and operating system, the North Star Horizon computer is common to nearly all the systems. The CTD program has been adapted to run on a Radio Shack TRS-80 Model II system. This modified system, however, is in limited use and, therefore, was not targeted for this study.

CRT Terminal

The computer mainframe is connected to a CRT terminal capable of displaying 24 lines by 80 columns of characters on a twelve-inch screen. The typewriter-like keyboard of the terminal serves to input data and instructions to the computer. The CRT terminal is typically either a SOROC Technology model IQ-120 or a Televideo, Inc. model 912. Brands differ between systems because of cost and availability considerations made at the time individual systems were purchased.

Printer

The computer is also connected to a printer to provide "hard-copy" output of program results or program listings. Early systems (typically those of SAC) use an Integral Data Systems "Paper Tiger" model 125 printer. Later systems (typically those of MAC) use either Centronics, Inc. model 737 or 739 printers or Epson MX-80 or MX-100 printers. The brands and models of printers which were bought have changed from time to time because of improvements in the various mechanisms and relative cost changes among brands.

CTD SYSTEM MAINTENANCE

Units of SAC and MAC which have purchased CTD systems have chosen different methods of handling maintenance for the computer hardware.

Some units have recognized the need for maintenance and have formed a centralized maintenance facility. Most SAC units fall in this category. If a CTD system fails, the fault is isolated to the system component (mainframe, terminal, or printer), and the defective component is sent to the central facility for repair. In this case, the central facility may not actually perform the repair, but may act only as an intermediary between the user and the repair service. The repair service may be Air Force personnel or a commercial, contracted service performing the actual repair. However, from the view of the user, they must deal only with the central facility. Additionally, the defective unit may simply be replaced to the user from a stock of spare components. Thus, the user may get back into operation faster, as he does not have to wait for his particular component to be repaired.

Other units have chosen to deal with maintenance on an as-required basis and to handle the repair process at the local level. Most units in the earlier MAC program were in this category. In this case, the unit may find capable repair personnel at the base, or may contract through the base contracting office to have repair done by a commercial firm. In the event that the repair is of a simple nature, this procedure may give faster results than even the exchange of components by a central facility. On the other hand, complex repair may cause considerable loss of CTD system service as the unit's own defective component must be repaired and returned.

With either central facility or unit level maintenance, the repairs may be covered by a maintenance contract with a commercial firm. Under this option the commercial firm provides all required repairs for a flat-rate, periodic (monthly or yearly) fee.

Combinations of the above plans for CTD systems have been tried with varying success. However, the trend has been toward the central (typically MAJCOM-level) facility concept because of the lack of expertise at the local level to deal directly with local contracting and repair agencies. Additionally, overseas units may not have nearby commercial repair facilities; and, therefore, they must rely on CONUS-based assistance.

CHAPTER 3

METHODOLOGY

This chapter outlines the procedure used to obtain measures of CTD system reliability. Definitions of key reliability-related terms are presented as they apply to the CTD system, and the method of obtaining research data on the CTD is described.

KEY TERMS DEFINED

Several key terms are set forth and defined as they apply to this study. Certain terms may have relatively common connotations which must be refined so that the reader may understand exactly how they apply in this paper.

Reliability

Kenney (5:p.32) defines "reliability" to be "the probability that a product will perform to a specified standard of performance for a specified period of time when used in a specified manner." In the case of the CTD, the system must be able to successfully execute the software program instructions, correctly display proper readouts on the screen, and respond correctly to keyboard entries to the system.

As with any computer system, improper operation of the

CTD may occur because of mechanical failures, electrical failures, programming logic errors, program coding errors or operator errors. In this study, mechanical and electrical failures are the only ones of concern. The CTD software programs have been sufficiently tested and found to be free of defects. Likewise, operator error is considered as a case of not operating the CTD in the "specified manner." Reliability of the system in terms of its ability to function properly both mechanically and electrically is the subject of this research.

Series System

A series system is one in which the failure of one component will cause the loss of the entire system (5:p.168). This is analogous to a string of series-wired Christmas tree lights in which burn-out of one bulb will cause the entire string to go dark. For purposes of this study, the CTD is viewed as a series system because the failure of any component will require a repair action to be undertaken.

Parallel System

A parallel system is one which can experience the failure of a portion of the system without complete loss of the entire system (5:p.197). A degree of redundancy exists in components such that partial or complete operation is maintained. In the CTD system, the printer could be considered a redundant component, because printer output may be directed to the CRT screen and; therefore, loss of the printer would not mean complete loss of CTD use to the owner. However, the printer would still have to be repaired to provide full system utilization, and repair would represent a cost of maintenance for the system. For this reason, the printer is viewed as a serial component rather than a parallel component of the system in this study.

Failure

The term "failure" in this study is used in the general sense as defined by Caplen (1:p.5): "...the termination of an item to perform its required function." However, this study further specifies that a "failure" must require some repair or replacement action before the system or component is returned to normal operation.

Caplen (1:p.6) further classifies failures by degree as being either "partial" or "complete." An example of both types of failure in the CTD system would be a situation in which the printer becomes inoperative. The CTD system function would not be totally lost, as all data which is normally printed can be directed to the CRT terminal screen and manually copied. The system failure is therefore "partial," but the printer failure is "complete" because it cannot be used at all. Since the printer must be repaired before it can be used, the failure is a valid one from the view of this study. Therefore, failures of CTD system components requiring repair are considered complete whether or not they cause the system to be totally unusable.

Failure Mode

The failure mode is a description of the system or component failure in terms of the device which failed. The failure mode may be viewed from the system major component level (e.g. the computer mainframe failed), from the system sub-component level (e.g. the computer mainframe power supply failed), or the electronic or mechanical device level (e.g. the computer mainframe power supply fuse failed). This study attempts to determine failure modes to the lowest possible level in order to spot trends or chronic problems.

Time Before Failure

The time before failure is simply the total system operating time between the installation of a functioning CTD system and a component failure. A "functioning CTD system" may be a new system or one which has just been restored to operation after repair of a previous failure. In the latter case, the term "time between failures" may be used. For the purpose of this study, the terms are interchangeable.

Note that the definition specifies system operating time as the measurement unit. Therefore, time during which the system is not in actual use is not counted in the measurement. Thus, a one year old system which accumulated

50 operating hours before it failed would have a time before failure of 50 hours, not one year.

Total Time to Repair

The total time to repair is the amount of time elapsed between the occurrence of the failure and the time the system is restored to service (1:p.183). This time is composed of three components: (1) time from failure until the defective system component is delivered to a repair facility, (2) actual time the component spent in the repair facility (facility time to repair), and (3) time elapsed from repair until the component is returned to service. Items one and three represent administrative delays (1:p.184) which, although important from the user's viewpoint, are not really relevant to an assessment of the maintainability of the system.

Facility Time to Repair

The actual time to repair the system component is, in reality, a portion of item two above, the time spent in the repair facility. It could be considered as active time to repair and would represent only the time actually spent working on the item, and would be independent of logistic del~ys associated with obtaining needed tools or parts (1:p.184). However, it is not practical to attempt to obtain this information because of the lack of records and the diversity of repair methods used. Therefore, for this study, facility time to repair is considered to be the time the system component spent in the repair facility regardless of the time needed to actually perform the repair operation.

Mean Time to Repair

The mean time to repair may be reported as the statistical average of either total time to repair or the facility time to repair. For this study, mean time to repair will be treated in both ways: (1) from the user's viewpoint which considers only the total time the system was out of commission (including all logistic and administration delays), and (2) from the system maintainability viewpoint which considers the time spent in the repair facility as the facility time to repair.

MEASURING INSTRUMENT

The measuring instrument for this study was a questionnaire which was sent to each Air Force unit owning a CTD system to request system reliability and maintenance data. The questionnaire was chosen as the data gathering method because most units do not maintain formal CTD operating logs from which data could be extracted. As a result, much of the data gathered was either incomplete or estimated. Certain data on CTD repair costs, usage times, etc. was researched on an individual basis by the system owner. Time and resource constraints prohibited the author from conducting the research personally, and therefore the aid of the actual users was solicited through the questionnaire.

The questionnaires were sent to all units identified as having CTD systems for two reasons: (1) a total census was feasible because the population of the study was fairly small, with only about 75 units in the field, and (2) it was expected that a significant number of respondents would not be able to supply all the data needed. Because operating logs typically are not kept, much data would either be missing or would be estimates. It was hoped that enough of the respondents would be able to provide accurate data so that small-sample statistical techniques could be used to produce statistically valid conclusions.

The Questionnaire

The questionnaire which was used appears in Appendix A. It is divided into three major sections: system background and configuration, system failure analysis, and system repair analysis. Each section of the questionnaire is discussed with regard to the data which was sought and the rationale for the questions used.

Section One - System Background and Configuration

The first questionnaire section gathers system background and configuration data. Since the CTD systems were purchased at different times and have different components as discussed previously, this section determines the age and specific components used in each particular system.

Question one asks for the system installation date. The system installation date was requested to allow a determination of failure times and modes as a function of system age.

Question two asks for system configuration information. Classification of systems as to their components was done to allow valid comparisons between slightly dissimilar systems. The system was broken down into major system components: computer, terminal, and printer. In the case of the computer mainframe, additional data was sought as to the amount of memory and number of disk drives installed. This was done to determine whether, for example, a system with more memory or more disk drives would experience more failures. The respondent was given check-off sections to identify the brands and models of components of his system. Components known by the author to be actually in use were listed along with certain components known to have been considered in system purchase bidding. Alternative blocks marked "other" were given which requested that the user supply the make and model of any unusual equipment in use.

Question three asks if an operating log was kept on the CTD use. This question was asked both to determine the percentage of units actually keeping records (expected to be small) and to allow subsequent data given on various time-related questions to be evaluated in light of whether or not the answers were estimated or extracted from actual historical records. Although subsequent questions ask the respondent to indicate any estimated data supplied, this question served as a cross-check and an indicator of validity of the answers given.

Question four asks for the CTD usage time. Data was sought as to the average operating time of each CTD on a daily, weekly or monthly basis to provide a picture of the intensity of use. Additionally, operating time until failure can be determined based upon usage if the actual operating time from logs was not known.

Question five asks for information concerning the maintenance plan used by the CTD owner. This data was sought to attempt to determine which plans were currently in use and which appeared to be most effective. As stated earlier, a comprehensive evaluation of the cost effectiveness of particular maintenance plans was not undertaken; but the data obtained is presented for review and possible use in future research. The question was presented as a check-off section to allow categorization of responses into known possibilities. Annual cost of any contract maintenance agreement was requested if local or regional repair facilities were employed. A write-in option was given to allow the user to indicate any repair procedure not covered in the options list.

Section Two - System Failure Analysis

The second section of the questionnaire gathered data on time between failures and failure modes of the system.

Question one asks if the user's system has experienced a failure which required repair. Attention is directed to the fact that routine maintenance actions such as replacing printer ribbons or replacing worn out floppy diskettes were excluded from consideration in this question because such actions do not fit the context of this study. While such maintenance could have been considered as affecting total system reliability, it was felt that such expendable-supply replacement would be routine and necessary in any such system, and thus would appear as a baseline level of maintenance actions common to all systems. This baseline was removed by eliminating such actions from consideration.

Likewise, operator error was excluded because such error would reflect the level of training of the operator and not the reliability of the equipment. Operator training would, in all likelihood, vary considerably in quality. Therefore, operator induced malfunctions (unusual results which might be interpreted as being caused by a system component failure) would represent effects of an uncontrolled variable which was not being measured in this study.

Programming error was also eliminated for similar reasons. The CTD program software had been tested in hundreds of hours of operation and had been demonstrated to be free of logic errors which would induce any kind of malfunction which would have been detected in this survey. However, other programs written by users for the CTD computer would not have the benefit of such testing and known performance. Therefore, any malfunction subsequently attributed to a user program software error would not be a reflection of the reliability of the system itself.

If the user's system had experienced a failure which required repair, the respondent was directed to complete the subsequent sections to report the nature of the failure. If no failure had been experienced, previous answers to usage questions could be used to determine the number of hours accumulated on the system. This figure could be useful as a reflection of the minimum length of time which can now be expected before failure, although such data was not directly employed in mean time before failure calculations since a failure had not yet occurred.

Question two is the failure mode and mean time before/between failure data gathering section. The system major components are listed and broken down into electronic sub-components to provide the most detailed picture possible of the exact failure which occurred. The categories were given to insure consistent reporting from the various respondents and to allow analysis to categorize the failures to pinpoint any recurring or chronic problem.

The data on failures was gathered on a failure-by-failure basis. The questionnaire provides space to report up to eight instances of system failure. This was done to limit the length of the questionnaire form. Personal experience and preliminary study indicated that eight was a sufficient number to include the failures experienced by most systems. It was planned to contact any unit which reported seven or more failures to obtain further information. (Results of the survey indicated that eight was indeed sufficient, as no unit reported more than seven failures on a single system.)

Space is given to allow a brief description of the failure to be provided in order to determine as much detail concerning the failure as is known. Since it was likely that many respondents would be non-technical persons, these responses would also allow interpretation and validation of the information provided in the previous section.

In order to obtain data for mean time between failure calculations, the respondent was instructed to treat each failure as occurring in a sequence and to report the system operating time for each failure as if he had new system components after each previous failure was corrected. This instruction was reinforced by the structure of the questions which asked for time between failures. Because system components may have been exchanged or replaced to a given user and because certain components (such as individual circuit boards) do not bear serial numbers, tracking failures by specific system components was not possible. Attempting to track failures by major system component would not allow a detailed examination of the reasons for failure. A computer mainframe which had a memory board exchanged would not be the "same" computer mainframe after the replacement. Therefore, the components were considered to have come from a population whose likelihood of failure would not be dependent on whether or not any particular component had been repaired or was a new one. Thus, the probability of failure of any component would be the same after repair as before. This assumption is consistent with an exponential failure rate characteristic (1:p.44).

To assist the respondent, a sample was given to illustrate the completion of the failure description section. It was requested that the respondent indicate when data being supplied was estimated rather than being submitted from operating logs or other factual documents.

<u>Section Three - System Repair Analysis</u>

The third section of the questionnaire gathered data on the time the system was out of commission and the time which was required to have the system repaired for each failure. This section was arranged to correspond to section two in that the history of repair of each failure was treated separately and in sequence. Groups of questions were provided for each of the eight possible failures which could be reported in section two.

Question one of each failure group requests the method used for the repair of that failure. Three coded choices were provided to classify the responses. These were unit/base level repair, MAJCOM or central facility repair, or local/regional commercial facility. This data was sought to be able to analyze the repair times and costs with respect to the repair method used.

Question two of each group asks for the time which elapsed between the failure and the time when the system (or component) was delivered to the repair facility. Personal experience had indicated that the actual repair of systems was typically smaller than the paperwork and other associated delays in getting systems to and from repair facilities. This question was included to quantify and isolate these administrative delays from the actual repair time. Thus, a figure for mean time to repair could be calculated with and without the delays included. This approach was taken because, from a users viewpoint, the total time including all delays is important; yet, from a system reliability viewpoint, repairability should be measured without the logistic and administrative delays influencing the calculation.

Question three asks for the amount of time the system spent in the repair facility. For the purpose of this study, this time represents the facility time to repair. Any logistic delays incurred by the repair facility in getting needed tools or parts would be included. While inclusion of these delays distorts the picture of the repair time actually needed to fix a broken system component, it was the total time seen by the user for repair which was considered important in this study.

Question four of each group asks for the time elapsed from the time the system was repaired until it was returned to service. This question identifies and isolates another element of administrative delay in the repair process which is important from the user's viewpoint, but which is independent of the actual mean time to repair from the system reliability viewpoint.

Questions five and six ask for the cost of the repair. The cost is broken into two elements: (1) cost of repair parts and labor charged by the repair facility, and (2) total cost charged to the user for the repair. This distinction was made to pinpoint instances of transportation cost for getting the system component to and from the repair facility. Additionally, any administrative overhead charged to the user could be identified. It was expected that, in the case of MAJCOM or centralized maintenance facilities, the cost of repair charged to the unit might be zero and would be borne by the central facility's overall budget. Also, any repair made while the component was in the factory warranty period would likely incur no charge for parts or labor, but might involve transportation charges. In this case, there would still be a cost to the user for maintenance which must be considered.

Question seven of each group asks how much training was lost because of the CTD failure. This question was included to determine the extent of dependence which the user's unit placed on the CTD for training. It does not bear directly on the reliability issue, although, for example, poor CTD reliability and long time to repair combined with severe loss of training because of CTD failure could indicate need for closer examination of repair methods being used. The determination of the optimum alternative in such a case would be the subject of further research. The question was presented as a Likert scale (2:p.272) with four possible choices. The respondent was asked to indicate which of the four statements described the situation. The choices ranged from no loss of training to loss of training so severe that actual aircraft flying hours had to be scheduled to make up the loss. The question was presented in this manner in order to classify possible responses into a limited number of categories for analysis.

The final question of the questionnaire asks for the name and phone number of a person who could be contacted for further information. It was this person who was initially contacted to clarify ambiguous or incomplete responses to the questions asked on the questionnaire. Additionally, the individual was contacted for more detail if any questionnaire responses indicated any unusual circumstances regarding the CTD system for that unit.

CHAPTER 4

DATA ANALYSIS

This chapter presents the results of the CTD questionnaire survey. In general, the presentation of the analysis parallels the questionnaire format.

In order to permit analysis, the questionnaire responses were numerically coded and placed into a computer data base. Questions requiring an explanatory answer were referenced directly from the questionnaire forms when necessary.

SURVEY RESPONSE ANALYSIS

A total of 76 questionnaires were sent to units of SAC and MAC identified as having at least one CTD system. In the event that more than one CTD was identified as belonging to any unit, additional questionnaires were sent so that each CTD in the field would be surveyed. A period of three weeks from questionnaire mailing was allowed for completed forms to be returned. After that time, contact was attempted with units which did not respond. This follow-up contact period lasted approximately two weeks. Because the order in which responses were received was not important, contacts were made with geographically closer units first to compensate for longer mailing delays expected for units further away. This procedure allowed the more remotely located units to have the maximum amount of time to receive, respond to, and return the questionnaire.

Response was excellent: either a completed questionnaire was received or contact was made with all but two of the original 76 units on the mailing list. The two units which could not be contacted were both overseas units. Despite several attempts, no personnel with knowledge of CTD matters could be reached. The principle reason was time zone differences making schedules incompatible. However, because of the high percentage of successful responses, extraordinary measures were not taken to pursue these two potential respondents. Table 1 below presents the responses obtained broken down by command.

	Number and Percent of Responses					
	MAC	Percent	SAC	Percent	All Users	Percent
Surveys Mailed	32	----	44	----	76	----
Surveys Returned	28	87.5	33	75.0	61	80.3
Follow-up Contacts	4	12.5	9	20.5	13	17.1
Response by Command	32	100.0	42	95.5	74	97.4

Table 1. Questionnaire Survey Response

SECTION ONE - SYSTEM BACKGROUND AND CONFIGURATION ANALYSIS

CTD System Age

The figure below represents system age by year and quarter reported for system installation. In the figure, "S" represents a SAC system, and "M" represents a MAC system. It was not expected that an exact installation date always would be available, especially in the case of older systems. However, it was hoped that age could be estimated to the nearest month. In several cases, respondents did not supply an exact date, but rather a phrase like "spring 1980" or "late 1981." In such cases, the response was placed in the quarter most appropriate for the phrase used.

Because exact dates were not always reported, the determination of age in months was made by assuming that any system reported in a given quarter was actually installed at the midpoint of the period. Thus, a system reported in the first quarter of 1983 would be 4.5 months old as of 1 July 1983. This approach caused the age used for calculation to be somewhat less accurate than using exact dates when they were reported; however, the maximum age error for any given system by this method is only plus or minus 1.5 months. Additionally, the errors, in general, averaged to near zero for cases in which multiple systems were installed in a particular quarter. Therefore, the potential error in age introduced by this method is considered to be insignificant for this study.

Year	Quarter	Systems Installed	Age as of 1 July 1983
1978	4	SSS	55.5 months
1979	1	S	52.5 months
	2		
	3	SSSSSS	46.5 months
	4	SSSSSS	43.5 months
1980	1	SSSSS	40.5 months
	2	SSSSSSSSSS	37.5 months
	3	SSSSS	34.5 months
	4	S	31.5 months
1981	1	S	28.5 months
	2	MMMMM	25.5 months
	3	MM	22.5 months
	4	MMMMMMM	19.5 months
1982	1	S	16.5 months
	2	MM	13.5 months
	3	M	10.5 months
	4	SSSMMMMMMMM	7.5 months
1983	1	MMMMMMM	4.5 months

(S = SAC, M = MAC)

Figure 2. Reported CTD System Age

Using the ages computed as described above, the mean and median age for the CTD systems was calculated and is shown in Table 2.

	SAC CTDs	MAC CTDs	All CTDs
	(All ages in months)		
Mean Age	38.3	13.7	27.7
Median Age	39.0	12.0	30.0

Table 2. Mean and Median CTD Age

CTD System Configuration

Tables 3-1, 3-2, and 3-3 indicate the numbers and percentages of respondents indicating their systems had particular components. Note that the equipment configurations fell into a smaller number of categories than were listed as options on the questionnaire form. This was expected because several choices listed in the questionnaire represented equipment which was offered by potential suppliers who did not subsequently receive contracts. The choices were included in case any such equipment was indeed acquired by any respondent. A small number of respondents indicated that they had equipment other than the choices provided. Typically, such equipment represents purchases of newer systems or of replacement of particular components in older systems.

System Component	SAC	MAC	All Users
	Number / Percent of Systems		
North Star Horizon	42 / 100.0	32 / 100.0	74 / 100.0
Disk Drives			
1 Drive	37 / 88.1	13 / 40.6	50 / 67.6
2 Drives	5 / 11.9	19 / 59.4	24 / 32.4
	42 / 100.0	32 / 100.0	74 / 100.0
Memory			
48 K	35 / 83.3	8 / 25.0	43 / 58.1
56 K	1 / 2.4	0 / 0.0	1 / 1.4
64 K	6 / 14.3	24 / 75.0	30 / 40.5
	42 / 100.0	32 / 100.0	74 / 100.0

Table 3-1. Computer Mainframe Configuration

System Component	SAC	MAC	All Users
	Number / Percent of Systems		
Soroc IQ-120	38 / 90.5	0 / 0.0	38 / 51.3
Soroc IQ-135	3 / 7.1	0 / 0.0	3 / 4.1
Televideo 910	0 / 0.0	2 / 6.3	2 / 2.7
Televideo 912	0 / 0.0	28 / 87.4	28 / 37.8
Televideo 925	1 / 2.4	2 / 6.3	3 / 4.1
	42 / 100.0	32 / 100.0	74 / 100.0

Table 3-2. Terminal Type

System Component	Number / Percent of Systems SAC	MAC	All Users
Centronics 737	0 / 0.0	11 / 34.4	11 / 14.9
Centronics 739	0 / 0.0	1 / 3.1	1 / 1.3
Epson MX-80	2 / 4.8	0 / 0.0	2 / 2.7
Epson MX-100	0 / 0.0	19 / 59.4	19 / 25.7
Integral Data 125	38 / 90.4	0 / 0.0	38 / 51.5
Integral Data 440	1 / 2.4	0 / 0.0	1 / 1.3
NEC 7720	1 / 2.4	0 / 0.0	1 / 1.3
Okidata 83	0 / 0.0	1 / 3.1	1 / 1.3
	42 / 100.0	32 / 100.0	74 / 100.0

Table 3-3. Printer Type

CTD Operating Log

Table 4 indicates the numbers and percentages of respondents indicating that some form of log was kept on the use of the CTD system.

Log Category	Number / Percent of Respondents SAC	MAC	All Users
Log Kept	33 / 78.6	5 / 15.6	38 / 51.4
No Log Kept	9 / 21.4	27 / 84.4	36 / 48.6
	42 /100.0	32 /100.0	74 /100.0

Table 4. CTD Operating Log

The high percentage of MAC units not keeping logs is due to the fact that there is no formal requirement to do so. Logs were viewed as unnecessary by those responsible for the MAC program for two reasons. First, the requirement for a formal log was not needed for reporting any information to higher headquarters. Second, the MAC viewpoint was that personnel should be encouraged to use the CTD and to seek additional uses for the computer system beyond use solely as a celestial trainer; therefore, any measure which would be counter to this goal was not promulgated as a user requirement. Individual units were not, however, prevented from keeping logs for their own use if they so desired.

The high percentage of use of logs reported by SAC units is a reflection of the command regulations governing their CTDs. Some units have elected to take advantage of the automatic usage-time logging provided by later versions of the CTD software, and have discontinued keeping separate logs in cases where the system is used exclusively for celestial training.

CTD Usage

Table 5-1 presents the numbers and percentages of respondents indicating relative amounts of CTD system use. Note that the system use includes running programs other than just the CTD navigation trainer program. No distinction was made as to type of programs because it was the total system use time which is important from a reliability viewpoint.

Use Category	Number / Percent of Responses SAC	MAC	All Users
Daily use	38 / 90.4	17 / 53.1	55 / 74.3
Weekly use	2 / 4.8	14 / 43.8	16 / 21.6
Monthly use	2 / 4.8	1 / 3.1	3 / 4.1
	42 /100.0	32 /100.0	74 /100.0

Table 5-1. CTD System Use

Respondents were also asked to indicate the number of hours that the CTD system was used in the above categories.

In order to obtain a common figure for use time, weekly and monthly figures were converted to provide a daily use time. Weekly figures were divided by five (five work days per week), and monthly figures were divided by twenty (four five-day work weeks per month). Using these normalized daily use figures, projection to yearly use was made by multiplying daily rates by 240 (12 months consisting of four 5-day work weeks per year). The result of the calculations is shown in Table 5-2. The range of use times is shown to provide additional insight into use.

Use Interval	SAC	Reported CTD Use Times MAC	All Users
		(All times in Hours)	
Daily Use			
Mean	4.3	2.4	3.4
Median	4.0	2.0	3.0
Range	1.8 - 8.0	0.8 - 6.0	0.8 - 8.0
Yearly Use			
Mean	1041	570	819
Median	960	480	720
Range	432 - 1920	180 - 1440	180 - 1920

Table 5-2. CTD Use Times

The lower use times for MAC are attributable to the fact that MAC, at present, has no formal requirement for use of the CTD celestial training program in routine navigator proficiency maintenance. Additionally, the SAC units, being older, have had a greater opportunity for additional uses beyond celestial training to be found for the systems. For these reasons, it is felt that the SAC use times are more representative of the steady-state use rates.

CTD System Maintenance Method

Table 6 presents the numbers and percentages of respondents indicating various methods they would use for repair of their CTDs. Note that the category of local or regional repair facility is subdivided to show which users currently have some form of established contract for system repair.

Maintenance Method	Number / Percent of Responses SAC	MAC	All Users
MAJCOM Central Facility	37 / 88.1	14 / 43.8	51 / 68.9
Local or Regional Facility with:			
No maintenance contract	3 / 7.1	16 / 50.0	19 / 25.7
Maintenance contract	2 / 4.8	0 / 0.0	2 / 2.7
No established method	0 / 0.0	2 / 6.2	2 / 2.7
	42 /100.0	32 /100.0	74 /100.0

Table 6. CTD Maintenance Method

The high percentage of SAC respondents indicating use of MAJCOM repair facilities reflects the fact that the SAC

CTD program was established from the start as a command sponsored program. The MAC program, on the other hand, was initially less structured: each MAC unit was responsible for the purchase of its own system as well as being responsible for its maintenance. The MAC program is currently undergoing centralization for system purchase, and maintenance of the newer systems is being handled by a central facility. Owners of older systems may also take advantage of the central facility if they choose, but they are not required to do so.

The only two units responding which had some form of standing maintenance contract indicated that the cost was based on a labor rate of 35 dollars per hour plus parts with no additional fixed fee. One overseas unit indicated that it was currently attempting to negotiate a local repair contract.

SECTION TWO - SYSTEM FAILURE ANALYSIS

Total Failures Reported

Table 7 presents the number and percentages of CTD users who reported that one or more failures have occurred with their systems.

Number Reported	Number / percent of Responses SAC	MAC	All Users
No Failures	22 / 52.3	20 / 62.5	42 / 56.8
1 Failure	12 / 28.6	7 / 21.9	19 / 25.7
2 Failures	4 / 9.5	1 / 3.1	5 / 6.8
3 Failures	1 / 2.4	2 / 6.3	3 / 4.0
4 Failures	1 / 2.4	0 / 0.0	1 / 1.3
5 Failures	0 / 0.0	0 / 0.0	0 / 0.0
6 Failures	1 / 2.4	1 / 3.1	2 / 2.7
7 Failures	1 / 2.4	1 / 3.1	2 / 2.7
More than 7	0 / 0.0	0 / 0.0	0 / 0.0
	42 /100.0	32 /100.0	74 /100.0

Table 7. Number of CTD Failures Reported

Note that none of the respondents reported more than 7 system failures to date.

System Failure by Component

To determine which components are subject to the most frequent failure, the failures were grouped according to the system component categories listed on the questionnaire form. System sub-components are listed alphabetically within each major category. Tables 8-1, 8-2, and 8-3 present the results of this categorization.

System Component	Reported Failures	Percent of Category	Percent of Total
Total Failures	40	---	100.0
Computer Mainframe	19	100.0	47.5
Clock Board	0	0.0	0.0
CPU Board	3	15.8	7.5
Disk Controller	1	5.3	2.5
Disk Drive Unit	8	42.1	20.0
Memory Board	7	36.8	17.5
Motherboard	0	0.0	0.0
Power Supply	0	0.0	0.0
Other	0	0.0	0.0
CRT Terminal	6	100.0	15.0
Keyboard	3	50.0	7.5
Logic Circuits	0	0.0	0.0
Picture Tube	0	0.0	0.0
Power Supply	1	16.7	2.5
Video Display	1	16.7	2.5
Other	1	16.6	2.5
Printer	15	100.0	37.5
Logic Circuitry	2	13.3	5.0
Mechanical Parts	4	26.7	10.0
Power Supply	0	0.0	0.0
Print Head	7	46.7	17.5
Other	2	13.3	5.0

Table 8-1. SAC CTD Failures by System Component

System Component	Reported Failures	Percent of Category	Percent of Total
Total Failures	28	---	100.0
Computer Mainframe	10	100.0	35.7
Clock Board	2	20.0	7.1
CPU Board	1	10.0	3.6
Disk Controller	1	10.0	3.6
Disk Drive Unit	4	40.0	14.2
Memory Board	1	10.0	3.6
Motherboard	1	10.0	3.6
Power Supply	0	0.0	0.0
Other	0	0.0	0.0
CRT Terminal	5	100.0	17.9
Keyboard	1	20.0	3.6
Logic Circuits	2	40.0	7.1
Picture Tube	0	0.0	0.0
Power Supply	1	20.0	3.6
Video Display	1	20.0	3.6
Other	0	0.0	0.0
Printer	13	100.0	46.4
Logic Circuitry	3	23.1	10.7
Mechanical Parts	1	7.7	3.6
Power Supply	2	15.4	7.1
Print Head	7	53.8	25.0
Other	0	0.0	0.0

Table 8-2. MAC CTD Failures by System Component

The CRT terminal power supply failure in Table 8-2 was attributed by the respondent to user carelessness. The terminal, which was set for 120 volt operation, was accidentally connected to a 220 volt power source resulting in damage to several parts in the terminal power supply.

System Component	Reported Failures	Percent of Category	Percent of Total
Total Failures	68	---	100.0
Computer Mainframe	29	100.0	42.6
Clock Board	2	6.9	2.9
CPU Board	4	13.8	5.9
Disk Controller	2	6.9	2.9
Disk Drive Unit	12	41.4	17.6
Memory Board	8	27.6	11.8
Motherboard	1	3.4	1.5
Power Supply	0	0.0	0.0
Other	0	0.0	0.0
CRT Terminal	11	100.0	16.2
Keyboard	4	36.3	5.9
Logic Circuits	2	18.2	2.9
Picture Tube	0	0.0	0.0
Power Supply	2	18.2	2.9
Video Display	2	18.2	2.9
Other	1	9.1	1.6
Printer	28	100.0	41.2
Logic Circuitry	5	17.9	7.4
Mechanical Parts	5	17.9	7.4
Power Supply	2	7.1	2.9
Print Head	14	50.0	20.6
Other	2	7.1	2.9

Table 8-3. Total CTD Failures by System Component

In order to provide a graphic picture of the proportions of all failures contributed by each sub-component, the figures of Table 8-3 are reproduced in the form of a pie chart in Figure 3.

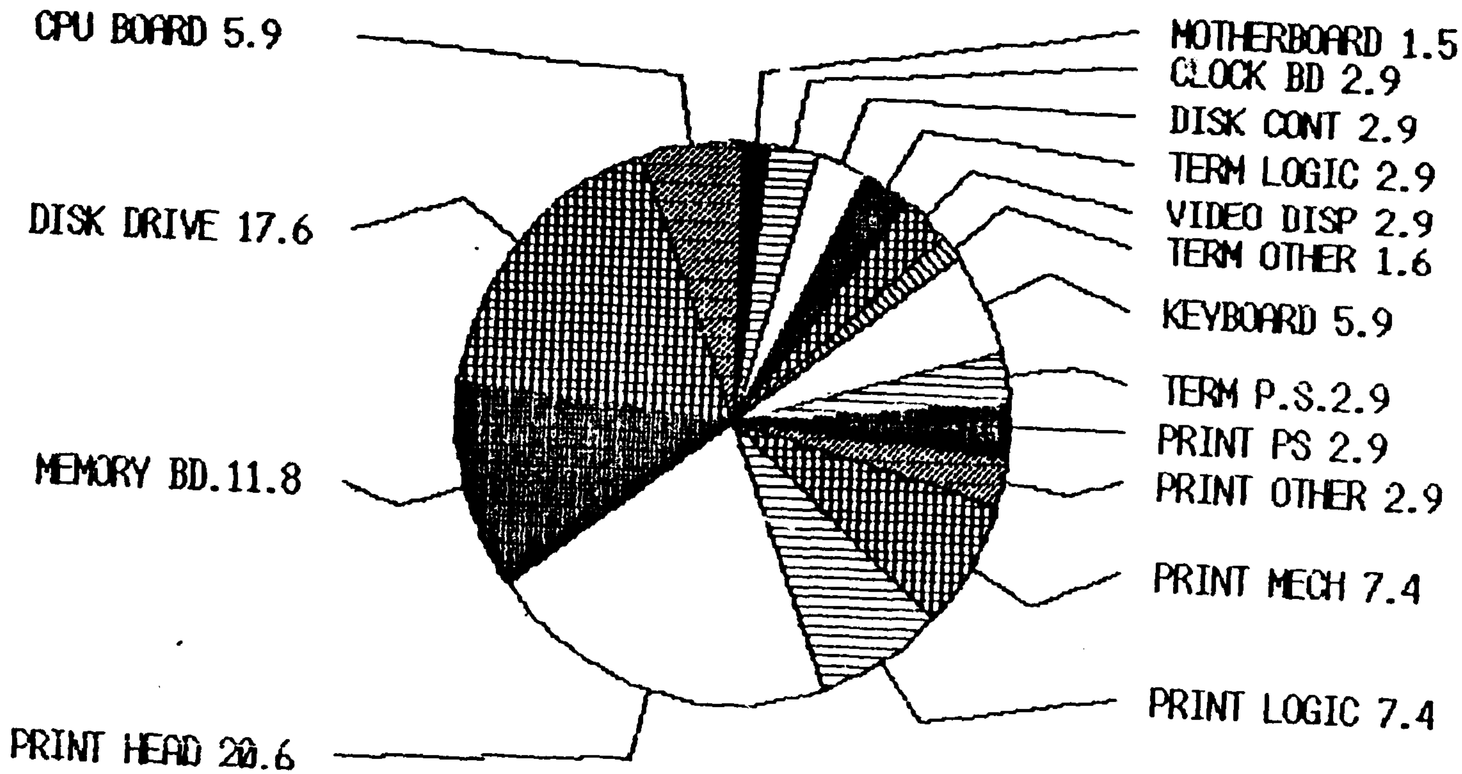

FIG.3 TOTAL FAILURES BY SYSTEM COMPONENT

Table 9 presents the ranking of components in descending order of occurrence of failure.

System Component	Percent of Total Failures	Cumulative Percentage
Print Head	20.6	20.6
Disk Drive Unit	17.6	38.2
Memory Board	11.8	50.0
Printer Mechanics	7.4	57.4
Printer Logic	7.4	64.8
Keyboard	5.9	70.7
CPU Board	5.9	76.6
Printer Power Supply	2.9	79.5
Printer Other	2.9	82.4
Disk Controller	2.9	85.3
Clock Board	2.9	88.2
Terminal Video Display	2.9	91.1
Terminal Logic	2.9	94.0
Terminal Power Supply	2.9	96.9
Terminal Other	1.6	98.5
Motherboard	1.5	100.0

Table 9. Ranking of Failures by System Component

The cumulative percentage figures for failures by component in Table 9 may be plotted as a cumulative percentage graph to give a Pareto distribution (1:p.208) for components which failed. This graph is presented in Figure 4.

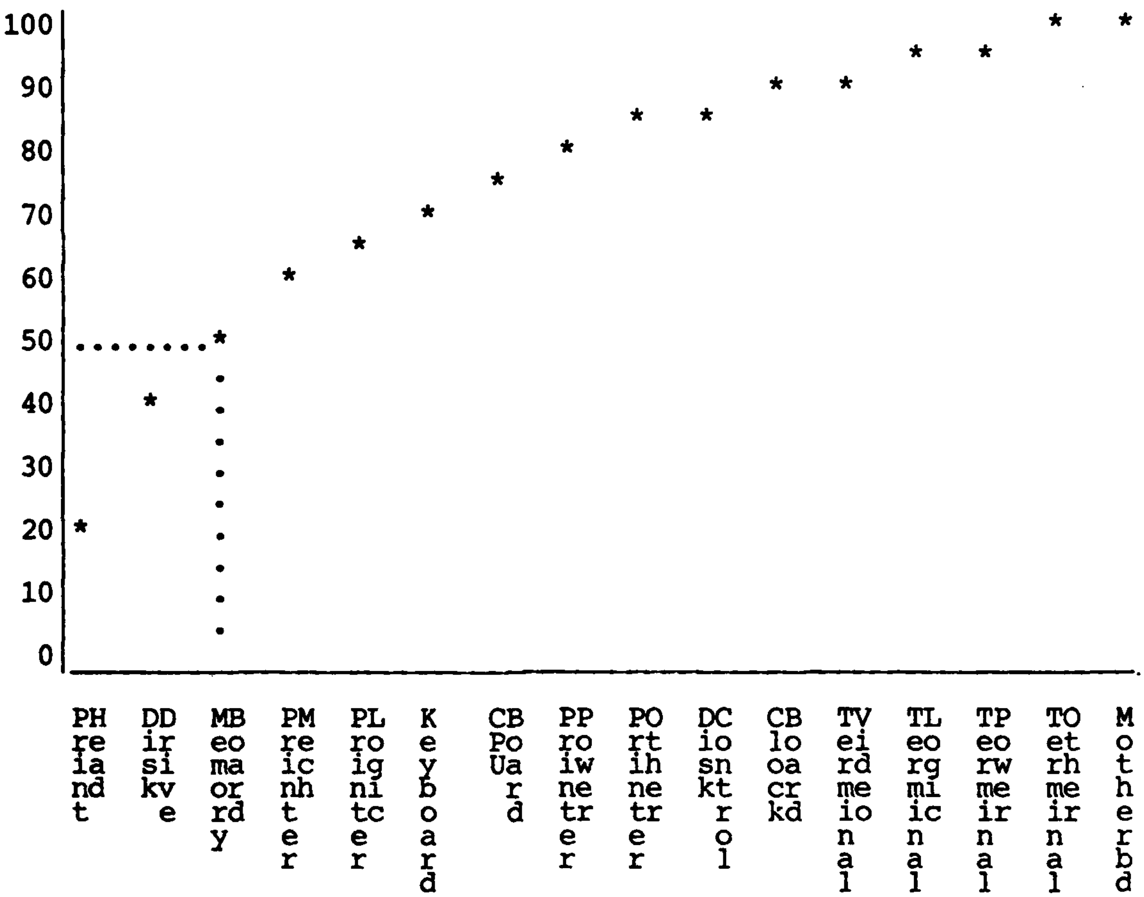

Figure 4. Cumulative Percent Failure by Component

Clearly, the percentage of failures is not evenly divided among the components. This phenomenon is not uncommon: often only a small number of components is responsible for the most failures. Since print head, disk drive, and memory board failures accounted for fifty percent of all reported failures, these items should be of most concern in any maintenance program. A maintenance plan which would exchange system sub-components should consider a higher number of spares of these items.

Because the terminals and printers used in various systems were made by different manufacturers, the number of failures of these components was categorized by component brand. Table 10 presents the results of that categorization listed alphabetically by make and model.

System Component	Total Component Population	Number of Reported Failures	Percent of Reported Failures
CRT Terminal	74	11	100.0
Soroc IQ-120	38	6	54.5
Soroc IQ-135	3	0	0.0
Televideo 910	2	0	0.0
Televideo 912	28	5	45.5
Televideo 925	3	0	0.0
Printer	74	28	100.0
Centronics 737	11	11	39.3
Centronics 739	1	2	7.1
Epson MX-80	2	0	0.0
Epson MX-100	19	0	0.0
IDS 125	38	14	50.0
IDS 440	1	1	3.6
NEC 7720	1	0	0.0
Okidata 83	1	0	0.0

Table 10. Printer and CRT Terminal Failures by Brand

Note that, in the case of terminals, the brands and models exhibiting the highest number of reported failures (Soroc 120, and Televideo 912) represent the largest percentages in terms of population within the terminal category. Additionally, these components are also the oldest components in continuous service within the command which owns them. For these reasons, the largest number of failures would be expected to come from these components if the failure rate for all brands and models was the same.

In the case of printers, however, the situation is somewhat different. The IDS 125, which represents 51.5 percent of the total printer population, exhibited the largest percentage of printer failures. This is not inconsistent with expectations. However, the Centronics 737/739 printer represents only 16.2 percent of the total printer population, behind the Epson MX-100 which represents 25.7 percent, yet it ranks second in the percentage of reported failures. (Note that the Centronics 737 and 739 are almost identical in mechanical design: the primary difference is in the printer's operating software which allows the 739 to plot graphics while the 737 does not provide this feature). This anomaly could be attributed to the fact that the Epson printers represent the newest printers in all systems, being purchased in quantity only for the very latest MAC systems. Therefore, the higher number of failures exhibited by Centronics printers could be a result of their age relative to the age of Epson printers. However, despite the fact that both the IDS 125 and the Centronics 737/739 are the oldest printer types within their commands, the data do not support the conclusion that the failures are age related or that the failures are related to wear out because of high usage rates. The Centronics and IDS models appear to be exhibiting failure due to design deficiencies, especially in the print head mechanism.

In Table 10, the reported failures within a particular component type category did not always occur to different components belonging to different users: some failures represent repeat failure of the same component. A repeat failure occurs when a particular user reports two or more failures attributable to the same component. Therefore, for example, even though there are eleven Centronics 737 printers and eleven reported failures within that category, it does not mean that each of the eleven printers failed: it is possible that some did not fail at all, and that others failed more than once.

Further insight may be gained by examining the number of repeat failures of various components. Repeat failures may indicate a component prone to failure, poor repair work on the previous repair, or a component subject to unusually high use or abuse by the particular user.

Table 11 presents the results of this analysis. Note that if a single user experiences two failures of his CTD system which were caused by two different components, the Total System category would reflect one repeat failure, but each of the component categories would reflect no repeat failures. Therefore, the Total System entry can be greater than the sum of repeat failures for the individual components.

System Component	Repeat Failures
Total System	13
Printer	8
CPU Board	1
CRT Terminal	1
Disk Drive	1
Memory Board	1

Table 11. Repeat Failures by Component

It cannot be assumed that the component responsible for subsequent failures following any particular repair is exactly the same piece of equipment because owners may exchange components as a means of system repair. Likewise, in the case of more than one component being used in a system (e.g. memory boards or disk drives), it cannot be determined from the data if the repeat failures occurred to the same item. However, in the case of printers and CRT terminals, repeat failures can be identified with a particular brand. All repeat printer failures were attributable to either Centronics 737/739 or IDS 125 printers. The one case of repeat CRT failure was attributable to a Soroc IQ-120.

Component Failure Times

In order to calculate the rate at which system components failed, the total operating hours on all systems was computed by summing the operating hours accumulated on each individual system. The total operating hours for each individual system was computed by multiplying the reported daily use, as determined in the CTD Usage section, by 20 (four 5-day weeks per month) to determine a monthly use; the monthly use was then multiplied by the reported system age as determined in the CTD System Age section. The individual system total use figures were then summed to yield the total operating hours for all systems. This estimating procedure was used because operating logs were not kept by all users from which exact usage times could be obtained. To date, all reported CTDs have accumulated an estimated total of 155,157 system operating hours.

The component failure time was calculated by dividing the total system operating hours by number of failures to date of a particular component. The assumption in this case is that all components are operated at the same time. It is assumed that all components would be turned on by the operator whenever using the system. Although power may be applied to a particular component, it may be actually called upon to perform its function during a small fraction of the time. Examples of such a situation include the printer and the disk drives: they typically may operate for only a small portion of the time the system is in use. Therefore the failure times must be viewed only in terms of average system operating hours and not as a failure time based on the operating hours for the component itself.

Table 12 presents the results of the failure time calculations.

System Component	Reported Failures	System Hours per Failure
Total Failures	68	2,282
Computer Mainframe	29	5,350
Clock Board	2	77,578
CPU Board	4	38,789
Disk Controller	2	77,578
Disk Drive Unit	12	12,929
Memory Board	8	19,394
Motherboard	1	155,157
Power Supply	0	155,157 +
Other	0	155,157 +
CRT Terminal	11	14,[illegible]
Keyboard	4	38,789
Logic Circuits	2	77,578
Power Supply	2	77,578
Picture Tube	0	155,157 +
Video Display	2	77,578
Other	1	155,157
Printer	28	5,541
Logic Circuitry	5	31,031
Mechanical Parts	5	31,031
Power Supply	2	77,578
Print Head	14	11,083
Other	2	77,578

Table 12. System Hours per Failure by Component

The times in Table 12 would represent mean time between failures if one were to assume that the failure rate (note: the failure rate is the reciprocal of the failure time as calculated above) for each component is constant with failures occurring randomly in time. However, many categories of devices, including electronic equipment, exhibit failure rate distributions which are not constant but appear "U" or bathtub shaped (1:p.13).

With such devices, failures will typically occur more often early in a component's lifetime. During this period of "infant mortality," components which have a weakness will fail. Such weakness may be caused by manufacturing or design defects. Also, inexperienced users may inadvertently misuse a new, unfamiliar device in a stressful and damaging manner (1:p.14). After the period of early failures, a prolonged period of stable performance will be observed in which the failure rate is nearly constant and much lower than in early life. This period, the bottom of the bathtub, represents the majority of the component's useful life. Finally, after the stable, low-failure-rate interval the failure rate will increase. This period results as components subject to wear begin to physically wear out and fail. This wear-out is characteristic of mechanical devices or devices such as light bulbs or vacuum tubes which consume some internal element during operation (1:p.20).

The constant failure rate period may be relatively short for mechanical and self-consuming devices. However, solid-state electronic devices (transistors, diodes, and integrated circuits) may, after the initial failures occur, exhibit lifetimes of many tens of years. Some early types of solid-state rectifiers have been operating for over 40 years with no measurable degradation of performance and "no indication that they will ever wear out [1:p.20]."

Times between failures reported for the CTD components appear to be following this general pattern. Table 13 presents the analysis of reported hours between component failures. The following discussion describes how the table was constructed.

The reported failures were grouped into the major component categories in which they occurred. In addition, failures in each major component category were further broken down into sub-component categories.

The Repeat Failures column also breaks down repeat failures to the sub-component level. The number of repeat failures was determined in the same manner as for the overall repeat failure analysis of Table 11. Therefore, the number of repeat failures for major component categories may be greater than the total of the repeat failures for sub-component categories.

When computing the values for the Mean Time Between Failures column in the table, the failure times fell into four categories which were handled as follows:

Category 1 - No failures were reported for the component. In this case, the mean time to failure cannot be computed because a failure has yet to occur, and no entry is shown in the table.

Category 2 - Only one failure was reported by all users for a particular component. In this case, the time before the failure is shown in the table.

Category 3 - Several users reported failure of the same component, but no user reported more than a single failure of that component. In this case, the individual times before the failure were averaged and the average is shown in the table.

Category 4 - One or more users reported multiple failures of the same component. In this case, all reported times before or between failures were averaged and the average is shown in the table.

The Range column lists the low and high value reported for failure times in each component and sub-component category. If only one number is given, it means that only one value was reported, either because there was only one failure in the category or only one response was given for failure time. In several cases, respondents did not supply operating time before the failure because they lacked adequate records. Since there was no time data for these failures, the Mean Time Between Failures and Range figures exclude these cases, although they are included in the Reported Failures column. If a figure of zero is listed, it indicates that the user experienced the failure immediately upon receiving the component. Such failures can be attributed to very early "infant-mortality" exhibited when a component functioned long enough to pass manufacturing tests but fails upon initial use. These failures may be induced by stresses incurred during shipment from the factory or supplier to the user. Indeed, one reported CRT failure, a broken chassis frame weld, was attributed to shipping damage. In cases of suspected shipping damage such as this, arguments may be made either that the component was treated excessively roughly, or that the component had an inherent weakness which resulted in failure even though reasonable care was exercised in shipping. In the case of the broken chassis frame weld above, the latter argument could carry more weight. However, in cases of electronic part failures, whether a failure could be attributed to handling, however rough, can be debated.

When the reported failures were distributed over the sub-component categories, many categories evidenced numbers of failure occurrences which were too small to provide statistically meaningful estimates of the mean time between failures. Therefore, extreme care must be exercised in interpreting the mean time between failures listed in the table. In cases of categories with few reported failures (particularly those categories with less than five failures), the calculated mean time between failures are, in all likelihood, not representative of the actual mean time between failure to be expected for components within that category. For example, the two disk controller failures both occurred at fifty hours of operation. This item is purely electronic, having no mechanical moving parts. Therefore, it would be expected that the mean time between failures for this sub-component would be much closer to the mean time between failures of other purely electronic sub-components, such as memory boards, which with eight reported failures, exhibited 1743 hours mean time between failures. Additionally, it must be kept in mind that the total number of reported failures in all sub-component categories represent a very small percentage of the total number of components within the category, most of which have not failed at all. Thus, the mean time between failure for any component category would be much higher if all components which have not failed were included in the computation of mean times between failures listed in the table. The figures in Table 13 are presented only to provide the reader with a general idea of the magnitudes of the numbers which were reported for failure times: only those categories with numerous failure occurrences will reflect mean times between failures which may actually be representative of that which may be expected for the particular component category.

System Component	Reported Failures	Repeat Failures	Mean Time Between Failures (Hours)	Range (Hours)
Total System	68	13	510	0 - 5200
Computer Mainframe	29	3	724	0 - 5200
Clock Board	2	0	80	0 - 160
CPU Board	4	1	2	2
Disk Controller	2	0	50	50
Disk Drive Unit	12	1	444	0 - 1680
Memory Board	8	1	1743	400 - 5200
Motherboard	1	0	150	150
Power Supply	0	0	-----	------
Other	0	0	-----	------
CRT Terminal	11	1	498	0 - 1945
Keyboard	4	0	450	30 - 790
Logic Circuits	2	0	136	2 - 270
Picture Tube	0	0	-----	------
Power Supply	2	0	1002	60 - 1945
Video Display	2	0	700	300 - 1100
Other	1	0	0	0
Printer	28	8	336	25 - 1400
Logic Circuitry	5	2	143	25 - 295
Mechanical Parts	5	0	517	50 - 970
Power Supply	2	1	265	150 - 380
Print Head	14	4	357	40 - 1400
Other	2	0	600	600

Table 13. Mean Time Between Failures by System Component

Note that the times obtained for mean time before/between failures in all categories in Table 13 above are much less than the System Hours per Failure obtained in Table 12. This is a clear indication that the failures reported typically reflect the early-life failures expected at the beginning of the "bath-tub" curve. A notable exception was the 5200 hour memory board failure: this failure represents one of the less-probable failure occurrences expected during the flat portion of the curve.

Using the average yearly use figure of 819 hours determined for all users in Table 5b, the failure times in Table 13 can be expressed in years and months for each component. This translation of failure times appears in Table 14 below.

The figures in Table 14, as those in Table 13, represent calculations based on the limited number of failures reported and therefore must not be interpreted as statistically significant estimates of failure times for any component. Again, the reader is cautioned to realize that only the categories with several reported failures will have mean times between failures which may be representative of that which may actually be expected. The figures are presented only to demonstrate that the occurrences of failure of even the most failure-prone components were early in the expected use life of the system.

System Component	Reported Failures	Mean Time Between Failures (Hours)	Mean Time Between Failures (Years - 819 hours per year)	Mean Time Between Failures (Months - 12 per year)
Total System	68	510	0.623	7.5
Computer Mainframe	29	724	0.844	10.1
Clock Board	2	80	0.098	1.2
CPU Board	4	2	0.002	0.0
Disk Controller	2	50	0.061	0.7
Disk Drive Unit	12	444	0.542	6.5
Memory Board	8	1743	2.128	1.5
Motherboard	1	150	0.183	2.2
Power Supply	0	-----	-----	-----
Other	0	-----	-----	-----
CRT Terminal	11	498	0.608	7.3
Keyboard	4	450	0.549	6.6
Logic Circuits	2	136	0.166	2.0
Picture Tube	0	-----	-----	-----
Power Supply	2	1002	1.233	14.8
Video Display	2	700	0.855	10.3
Other	1	0	0	0
Printer	28	336	0.410	4.9
Logic Circuitry	5	143	0.175	2.1
Mechanical Parts	5	517	0.631	7.6
Power Supply	2	265	0.324	3.9
Print Head	14	357	0.436	5.2
Other	2	600	0.733	8.8

Table 14. Mean Time Between Failures by Average Yearly Use

Note that the failure time figures are typically less than one year, with several being less than 6 months. If it is assumed that failure is strictly a function of use time, the table shows that most early failures will occur during the manufacturer's warranty period, which will typically be from 3 months to one year, if the CTD system is used the average amount.

System Time Out of Commission

Reported system time out of commission for each failure was tabulated by command and for all CTDs. In four cases (1 MAC and 3 SAC) respondents indicated current problems which were being resolved at the time of the survey. Because a final figure for time out of commission for those repairs was not then available, these cases were excluded from the calculations. Table 15 presents the results of this tabulation.

	Total Time Out of Commission		
	SAC	MAC	All Use s
	(All times in days)		
Mean	16.5	32.6	23.3
Median	14.0	21.0	17.5
Mode	21.0	15.0	21.0
Range	1 - 60	1 - 141	1 - 141

Table 15. System Time Out of Commission

SECTION THREE - SYSTEM REPAIR ANALYSIS

Repair Methods Used

Often, the actual method used for repair of a specific failure was different from the normal established repair method indicated by respondents in section one of the questionnaire. The actual reported repair method for each repair was tabulated for each command and for all repairs. Table 16 presents the number and percentages of repairs for the categories listed. Note that in some cases, the component (always a printer) was completely replaced due to uneconomical repair cost estimates. The category "other" includes one case where the method was not reported and one case (again a printer) which has not yet had a decision made as to course of action.

Repair Method	Number / Percent of Responses SAC	MAC	All Users
Base Level "Blue-suit"	4 / 10.0	3 / 10.7	7 / 10.3
MAJCOM Central Facility	27 / 67.5	1 / 3.6	28 / 41.2
Local / Regional Commercial Facility	6 / 15.0	20 / 71.4	26 / 38.2
Component Replaced	1 / 2.5	4 / 14.3	5 / 7.4
Other	2 / 5.0	0 / 0.0	2 / 2.9
Total of All Methods	40 /100.0	28 /100.0	68 /100.0

Table 16. Actual Repair Method Used

Repair Method Effect on System Time Out of Commission

Reported down times were categorized by repair method used for each repair in order to determine what effect, if any, the method used for repair had on the system time out of commission. Table 17 presents the results of this categorization.

	Repair Method Used		
	Base-level "Blue-suit"	MAJCOM Facility	Local Commercial Facility
	(All times are in days)		
Mean	5.8	21.1	26.8
Median	2.5	17.5	19.5
Range	1 - 21	4 - 83	1 - 142

Table 17. System Time Out of Commission by Repair Method

The table indicates that base-level "blue-suit" maintenance provides the shortest system down time when it is used. However, from the comments accompanying the repair histories, it was clear that this method was only used for simple repairs of a minor nature (clearing mechanical printer jams, or changing a blown fuse).

To further understand the differences affecting system down time, the administrative delays of preparing the required paperwork and shipping the component to the repair facility and the delay in receiving the component back from the repair facility were separated from the actual time the component spent in the facility. Table 18 presents the results of this analysis. Note that in some cases, respondents did not supply the information requested because of lack of detailed records. These cases were excluded from the calculations performed to prepare the table.

Repair Method	Time from Failure to Delivery to Repair Facility	Time at Repair Facility	Time from Repair to Return to Service
	(All times are mean times in days)		
Base Level	0.4	3.8	0.3
MAJCOM Facility	8.9	7.5	3.0
Comml. Facility	9.5	15.7	1.6

Table 18. Administrative Delays and Facility Time to Repair

It is apparent that the time saved by using MAJCOM facilities for repair instead of a commercial facility comes in the time the component spends in the facility. However, the data reflect only the times seen by the user. Frequently, the MAJCOM facility may simply exchange the users component for another from a reserve of spares. The data do not show the time it may have taken to actually repair the particular component sent to a MAJCOM facility after the exchange to the user is made. In the event that an operational spare is not readily available at the MAJCOM facility for exchange, the facility time would increase up to that actually required for repair. Also, in this case, there may be additional administrative delays at the MAJCOM level. If it is assumed that the average time between incoming failures at the MAJCOM facility is greater than the average repair time, it would be possible to maintain adequate spare stock.

Reported CTD Repair Cost

Repair cost for each repair was requested, however the responses were sparse, with most respondents either not responding or reporting the cost as zero. This is attributed to several factors. Many responses indicated that failures were covered under the factory warranty for the component which failed, therefore the direct cost was zero. Also, in the case of MAJCOM facility repair, repair costs were borne by the facility and there was no repair cost passed on to the user. A third reason given for no response was that no detailed records were available on repair costs, particularly in the case of failures which occurred more than a year in the past.

Table 19 presents the results of analysis of the repair costs which were reported as being other than zero. Costs are grouped by major system component because of lack of an even distribution of responses for individual repairs.

Additionally, cost of components which were completely replaced are not figured in the table.

System Component	Reported Repair Cost Mean	Median	Range
	(All costs are in dollars)		
Computer Mainframe	301.91	272.50	116.50 - 650.00
CRT Terminal	151.00	167.50	47.50 - 250.00
Printer	102.81	96.25	50.00 - 165.00

Table 19. Reported Repair Cost

Some comments are in order regarding the figures presented in the table above.

With regard to the computer mainframe repair charges, the higher range figure of 650 dollars represents an instance of the user paying a local repair facility for repair of a disk drive. Although the 650 dollars was paid, and therefore must be included in the consideration of repair costs, the reasonableness of the charge is in question. This author has many years of personal experience in repairing electronic and computer equipment of the types which make up the CTD system. There is no conceivable repair which could be made to the Shugart SA-400 disk drives which are used in the CTD which could justify a charge of this magnitude: a complete new drive costs less than 400 dollars retail (about 150 - 200 dollars from large parts houses) and the entire drive can be changed in the CTD computer in less than 15 minutes. Follow-up conversation with the user in this case did not reveal any unusual circumstances surrounding this repair.

With regard to the printer repair charges, the lower range figure of 50 dollars represents an instance when the local commercial repair facility estimated that the parts cost to repair the printer in question would be over 600 dollars. The 50 dollar charge was made as an estimate charge when the user decided to replace the printer rather than repair it. Again, the reasonableness of the estimated repair cost (fortunately, not paid in this instance) is in question: the manufacturer's suggested retail price for the entire printer was less than 750 dollars.

These two cases are the two outstanding ones in which, in this author's opinion, the repair charges paid were excessive for the repair which was reported to have been made. Additionally, in a few cases respondents indicated that the reason given to them for some of the longer local facility repair times was that the agency being used had to order needed parts or service manuals for the component being repaired.

The conclusion reached is that using local commercial repair facilities can be disadvantageous in terms of both repair cost and system down time if insufficient expertise is available to make a critical choice of which repair agency is chosen to perform the repair. Because a MAJCOM central facility would have more repair situations to deal with, it would have more experience in expediting the repair process than would the user who experiences only a few failures. Such a facility may provide better service to the user and incur less cost to the Government for component repair, especially if individual users do not have the ability to judge the qualifications of local repair agencies.

Loss of Training Due to CTD Failure

In order to assess the impact of CTD failures on the user's training program, respondents were asked to indicate, on a Likert scale question, the amount of training lost for each failure. Table 20 presents the analysis of the responses.

Reported Training Loss	Number / Percent of Responses SAC	MAC	All Users
No Training Lost CTD was not missed	6 / 16.7	4 / 14.3	10 / 15.6
Some Training Lost No Make-up needed	9 / 25.0	7 / 25.0	16 / 25.0
Training was lost requiring make-up or using another unit's CTD	21 / 58.3	17 / 60.7	38 / 59.4
Training was lost requiring aircraft flying hours to make up	0 / 0.0	0 / 0.0	0 / 0.0
Total Responses	36 /100.0	28 /100.0	64 /100.0

Table 20. Training Lost Due to CTD Failure

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

The Celestial Training Device microcomputer system has now been operational for some users for over four years. The 74 CTD systems surveyed have accumulated over 155,000 operating hours with only 68 reported failures serious enough to require repair or replacement of a system component. Over 50 percent of all users have reported no failures to date. Many of the failures which were reported occurred during the first 800 hours of operation, or typically within the first operational year for the system. Such repairs were often covered under the component manufacturer's warranty at little or no dollar cost to the user. The long-term mean time between failures for the entire system is on the order of 2000 hours or about two and one-half operating years at average use rates for all systems surveyed. These facts clearly support the contention that the CTD system as a whole may be called "reliable."

The data indicate that the most chronic problem areas have been with mechanical components of the system such as printers and disk drives. This is not unusual, as any mechanical device is subject to wear from use, unlike solid-state electronic parts which typically have very long lifetimes. It is recommended, therefore, that any proposed maintenance program should concentrate on the likelihood that mechanical components will probably give the most trouble. From a life-cycle cost viewpoint, allowance should be made for higher maintenance costs for these items and their early replacement may be warranted.

Data on repair methods indicate that the MAJCOM central facility typically can provide the fastest repair or exchange of CTD components in the event that repairs are serious enough to require expert attention. Additionally, a central facility can provide the attention needed to expedite and monitor the repair process to avoid extremely long delays in having repairs completed.

Data on reported repair cost also suggest that users employing local commercial repair agencies may not be obtaining optimum service with regard to repair cost. It is recommended, therefore, that a MAJCOM central facility be used to either repair or replace failed components to the user unless the user has sufficient expertise to insure that he is not being unreasonably charged.

The recommendation for use of a centralized maintenance facility is based upon the fact that both MAC and SAC already have a command point of contact to administer the command's CTD program. Because there are many similar systems throughout the two commands which perform the same function of celestial training and because the CTD software needs yearly updates to keep the celestial body position data current, such a command point of control is warranted. However, as hardware prices drop and new equipment becomes available, it is likely that many purchasers of desk-top microcomputers will be purchasing systems to suit their particular application which are one of a kind. In these cases, lack of homogeneity of hardware and applications software would not allow the advantages of a central maintenance facility to be realized. The central facility would not be able to stock spares for the many types of system components, nor would it develop the desired familiarity with all the equipment which would allow the repair process to be scrutinized as closely. For these reasons, the central facility maintenance program may only be warranted in cases where there is widespread use of similar equipment. The decision on the appropriate maintenance method should be made on a case-by-case basis.

If local repair is chosen, the option of a flat rate maintenance contract must be evaluated carefully. Although the use of flat-rate maintenance contracts could eliminate excess charges for any single repair, the repair cost data do not support the cost-effectiveness of this method. As pointed out in Chapter 1, the system would have to have a lack of reliability sufficient to have the maintenance contract "pay for itself." An informal survey of dealers in the Dayton, Ohio area revealed that yearly maintenance contract prices for any component were based on ten to fifteen percent of the retail price of the component. The exact percentage was generally determined by the dealer's perception of the amount of service he would have to provide under the contract: the more he thought the component would need repair during the contract period, the higher the price he charged for the contract. Using today's system component prices, a contract covering the entire CTD system would run about 400 to 600 dollars. The reported repair costs indicated that the required repair for CTD systems typically do not approach this figure. Therefore, a flat-rate contract for the entire system is not warranted. However, such a contract on a component prone to failure (such as the printer) may be feasible. Such a determination would have to be made on an individual component basis in the light of the particular component's failure rate and the amount charged for the contract. In general, however, the survey data indicate that funds which would be needed for system maintenance contracts would be better used to provide for early replacement of individual components exhibiting chronic problems.

The analysis of training lost due to CTD component failures revealed that about 60 percent of the failures caused enough impact on the user's training program to require make-up which required rescheduling of training or use of another CTD system to complete the required training, and an additional 25 percent of failures caused some training loss which was not made up. Although no responses indicated need to schedule additional aircraft flying hours for make-up, the training loss data suggest that the CTD system is an important part of the unit's ongoing training program. The impact of system failures will become more acute if, as has been proposed, training events logged on the CTD may be substituted for annual or semi-annual training events currently required by regulation to be accomplished in actual flight.

Although this study was targeted at the CTD system, the equipment involved is representative of most microcomputer systems available today. The components (processor, memory, CRT display, keyboard, disk drives, etc.) will be present in some form in any system, though the packaging of some systems may vary. The analysis of failures obtained for the CTD system, therefore presents a picture of the relative failure rates to be expected for such equipment. The reader must be cautioned from projecting the failure rates directly to other systems, however, because differences in quality of parts and construction employed by other manufacturers may alter the failure patterns for different components. Additionally, the CTD represents a system which is relatively old by comparison to today's state of the art. Equipment purchased today may reflect the benefit of newer technology and lessons learned by manufacturers. (For example, the Centronics printers which exhibited the highest failure rate in the survey were dropped by many dealers and have been discontinued by the manufacturer.)

The primary conclusions of this study which may be applicable to other systems may be expressed in terms of observed system reliability and in terms of proposed maintenance method suitability.

From the system reliability viewpoint, two conclusions are apparent: (1) microcomputer systems can be considered "reliable," and (2) the mechanical components of the system will probably give the most trouble.

From the maintenance method viewpoint, four conclusions are apparent: (1) any proposed maintenance method for the system, in order to be cost-effective, must be evaluated in terms of the failure patterns expected to be exhibited by that system, (2) proposals for use of flat-rate maintenance contracts must be evaluated carefully because the reliability of components will warrant their use only in special circumstances, (3) the maintenance method chosen should take into account the system configuration and the number of similar systems to be maintained, and (4) the maintenance method chosen must take into account the importance of system down time to the system user's application.

APPENDIX A

SURVEY QUESTIONNAIRE

DEPARTMENT OF THE AIR FORCE
AIR FORCE INSTITUTE OF TECHNOLOGY (ATC)
WRIGHT-PATTERSON AIR FORCE BASE, OH 45433

REPLY TO ATTN OF: LSH (LSSR 85-83)/Capt G. Nemeyer/AVN 255-6969/HOME (513) 233-0532

SUBJECT: Celestial Training Device (CTD) Reliability Questionnaire

TO:

1. The attached questionnaire was prepared by a researcher at the Air Force Institute of Technology, Wright-Patterson AFB, OH. The purpose of the questionnaire is to acquire data concerning the maintenance reliability of CTD microcomputer systems employed in SAC and MAC.

2. Personal information is not being requested; only factual data on the CTD is being solicited. This information may be extracted from operating logs or other CTD documents. The custodian's name and phone number are requested only to permit further contact to amplify or clarify responses. Responses will be held confidential. Your participation in this research is voluntary.

3. If you receive more than one questionnaire mailing, it is because you have been identified as the official custodian of more than one CTD system. Each questionnaire should apply to only one CTD. Please match each questionnaire with a different CTD and complete the questions for that particular system.

4. Do not remove this cover sheet before returning the completed questionnaire (The control number listed above is being used to keep track of responses). Please return the completed questionnaire in the attached envelope within one week after receipt.

5. Your cooperation in providing this data will be appreciated and will be very beneficial in determining the reliability and the maintenance needs of CTD systems.

George F. Nemeyer

George F. Nemeyer, Jr., Capt USAF
Graduate Student
Air Force Institute of Technology

2 Atch
1. Questionnaire
2. Return Envelope

AIR FORCE—A GREAT WAY OF LIFE

AD-A135 003 A RELIABILITY AND FAILURE MODE ANALYSIS OF CELESTIAL TRAINING DEVICE MICR..(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF SYST.. G F NEMEYER 2/2

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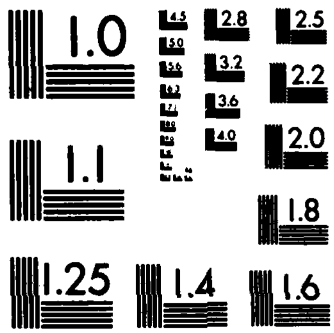

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NATIONAL BUREAU OF STANDARDS-1963-A

CTD RELIABILITY QUESTIONNAIRE

The information below is being collected to assess the reliability of CTD computer systems. Please provide answers in as much detail as possible.

System Background and Configuration

1. When was your CTD System first installed? Date:__________

2. Please describe your CTD System configuration (Mark in all blocks which apply):

Computer: North Star Horizon _____
Number of Disk Drives: 1___ 2___ More(#) ___
Memory: 48k _____ 56k _____ 64k _____

Other (Make & Model) ____________________
Floppy Drives: 5 1/4" _________ 8" _________
Number of Disk Drives: 1___ 2___ More(#) ___
Memory: 48k _____ 56k _____ 64k _____
More than 64k (amount) ____k

Terminal: Soroc IQ-120 _____ Soroc IQ-135 _____
Televideo 910 _____ Televideo 912 _____
Heath H-19 _____ Zenith Z-19 _____
Other (Make & Model) ____________________

Printer: Integral Data Systems (IDS Paper Tiger) _____
Epson MX-80 _____ Epson MX-100 _____
Centronics 737 _____ Centronics 739 _____
Other (Make & Model) ____________________

3. Is a log kept on CTD System time in use? YES ___ NO ___

4. Please indicate how often your CTD System is in use. (Include total time running all programs, not just the CTD Nav Trainer program.)

Category (Check one):		Your Best Figure for Time:	
A. Daily	_____	Hours per Day	
B. Weekly	_____	Hours per Week	_____
C. Monthly	_____	Hours per Month	_____

5. Please indicate the method which is (or would be) employed for repair of your CTD System:

A. Unit/Base Level "Blue Suit" Maintenance _____
B. Send to a MAJCOM Central Maintenance Facility _____
They would: repair ____ exchange ____ either ____
C. Send to Local or Regional Commercial Facility ____
Is there a Maintenance Contract now? Yes ____ No ____
If YES, what is the annual cost of the contract?
$_____________ per year.
D. There is no established procedure for repair. _____
E. Other (Please describe) ____________________

CTD RELIABILITY QUESTIONNAIRE

System Failure Analysis

1. Has any component of your CTD System had an electrical or mechanical failure which required repair? (Do not count incidents of routine nature such as replacing printer ribbons, worn out floppy diskettes, operator error, or programming error.)

   YES ____ NO ____

2. If the answer to 1. was YES, please complete the following section.

   The answers to the following questions will present a chronological picture of the failures of your system. Describe in as much detail as possible the nature of the failure(s). Indicate the part which failed (i.e. Memory Chip, 5 volt regulator IC, etc.) if known. If estimates of times are given, please so indicate.

   Use the following codes for the item which failed.

A. Computer:
1. CPU Board
2. Disk Controller Board
3. Real Time Clock Board
4. Motherboard (I/O Ports)
5. Memory Board
6. Disk Drive Unit
7. Power Supply
8. Other

B. Terminal:
1. Keyboard (Mechanical)
2. Video Display Circuitry
3. Power Supply
4. Logic Circuitry
5. Picture Tube
6. Other

C. Printer:
1. Print Head
2. Power Supply
3. Mechanical Parts
4. Logic Circuitry
5. Other

The following is a sample of how to complete this section.

Number of OPERATING HOURS from INITIAL INSTALLATION until FIRST FAILURE: 50
System component which failed: A-2
Description of failure: Data Buffer IC shorted

Total time system was out of commission: 8 days

Number of OPERATING HOURS from REPAIR OF FIRST FAILURE until SECOND FAILURE: 20 Estimated
System component which failed: B-6
Description of failure: Terminal power cord accidentally cut while moving furniture
Total time system was out of commission: 5 hours Est

****

NOTE: Failures are cumulative for your entire system. If a component of the system (i.e. CRT terminal) is entirely replaced, any subsequent failure is still counted as the NEXT failure in the questionnaire sequence.

CTD RELIABILITY QUESTIONNAIRE

1. Number of OPERATING HOURS from INITIAL INSTALLATION until FIRST FAILURE: __________
   System component which failed: __________
   Description of failure: ______________________________

   Total time system was out of commission: __________

2. Number of OPERATING HOURS from REPAIR OF FIRST FAILURE until SECOND FAILURE: __________
   System component which failed: __________
   Description of failure: ______________________________

   Total time system was out of commission: __________

3. Number of OPERATING HOURS from REPAIR OF SECOND FAILURE until THIRD FAILURE: __________
   System component which failed: __________
   Description of failure: ______________________________

   Total time system was out of commission: __________

4. Number of OPERATING HOURS from REPAIR OF THIRD FAILURE until FOURTH FAILURE: __________
   System component which failed: __________
   Description of failure: ______________________________

   Total time system was out of commission: __________

5. Number of OPERATING HOURS from REPAIR OF FOURTH FAILURE until FIFTH FAILURE: __________
   System component which failed: __________
   Description of failure: ______________________________

   Total time system was out of commission: __________

6. Number of OPERATING HOURS from REPAIR OF FIFTH FAILURE until SIXTH FAILURE: __________
   System component which failed: __________
   Description of failure: ______________________________

   Total time system was out of commission: __________

7. Number of OPERATING HOURS from REPAIR OF SIXTH FAILURE until SEVENTH FAILURE: __________
   System component which failed: __________
   Description of failure: ______________________________

   Total time system was out of commission: __________

8. Number of OPERATING HOURS from REPAIR OF SEVENTH FAILURE until EIGHTH FAILURE: __________
   System component which failed: __________
   Description of failure: ______________________________

   Total time system was out of commission: __________

CTD RELIABILITY QUESTIONNAIRE

System Repair Analysis

The answers to the following questions will present a history of the repair time and cost for your CTD system. The purpose of this section is to identify whether the primary delays occurred in the repair facility or in the transportation/paperwork process getting the system to and from the repair facility. Additional information is sought as to the cost of repair and loss of training caused by the failure.

How to complete this section:
ANSWERS FOR EACH FAILURE SHOULD CORRESPOND TO THE SAME NUMBERED FAILURE DESCRIBED IN THE PREVIOUS SECTION.

The first question asks about the method used for the repair of your CTD system (or component). Use the following categories for method of repair:

BS -- Unit/Base level "Blue Suit" Maintenance
MC -- MAJCOM Central Maintenance Facility
LR -- Local or Regional Commercial Facility

Note that, for all failures after the first, you are asked if the method used for repair has changed. If you did change methods please indicate in a few words why the change was made (such as command directed, poor service, etc.).

The next three questions ask for data on the time for delivery of the broken system component to the repair facility, time spent in the repair facility and time from repair to return to service. Answer these questions with your best record or estimate of the number of hours or days required in each case. Indicate when the answers are estimates.

The next two questions ask about cost of repair. The distinction is made between the actual cost of the repair (parts and labor) and the total cost incurred by your unit for the repair. This will allow determination of the amounts of any transportation charges, supply system charges, and any other incidental cost beyond the cost of the actual repair. Use your best record or estimate of costs. Indicate when estimates are used.

The next question will assess the loss of training which was incurred because of the CTD system failure. Please check the blank next to the statement which most closely applies.

The last question asks for your name and phone number. In case there is any other information which may be needed based upon your particular situation, you will be contacted by phone for further discussion.

CTD RELIABILITY QUESTIONNAIRE

The following is a sample of how to complete this section.

FIRST FAILURE repair history -

What was the method used for repair: LR
How much time elapsed between the first failure and delivery of the system to the repair facility: 3 days
How much time did the system spend in the repair facility: 4 days
How much time elapsed between completion of repair until the system was returned to service: 1 day
What was the total cost charged for parts and labor by the repair facility: $34.50
What was the total cost charged to your unit for the repair (Note that this figure may be different because of transportation or other incidental charges.): $74.00
How much training was lost because of CTD system failure (Check the statement which most closely applies):

The CTD was not missed - No training was lost.	
Some training was lost, but it was not necessary to make it up.	
Training was lost requiring rescheduling or use of another unit's CTD to make up.	X
Training was lost and required additional aircraft flying hours to make up.	

SECOND FAILURE repair history -

What was the method used for repair: BS
If the method for this repair differed from the one above, why was the method changed? Minor Repair
How much time elapsed between the second failure and delivery of the system to the repair facility: 2 hours
How much time did the system spend in the repair facility: 1 hour
How much time elapsed between completion of repair until the system was returned to service: 1 hour Est
What was the total cost charged for parts and labor by the repair facility: $0.00
What was the total cost charged to your unit for the repair (Note that this figure may be different because of transportation or other incidental charges.): $0.00
How much training was lost because of CTD system failure (Check the statement which most closely applies):

The CTD was not missed - No training was lost.	X
Some training was lost, but it was not necessary to make it up.	
Training was lost requiring rescheduling or use of another unit's CTD to make up.	
Training was lost and required additional aircraft flying hours to make up.	

CTD RELIABILITY QUESTIONNAIRE

1. FIRST FAILURE repair history -

What was the method used for repair: ______
How much time elapsed between the first failure and delivery of the system to the repair facility: ______
How much time did the system spend in the repair facility: ______
How much time elapsed between completion of repair until the system was returned to service: ______
What was the total cost charged for parts and labor by the repair facility: ______
What was the total cost charged to your unit for the repair (Note that this figure may be different because of transportation or other incidental charges.): ______
How much training was lost because of CTD system failure (Check the statement which most closely applies):
The CTD was not missed - No training was lost. ______
Some training was lost, but it was not necessary to make it up. ______
Training was lost requiring rescheduling or use of another unit's CTD to make up. ______
Training was lost and required additional aircraft flying hours to make up. ______

2. SECOND FAILURE repair history -

What was the method used for repair: ______
If the method for this repair differed from the one above, why was the method changed? ______
How much time elapsed between the second failure and delivery of the system to the repair facility: ______
How much time did the system spend in the repair facility: ______
How much time elapsed between completion of repair until the system was returned to service: ______
What was the total cost charged for parts and labor by the repair facility: ______
What was the total cost charged to your unit for the repair (Note that this figure may be different because of transportation or other incidental charges.): ______
How much training was lost because of CTD system failure (Check the statement which most closely applies):
The CTD was not missed - No training was lost. ______
Some training was lost, but it was not necessary to make it up. ______
Training was lost requiring rescheduling or use of another unit's CTD to make up. ______
Training was lost and required additional aircraft flying hours to make up. ______

3. THIRD FAILURE repair history -

What was the method used for repair: ______
If the method for this repair differed from the one above, why was the method changed? ______
How much time elapsed between the third failure and delivery of the system to the repair facility: ______
How much time did the system spend in the repair facility: ______

How much time elapsed between completion of repair until the system was returned to service: ______
What was the total cost charged for parts and labor by the repair facility: ______
What was the total cost charged to your unit for the repair (Note that this figure may be different because of transportation or other incidental charges.): ______
How much training was lost because of CTD system failure (Check the statement which most closely applies):
The CTD was not missed - No training was lost. ______
Some training was lost, but it was not necessary to make it up. ______
Training was lost requiring rescheduling or use of another unit's CTD to make up. ______
Training was lost and required additional aircraft flying hours to make up. ______

4. FOURTH FAILURE repair history -

What was the method used for repair: ______
If the method for this repair differed from the one above, why was the method changed? ______
How much time elapsed between the fourth failure and delivery of the system to the repair facility: ______
How much time did the system spend in the repair facility: ______

How much time elapsed between completion of repair until the system was returned to service: ______
What was the total cost charged for parts and labor by the repair facility: ______
What was the total cost charged to your unit for the repair (Note that this figure may be different because of transportation or other incidental charges.): ______
How much training was lost because of CTD system failure (Check the statement which most closely applies):
The CTD was not missed - No training was lost. ______
Some training was lost, but it was not necessary to make it up. ______
Training was lost requiring rescheduling or use of another unit's CTD to make up. ______
Training was lost and required additional aircraft flying hours to make up. ______

5. FIFTH FAILURE repair history -

What was the method used for repair: ______
If the method for this repair differed from the one above, why was the method changed? ______
How much time elapsed between the fifth failure and delivery of the system to the repair facility: ______
How much time did the system spend in the repair facility: ______

How much time elapsed between completion of repair until the system was returned to service: ______
What was the total cost charged for parts and labor by the repair facility: ______
What was the total cost charged to your unit for the repair (Note that this figure may be different because of transportation or other incidental charges.): ______
How much training was lost because of CTD system failure (Check the statement which most closely applies):
The CTD was not missed - No training was lost. ______
Some training was lost, but it was not necessary to make it up. ______
Training was lost requiring rescheduling or use of another unit's CTD to make up. ______
Training was lost and required additional aircraft flying hours to make up. ______

6. SIXTH FAILURE repair history -

What was the method used for repair: ______
If the method for this repair differed from the one above, why was the method changed? ______
How much time elapsed between the sixth failure and delivery of the system to the repair facility: ______
How much time did the system spend in the repair facility: ______

How much time elapsed between completion of repair until the system was returned to service: ______
What was the total cost charged for parts and labor by the repair facility: ______
What was the total cost charged to your unit for the repair (Note that this figure may be different because of transportation or other incidental charges.): ______
How much training was lost because of CTD system failure (Check the statement which most closely applies):
The CTD was not missed - No training was lost. ______
Some training was lost, but it was not necessary to make it up. ______
Training was lost requiring rescheduling or use of another unit's CTD to make up. ______
Training was lost and required additional aircraft flying hours to make up. ______

7. SEVENTH FAILURE repair history -
What was the method used for repair: ______
If the method for this repair differed from the one above, why was the method changed? ______
How much time elapsed between the seventh failure and delivery of the system to the repair facility: ______
How much time did the system spend in the repair facility: ______

How much time elapsed between completion of repair until the system was returned to service: ______
What was the total cost charged for parts and labor by the repair facility: ______
What was the total cost charged to your unit for the repair (Note that this figure may be different because of transportation or other incidental charges.): ______
How much training was lost because of CTD system failure (Check the statement which most closely applies):
The CTD was not missed - No training was lost. ______
Some training was lost, but it was not necessary to make it up. ______
Training was lost requiring rescheduling or use of another unit's CTD to make up. ______
Training was lost and required additional aircraft flying hours to make up. ______

8. EIGHTH FAILURE repair history -
What was the method used for repair: ______
If the method for this repair differed from the one above, why was the method changed? ______
How much time elapsed between the eighth failure and delivery of the system to the repair facility: ______
How much time did the system spend in the repair facility: ______

How much time elapsed between completion of repair until the system was returned to service: ______
What was the total cost charged for parts and labor by the repair facility: ______
What was the total cost charged to your unit for the repair (Note that this figure may be different because of transportation or other incidental charges.): ______
How much training was lost because of CTD system failure (Check the statement which most closely applies):
The CTD was not missed - No training was lost. ______
Some training was lost, but it was not necessary to make it up. ______
Training was lost requiring rescheduling or use of another unit's CTD to make up. ______
Training was lost and required additional aircraft flying hours to make up. ______

9. Please provide the name and phone number of someone who may be contacted to provide any additional information or clarification concerning this particular CTD system.
Name: ______ Unit: ______
Commercial Phone: (   ) ______ -
Autovon Phone: ______

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