AUTOMATED TOOLS
FOR TEST AND ANALYSIS OF
RADAR WARNING RECEIVER SOFTWARE

THESIS

AFIT/GCS/EE/82D-28 JOEL R. ROBERTSON
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DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY (ATC)
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Wright-Patterson Air Force Base, Ohio

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**Automated Tools for Test and Analysis of Radar Warning Receiver Software**

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**Abstract**

See reverse
20. Abstract

The Data Extraction and Analysis System (DEAS) was designed and implemented for the Electronic Warfare Avionics Integrated Support facility at the Warner Robins Air Logistics Center. The DEAS is designed to be used with the ALR-46 Integrated Support System (ISS) to assist testing and evaluation of operational flight software. The system is written in DEC standard Pascal.
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THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
in Partial Fulfillment for the Degree of
Master of Science in Computer Engineering

by
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December 1982

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PREFACE

The ALR-46 Data Extraction and Analysis System was developed for the Electronic Warfare Avionics Support Facility to assist in testing of the ALR-46 operational flight program.

I would like to express my appreciation to my thesis committee, and in particular Dr. Gary B. Lamont my thesis advisor, for their assistance and guidance during this thesis. Finally, I would like to extend my sincerest thanks to my wife, Tami, for her encouragement and assistance in typing this thesis.
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The Data Extraction and Analysis System (DEAS) was designed and implemented for the Electronic Warfare Avionics Integrated Support facility at the Warner Robins Air Logistics Center. The DEAS is designed to be used with the ALR-46 Integrated Support System (ISS) to assist testing and evaluation of operational flight software. The system is written in DEC standard Pascal.
CHAPTER 1

INTRODUCTION

1.1 BACKGROUND.

The primary function of an electronic warfare (EW) system is to detect radiation, identify and evaluate threats, and generate appropriate responses (Ref 13:3). One type of electronic warfare system is the Radar Warning Receiver (RWR). The response produced by a RWR is to inform the pilot when his aircraft is being illuminated by a hostile threat. The two types of RWR's are analog and digital (Ref 8). Analog RWR's were developed first and gave only signal direction and relative signal strength information. The digital RWR's contain an embedded computer and identify the threat by comparing measured signal parameters to those stored in a data base. The digital RWR would then display the type and position of the threat on a cockpit CRT display. The program that the RWR executes is called the Operational Flight Program (OFP) and the data base is called the Emitter Identification Data (EID).
1.1.1 ALR-46 Radar Warning Receiver - The Electronic Warfare Avionics Integrated Support Facility (EWAISF) at Robins AFB provides hardware and software support for the Air Force Electronic Warfare systems. One of the largest systems maintained by the EWAISF is the ALR-46. The ALR-46 is a 2 to 18 Ghz digital radar warning receiver (RWR). It is capable of analyzing and identifying up to 16 emitters concurrently. The ALR-46 is the most widely used RWR in the Air Force inventory (Ref 23:193). The ALR-46, shown in figure 1, consists of the following (Ref 16:6,13): four amplifier/detectors located at 45, 135, 225, and 315 degrees, an omni-directional low band receiver, the signal processor, up to two azimuth indicators, one "threat display and control unit" for each azimuth indicator, and interfaces to aircraft avionic systems.

Two hardware versions of the ALR-46 are currently maintained by the EWAISF, the original version and an updated version. The original version of the ALR-46 has a five board CPU and draws the CRT display symbols with software. The updated version has a single board CPU and has a dedicated graphics processor for drawing the symbols on the CRT. The different hardware configurations require different versions of software. The Tactical Air Command (TAC) and the Strategic Air Command (SAC) have different mission requirements and therefore use different versions of software for each hardware configuration. Therefore, each of the two hardware configurations have two versions of the
1.1.2 Program Maintenance - Routine changes to the flight software are made during a Block Change Cycle (Ref 14: Sec 4, 7). A Block Change cycle is a scheduling method to collect, develop, implement, and test computer program changes in a fixed time frame (Ref 14: Sec 1, 4).
Program changes are collected to be processed concurrently in each change cycle. Program changes are prioritized and placed in a queue up to the block cycle cutoff date. Changes received after the cutoff date are held for the next change cycle. The software for each of the four versions is updated once each year. The primary reasons for updating the software are: to update the EID to include new intelligence data or to reflect changing mission requirements, to add new capabilities to the OFP, and to correct errors found by either the user or by maintenance personnel.

The ALR-46 Integration Support System (ISS), provides a facility for testing and evaluating the performance of the ALR-46. Data can be extracted from the signal processor without interfering with the program execution. The ISS allows operation of the signal processor with up to 32K of external RAM or with its internal RAM/PROM. The use of external RAM allows program modification or instrumentation without "burning" new PROMS (Ref 2: Sec 3,1).

1.2 PROBLEM.

The software delivered with the ISS enables the user to load operational flight software into the ALR-46 signal processor RAM, to extract data from the 32K external RAM memory without interfering with OFP execution, and to validate proper operation of the data extraction subsystem.
(Ref 1: Sec 2,1). Software has been developed (Ref 22) in response to user requirements to duplicate the ALR-46 CRT on a Tektronix 4027 color graphics terminal and to display extracted data on a video terminal. However, since no other software tools have been developed for the ALR-46 ISS, flight software is still tested and debugged with the traditional co-resident debug program. Testing requirements need to be established, and the necessary software tools need to be developed to exploit the capabilities of the new systems as fully as possible.

1.3 **SCOPE.**

This study has three goals. The first goal is to establish the requirements for automated tools for test and analysis of ALR-46 flight software. The second goal is to identify software tools already available. The final goal is to develop a system of test tools for use with the ALR-46 ISS. An overall system design of the tools will be done before coding will begin. The tools will then be coded and tested. Those tools which are not currently available but outside the scope of this study will be recommended for future investigation. The completed software will be delivered to the sponsor (EWAISF).
1.4 **STANDARDS.**

Top-down procedures of software development will be adhered to. This means that program development will proceed from program requirements to functional specification, to design, to coding, and to validation and verification.

The top-down approach leads to structured programs in which the main program can be decomposed into smaller subprograms. The design of subprogram "stubs" allow testing to begin as code is developed (Ref 20:29,31).

Both FORTRAN and Pascal are available at the sponsor's facility (EWAISF). Even though FORTRAN is the most commonly used high level language at the EWAISF, Pascal was chosen as the language for program development. Pascal is a block oriented language and supports structured programming constructs (Ref 7). The use of Pascal will enable the development of a more easily maintained system.

1.5 **APPROACH.**

The first objective of this study is to determine the user's requirements for software testing. This is to be done primarily through a series of interviews with EWAISF personnel.
The second objective is to determine the software tools requirements. A detailed literature search will be done to determine which software tools are already available. A feasibility study will be done to determine which tools are within the scope of this effort. The third and major effort is to design the system of test tools. The final objective will be to code and test the software tools. An integrated test plan will be developed. Final testing and installation will be done on the ISS at Robins AFB at the prerogative of the EWAISF.

1.6 THESIS DEVELOPMENT.

This thesis will be developed in five sections. Chapter 2 covers the overall testing requirements for electronic warfare embedded computer systems in general and the ALR-46 RWR in particular. Chapter 3 describes the requirements for the automated test tools which will be developed during this study. Chapter 4 discusses the design of the automated test tools. Chapter 5 describes the implementation and the testing of the tools. The final chapter covers results and recommendations for further study. Appendix A contains an index of available software testing tools. Appendix B contains the formats required by the software tools. Appendix C contains the Structured Analysis and Design Technique (SADT) diagrams. Appendix D contains the structure charts. Appendix E contains the data dictionary listed in alphabetical order. Appendix F
contains the source listing of the software tools. Finally, Appendix G contains the test documentation for the software tools.
CHAPTER 2

SYSTEM REQUIREMENTS

2.1 INTRODUCTION.

A software requirement is a need established for a piece of software by an organization in order to achieve certain goals. The requirement-generation activity culminates in the approvals, negotiations, and commitments of resources necessary to initiate, sustain, and complete the software development. The software requirements should identify the objectives of the program, its environment, the configuration required for its operation, and the resources required for its support. The software requirements should be complete enough to allow development to proceed without major changes in the requirements (Ref 21:2-3).

This chapter will discuss the overall requirements for ARL-46 flight software testing. The environment in which software testing is to be done will be presented, and user requirements for software test tools will be discussed. Available software tools which meet these requirements will
also be described. Finally, the method used in determining which software tools to develop will be discussed.

2.2 ENVIRONMENT.

2.2.1 Introduction - The environment in which the software tools must operate is composed of three ALR-46 Integration Support Systems (ISS), an interface controller (VAX 11/780), and an edit and assembly station (ECLIPSE S/230). The interface controller is connected to the three ISSs and to the edit and assembly station by a star configuration computer network, as shown in figure 2. The network utilizes the Digital Equipment Corporation DECNET protocol.

![Diagram of ALR-46 ISS network](image-url)
2.2.2 ALR-46 ISS - Each ALR-46 ISS, shown in figure 3, consists of three subsystems, the hot mock-up subsystem, the data extraction subsystem, and test equipment (Ref 2: Sec 3, 1).

2.2.2.1 Hot Mock-up Subsystem - The hot mock-up subsystem, shown in figure 4, supplies the required power for the ALR-46. Test points, not available during airborne operation, are provided for signal monitoring. The hot mock-up subsystem provides a means to control the operation of the signal processor with its resident OFP.

The hot mock-up subsystem contains the AN/ALR-46(V) radar warning receiver (RWR), the adaptor subsystem, the system monitor panel, and the 400 hz power source (Ref 2: Sec 3, 1-4).

![Diagram of ALR-46 ISS subsystems]

Figure 3. ALR-46 ISS.
The operation of the signal processor is controlled by the adaptor subsystem. The adaptor subsystem contains the DX adaptor board, which provides the means to extract data from the ALR-46 signal processor. The adaptor subsystem also provides the basic I/O capability for the signal processor (Ref 2: Sec 3 5,10). The adaptor subsystems are slightly different for the two hardware configurations of the ALR-46 (Ref 3, 4).

The system monitor panel provides test points, used primarily to aid in detection and isolation of RWR hardware problems. The system monitor panel also contains various status indicators and controls.
2.2.2.2 **Data Extraction Subsystem** - The data extraction subsystem, shown in figure 5, provides the means for specifying data to be extracted and for collecting the extracted data. The data exchanges between the data extraction subsystem and the adaptor subsystem occur via a DRll-B DMA interface. The data extraction subsystem consists of a PDP-11/34 computer, a PDT-11/130 CRT, a LA120 printer, a TE16 magnetic tape unit, and two RL01 disk drives. The PDP-11/34 runs under the RSX-11M operating system (Ref 2: Sec 3, 11-12).

2.2.2.3 **Test Equipment** - The ISS contains test equipment for monitoring signals at the test points provided by the system monitor panel. The test equipment included are: an oscilloscope, a digital multimeter, and a universal counter (Ref 2: Sec 3, 12).

2.2.3 **Interface Controller** - The interface controller consists of a Digital Equipment Corporation VAX 11/780 computer. The peripherals associated with the VAX 11/780 are, two REP06 disc drives, a TEU77 tape transport, a LA120 console terminal, and four VT100 CRTs.

The interface controller performs two primary functions. One function is to control the DECNET data exchanges and the other is to do off line analysis and storage of extracted data. The VAX 11/780 runs under the VMS operating system.
2.2.4 Edit And Assembly Station - The edit and assembly Station consists of a Data General Eclipse S/230 minicomputer. The peripherals associated with the Eclipse are two 20 M byte disk drives, a 190 M byte disk drive, two magnetic tape transports, a line printer, a printing terminal, and three CRTs. The Eclipse runs under the Data General Advanced Operating System (AOS). AOS is a multi-user multi-tasking operating system.

The primary function of the Eclipse is to assemble the ALR-46 flight software. The ALR-46 signal processor executes the Data General Nova instruction set. Since the Nova instruction set is a subset of the Eclipse instruction set, the ALR-46 flight software can be assembled by the AOS Macro Assembler. The assembled flight software is transferred to the interface controller which in turn routes it to the appropriate ISS.
2.3 USER REQUIREMENTS.

2.3.1 Interviews - A series of interviews have been held with EWAISF personnel in order to establish requirements for automated test and support tools. The Engineering and Reliability Branch Chief, the EW Receivers System Section Chief, the ALR-46 Unit Chief, five engineers, and one technician participated in the interviews.

Eight requirements for automated test and support tools were identified. The tools would be used for support of software development and testing. The automated tools requirements identified were:

1. Automated control of the threat generators. The software to generate threat signals is scheduled to be delivered with the threat generator system. The capability to compare the response of the ALR-46 to the threats generated has not been developed at present.

2. The capability to perform statistical analysis of the decision paths executed, such as the percentage of times one path is executed instead of another, and to determine the testing coverage.

3. The capability to determine performance characteristics, such as the execution time of programs and modules.
4. A computer simulation of the ALR-46 system. This would be used to evaluate hardware as well as software modifications.

5. The capability to generate input buffers. This would allow testing of the software without having to generate actual RF signals and for repeatability of tests.

6. Automated generation of test data.

7. The capability to test programs and modules independently.

8. The capability to assemble flight programs on the VAX 11/780. The specified function of the VAX 11/780 is offline support of the ICS. This includes mass storage, message routing, data analysis, and the production of flight software. The Eclipse S/230 is being retained for the sole function of assembly of flight software.

Two additional requirements not identified in the user interviews are: the ability to identify variable out of range conditions, and "hooks" for inclusion of previously developed software (Ref 22).
2.4 HUMAN-FACTORS REQUIREMENTS.

2.4.1 Introduction - Human factors is a discipline which attempts to take into consideration human strengths and limitations in the design of computer hardware and software (Ref 19:108-132). If human factors are not considered, a computer system may be difficult for people to operate.

Human beings vary in intelligence, education, and motivation. The general rule in considering human factors in the design of a system is to consider the needs of the intended users.

The relative importance of human factors varies with the program environment and application. Four aspects of a computer program to consider are: the number of users, the diversity of the users backgrounds, program complexity, and the consequences of user error.

2.4.2 Design Principles - Six human-factors design principles which will be discussed are: provide feedback, be consistent, minimize human memory demands, keep program simple, match the program to the operator's skill level, and sustain operator orientation.

When a user makes an action he needs to know when that action has taken effect. If an entry is made and no feedback is provided, the action may be repeated or another action may be tried, which may have unintended results.
Feedback should be immediate and appear in an expected location.

The program should be consistent. Consistency allows the user to learn the operation of one part of the program and apply that knowledge to other parts of the program.

The program should minimize human memory demands. Since computers have better memories than people, and remember things exactly, the computers memory should be relied on as much as possible. Selecting an option from a displayed menu is generally preferable to entering memorized mnemonics.

The program should be kept simple. A program which is unnecessarily complex is both difficult to learn and use.

The program interface should be matched to the operators skill level. The skill level of the intended users should be determined before the program is designed.

The possibility of a user becoming disoriented should be minimized. The user should be provided with messages telling the user where the user is and how to return to where the user came from.
2.5 AVAILABLE TOOLS.

The software tools available for software testing fall into two categories, static and dynamic.

2.5.1 Static Analysis - Static analysis of software uses methods of validation which do not require the program to actually be executed (Ref 11:83). Static analysis may use some method of simulated execution. There are three types of static analysis of programs. The first type provides general information about a program, and are not designed to find a particular kind of logical error. An example of this type would be cross reference generators. The second type uses techniques which are designed to find particular types of errors or abnormal program constructs. This class of techniques is called Static Error Analysis techniques. The third type of static analysis is Symbolic Evaluation. Several types of automated tools useful in static analysis are described.

2.5.1.1 Source Comparator - A source comparator is a computer program used to compare two versions of the same computer program source code. The program will identify changes made to the source program or establish identical configurations (Ref 18:55).
2.5.1.2 Cross-Reference Generator - A cross-reference generator is a computer program which provides cross-reference information on system components. A program can be cross-referenced with other programs, macros or parameter names. This program is useful in determining the impact of a change made in one area to other sections of the program by showing the scope of variables (Ref 18:55).

2.5.1.3 Flow-Chart Generator - A flow-chart generator is a computer program used to show the logical control-flow structure of a computer program. The logic flow is determined from the program instructions and not from the comments. The flow-charts generated by the program can be compared to the flow-charts supplied with the code to identify discrepancies (Ref 18:56).

2.5.1.4 Standards Analyzer - A standards analyzer is a computer program used to determine if predefined procedures, rules, and conventions have been followed. The standards analyzer can check for violations in conventions such as program size, comments, and structure (Ref 18:58).

2.5.2 Dynamic Analysis - Dynamic analysis primarily involves program testing (REF 10:185). There are several other techniques such as dynamic assertions and recovery control blocks.
Program testing involves executing the program with a set of sample data as input. The test output may be program output variables, intermediate values of selected variables, or timing information in "real time" systems.

2.5.2.1 **Test Data Generator** - A test data generator is a program which generates test data or test cases to exercise the system under test. Test data generators are useful in systems where "live" data is not available (Ref 18:56).

2.5.2.2 **Data Base Analyzer** - A data base analyzer is a computer program which provides information on the usage of data. It indicates whether the program inputs, uses, modifies, or outputs the data element (Ref 18:55).

2.5.2.3 **Debugger** - A debugger is a computer program which helps to identify and isolate program errors. It usually includes commands such as DUMP, TRACE, MODIFY, CONTENTS, BREAKPOINT, etc. (Ref 18:56, 9:426-428).

2.5.2.4 **Simulator** - A simulator is a computer program which provides the system under test with inputs or responses which "resembles" those which would have been provided by the device being simulated (Ref 12:3-4). A description of several of the various types of simulators follows:
2.5.2.4.1 Environment Simulator - An environment simulator is a computer program which is used to test operational programs on a host computer. The operational programs run under simulated conditions as if they were operating within the real-time constraints of a machine to which all the components of the ultimate system are attached (Ref 18:56).

2.5.2.4.2 Peripheral Simulator - A peripheral simulator is a computer program used to present functional and signal interfaces representative of a peripheral device to the target system.

2.5.2.4.3 System Simulator - A system simulator is a computerized model of the system (hardware, software, interfaces) used to predict system performance over time. A system simulator allows full control of inputs, and computer characteristics. It allows processing of intermediate outputs without destroying simulated time, and allows full test repeatability and diagnostics (Ref 18:58).

2.5.2.4.4 Instruction Simulator - An instruction simulator is a computer program used to simulate the execution characteristics of a target computer. The instruction simulator provides bit for bit fidelity with the results that would have been produced by the target computer (Ref 18:56).
2.5.2.5 Interactive Test Bed - An interactive test bed performs three functions. First, it preprocesses the module under test so that instrumentation to measure testing coverage can be inserted in the code. Second, it links the instrumented module into a test harness which can control these functions: 1) Set-up of input data, 2) Intercept of stub calls, 3) Supply of stub return data, 4) Capture of output data, and 5) Reporting of coverage. Finally, it documents the test actions so testing can be repeated (Ref 18:58).

2.6 TOOLS SELECTION.

Since the contractor is scheduled to supply software to drive the threat simulators, the development of this software will not be considered during this study. The capability for closed loop testing by generating a threat and then analyzing the response of the system cannot be addressed until the specific implementation details of the threat generators are established.

A computer simulation of the ALR-46 system has been developed and is identified in Appendix A. This simulator should be evaluated by the EWAISF before any other work is done in this area.
The production of a software package to assemble flight software on the VAX 11/780 is a large programming task but would not have sufficient theoretical content to warrant thesis level attention.

The tools selected for development meet the following requirements: to determine the testing coverage, to determine the execution time of modules, and to identify variable out of range conditions.

It has been determined that the remainder of the user requirements could not be accomplished in the time available for this study.

2.7 SUMMARY.

Many software testing tools have been developed, however most are software or application dependent. The majority of these tools were developed for use with a specific high level language, such as FORTRAN. Since the ALR-46 flight software written is Nova assembly language, the number of tools directly applicable is greatly reduced. The tools found which are directly applicable are identified in Appendix A. Further, the unique design of the ALR-46 ISS data extraction subsystem requires custom software to be written for it.
This chapter has discussed the requirements for software test tools and the types of automated tools available to meet those requirements. Finally, the process used in determining which software tools to develop during this study was described.
CHAPTER 3
SOFTWARE REQUIREMENTS

3.1 INTRODUCTION.

Chapter 2 discussed the ALR-46 flight software testing requirements, what software tools are available to meet the requirements, and which tools were selected for development in this study. This chapter will discuss the requirements for the software tools.

3.2 SOFTWARE MONITORS.

Monitors for software testing can be divided into four categories (Ref 17:405-406). The first category is composed of monitors used for enforcing or ascertaining the traversal of paths. The second category is composed of monitors used for measuring path traversal frequencies. The third type is used for detecting erroneous conditions, such as variable out of range. The fourth type is the performance monitor which is used for observing performance behaviors, such as excessive delay.
There are two approaches for ascertaining the traversal of test paths. The first method inserts code segments, called flow controlling monitors, in the test paths. A flow controlling monitor is said to be "closed" when it is set to transfer control to the test supervisor, and "open", otherwise. The use of flow controlling monitors requires modification of the software under test. The normal operation of the data extraction subsystem only allows reading of data and not insertion. Therefore, flow-controlling monitors will not be considered in this study. The second method detects the traversal of paths by analyzing the data recorded during the test run by a set of monitors called traversal markers.

The following software monitors were selected for use in the Data Extraction and Analysis system (DEAS) because they could be implemented on the ISS data extraction subsystem. The ISS data extraction subsystem allows extraction of data without insertion of probes into the code under test. The monitors to be used will determine what data will be extracted by the ISS data extraction subsystem. Performance monitors will be used to determine the execution time of modules. Traversal markers will be used to determine the path traversal frequencies. Error detecting monitors will be used to detect variable out of range errors.
3.3 SOFTWARE REQUIREMENTS.

The DEAS operates in one of five modes. The first mode, called the "performance analysis mode", measures the execution time of each subroutine call. The second mode, called the "coverage analysis mode", determines the frequency of path coverage of marked paths during a particular test. The third mode, called the "error analysis mode", detects variable out of range errors. The fourth mode, called the "trackfile analysis mode", and the fifth mode, called the "RWR mode", are from a previous study (Ref 22). The organization of the DEAS is shown in figure 6.

The Data Extraction and Analysis System (DEAS) software is composed of three tasks. The function of the first task is to specify the data to be extracted and when it is to be extracted. The second task controls the extraction of the data and saves the raw data in a disk file. This software was delivered by the contractor who developed the ISS (Ref 1). The third task analyzes and presents the data in tabular format. This will provide the test engineer with test results in a form which can be more easily decyphered than large amounts of raw data.
3.3.1 **Performance Analysis Mode** - The performance analysis mode marks the time when a subroutine is entered and when the subroutine is exited. The difference in these times is the time spent in execution. The entry and the exit point of each subroutine is entered. The output is a table of execution times for the subroutines.

3.3.2 **Coverage Analysis Mode** - The coverage analysis mode counts the number of times each of the selected paths are executed. The addresses of instruction to be used for path markers are entered. The output is a table of the paths and number of times executed.
3.3.3 Error Analysis Mode - The error analysis mode checks for "variable out of range" errors. The addresses of variables to be monitored are entered. The output is a table of the variables and their minimum and maximum values.

3.3.4 Trackfile Mode - The trackfile analysis mode displays the contents of the emitter track file. Provisions will be made to include the code for this function which was developed by another study (Ref 22).

3.3.5 RWR Mode - The RWR mode displays a copy of the ALR-46 CRT on a color graphics terminal. Provisions will be made to include the code for this function which was developed by another study (Ref 22).

3.4 SUMMARY.

This chapter has described the software requirements for the Data Extraction and Analysis system. The requirements were derived from the user, environmental, and other requirements described in chapter 2. Briefly the software requirements are as follows:

1. Determine module performance characteristics

2. Determine path traversal frequency
3. Detect variable out of range conditions

4. Provide for previously developed software

The next chapter will describe the system design.
4.1 INTRODUCTION.

The previous two chapters described the software requirements. This chapter will discuss the design methodology and describe the detailed system design for the Data Extraction and Analysis System (DEAS). The design strategy will be described followed by the techniques used in the design of the DEAS.

4.2 DESIGN STRATEGY.

There are primarily two design strategies for developing computer software. The first is top-down design. In this method the major functions of a system are identified and expressed in terms of lower level functions (Ref 24:322). The process of functional decomposition is repeated until all the subfunctions can be easily implemented. A potential problem in strict top-down design is that there may be no way to ensure that operations at one
level in the hierarchy are supportable by some resource to be provided at subordinate levels (Ref 20:21). The second design strategy is bottom-up design. In this method, design is started at the bottom of the hierarchy before the design at the top has been completely thought out (Ref 20:5). The "bottom-up" approach can lead to difficulty in integrating system components.

The top-down approach was chosen for the design of the Data Extraction and Analysis System. The danger of having system integration problems with the bottom-up approach outweighs any advantages it might have. The top-down hierarchical decomposition leads directly to structured programs.

4.3 DESIGN TECHNIQUES.

Several techniques were considered for the design of the DEAS. The techniques considered were: Structure Charts (Ref 24:25), Data Dictionaries (Ref 24), Data Flow Diagrams (Ref 24), Structured Analysis and Design Techniques (SADT) (Ref 6), and Hierarchical Input-Process-Output (HIPO) (Ref 24). A combination of SADT, Structure Charts, and a Data Dictionary were selected for the system design. SADT shows more detail than Data Flow Diagrams. SADT allows the inclusion of control flow into the diagrams, Data Flow Diagrams do not. Structure Charts show the relationship between the modules more clearly than HIPO. A Data Dictionary is desirable for any design technique.

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4.3.1 SADT Diagrams. - To apply SADT to a problem, a model is built which expresses a "complete" understanding of the nature of the problem. SADT breaks a complex subject into its component parts. SADT begins with the most general description of the system, represented by a single box, and breaks that box into a number of more detailed boxes. Each of these boxes is further broken down into more detailed boxes.

The number of detailed boxes, which any parent box is broken into, is limited to a maximum of six and a minimum of three. The upper limit prevents too much detail from being introduced at any one level. The lower limit ensures enough detail to make the decomposition worthwhile.

Each module in a SADT model is represented by a box. The relationship between modules is shown by interconnecting arrows. This box structure is shown in figure 7. When a module is broken down into submodules, the interfaces between them are shown as arrows.

The arrows on the left show input data, which are transformed into output data, shown by the arrows on the right. Controls, represented by the arrows on the top, govern the way the transformation is done. Mechanisms, represented by the arrows on the bottom, indicate the process or device which performs the activity (Ref 6: Sec 4, 5, 22).
Figure 7. Box/Interface Arrow Definition.

A representative SADT diagram is shown in figure 8. The SADT diagrams developed for the DEAS are contained in Appendix C.

4.3.2 Structure Charts - Structure charts were used to develop the detailed system design. Their use along with top-down design causes the major functions to be developed first (Ref 24:141-147). Figure 9 shows the symbols used in the structure charts. A representative structure chart is shown in figure 10. The structure charts developed for the DEAS are contained in Appendix D.

4.3.3 Data Dictionary - A data dictionary defines all the terms used in system development. A data dictionary entry should contain a concise description of the term, all associated aliases, and the composition of the entry (Ref 24:150-163). The Data Dictionary for the DEAS is contained in Appendix E.
FIGURE 8. SADT Diagram.
Module A calls Module B passing data P, Module B returns data D and control Flag.

Module A calls Module B on the basis of a decision made in A. Module A calls Module C on the basis of a loop in A.

Figure 9. Structure Chart Symbols.
4.4 **SUMMARY.**

This chapter described the design strategy and design techniques used in developing the DEAS. The use of SADT diagrams, structure charts, and the data dictionary were described. The SADT diagrams, structure charts, and data dictionary used in the design of the DEAS are contained in Appendices C, D, and E respectively. The next chapter discusses the implementation and testing of the DEAS.
CHAPTER 5

IMPLEMENTATION AND TESTING

5.1 INTRODUCTION.

The implementation of the Data Extraction and Analysis System was done in VAX/11 Pascal (Ref 7). The reasons Pascal was chosen were discussed in Chapter 1. Appendix F contains the source listing for the DEAS. The implementation was accomplished in accordance with the design set forth in Chapter 4. The data structures used will be described followed by a description of each of the functional components of the system. Finally, the testing of the system will be discussed.

5.2 IMPLEMENTATION STRATEGY.

As in design, two strategies were considered. The first is "top-down" implementation. With this strategy the higher level modules are coded first with the next lower level modules replaced with "dummy stubs" for testing. Modules are coded working down until the entire design has
been coded. The second strategy is "bottom-up" implementation. With this strategy modules are coded starting with the lowest level. For testing, the remainder of the system is replaced with a "test harness".

The top-down approach was selected because modules could be tested as they are coded without requiring a test harness for each module. The top-down approach minimizes interfacing problems by defining the interfaces in the higher level modules.

5.3 IMPLEMENTATION DETAILS.

5.3.1 Data Structures - Consideration was given to three types of data structures for temporary storage of information: the array, the linked list, and the internal file. The array is the simplest data structure. The size of an array is fixed regardless of the amount of information stored in it. The size of an array must be set to the maximum amount of data to be stored. The handling of a linked list is more complex than an array, but the storage is allocated dynamically. The internal file is more complex to handle than a linked list but can store large quantities of data. The linked list was chosen for temporary data storage because storage space can be allocated dynamically and the expected amount of storage required did not justify the extra complexity of internal files.
5.3.2 **Main Executive** - The main executive accepts commands from the terminal. The complete list of valid commands is shown in Table 1. A menu is printed if "help" was entered, if a valid command was entered one of the five modes of operation is started.

The user cannot cause the program to abnormally terminate by typing invalid data. User input is accepted in an array of characters (string array). Command inputs are compared against valid commands until a match is found or the entire list has been searched. Data inputs are checked for invalid characters then, if necessary, converted into the appropriate data type. Upper or lower case characters are acceptable as input since lower case characters are converted internally to upper case.

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HELP</td>
<td>select from menu</td>
</tr>
<tr>
<td>PERFORMANCE</td>
<td>performance analysis</td>
</tr>
<tr>
<td>COVERAGE</td>
<td>coverage analysis</td>
</tr>
<tr>
<td>ERROR</td>
<td>error condition detection</td>
</tr>
<tr>
<td>TRACK</td>
<td>trackfile analysis</td>
</tr>
<tr>
<td>RWR</td>
<td>RWR color graphics display</td>
</tr>
<tr>
<td>QUIT</td>
<td>exit program</td>
</tr>
</tbody>
</table>

Table 1.
Valid Commands.
5.3.3 **Subroutine Execution Time Calculation** - When this mode is executed the user is instructed to enter a name, used to identify the subroutine, and its entry and exit addresses. This mode builds an "event" type data extraction file, as described in Appendix B. When the data for all the subroutines have been entered the DEAS will begin to extract the specified data.

After data collection is terminated the DEAS will calculate the execution time of each subroutine call. Two stacks are implemented for each subroutine. One stack stores the entry time for each subroutine call and the other stack stores the calculated execution time for each call. Each time an event record is read, the event address is compared with the entry address and the exit address for each subroutine. If a match is found with an entry address, the entry time is pushed on the "entry time" stack. If a match is found with the exit address, the entry time is popped off the "entry time" stack and subtracted from the exit time to obtain the execution time. The execution time is then pushed on the "execution time" stack. When all data in the "raw data file" has been analyzed, the list of subroutines will be searched and the execution time of each call will be popped from the "execution time" stack and displayed on the console.
5.3.4 **Coverage Analysis** - When this mode is executed the user is instructed to enter an address to serve as a path marker for each path to be monitored. The coverage analysis mode builds a data extraction file to collect "event" data. The format for this file is found in Appendix B. The extracted data is reduced by inserting it into a binary tree. A count is maintained of the number of traversals of each path. An "in-order" traversal of the tree is made and the paths traversed are printed out along with the number of traversals of each path.

5.3.5 **Error Analysis** - When this mode is entered the user is instructed to enter the address of each variable to be monitored. The error analysis mode builds a data extraction file to collect "location" data. The format for this file is found in Appendix B. The extracted data is reduced by inserting it into a binary tree, ordered by address value. The minimum and the maximum value attained by the variable is inserted into the binary tree. An "in-order" traversal is made of this tree also. The addresses of extracted variables, with their minimum and maximum values, are printed out in ascending order.

5.4 **TESTING.**

Two levels of testing were done, white box and black box. "White box testing" is done using knowledge of the internal structure of the code. "Black box testing" uses
the functional requirements and the system specification to evaluate the performance of a system.

5.4.1 **White Box Testing** - White box testing started when the first module was coded. "Dummy stubs" replaced the modules which had not yet been coded. The primary method of white box testing was path analysis. This testing technique attempts to execute each decision to decision path.

5.4.2 **Black Box Testing** - After the entire DEAS system was coded black box testing was done. Black box testing was done using equivalence class testing and boundary value analysis.

5.4.2.1 **Equivalence Partitioning** - Equivalence classes are identified by taking each input condition and dividing it into several groups (Ref 15:44-50). There are two types of equivalence classes. The first type is "valid equivalence classes" which represents valid inputs to the program. The second type is "invalid equivalence classes" which represent all other possible inputs. A set of guidelines for identifying equivalence classes is:

1. If an input condition specifies a range of values, choose one valid equivalence class and two invalid equivalence classes.
2. If an input condition specifies the number of values, choose one valid equivalence class and two invalid equivalence classes.

3. If an input condition specifies a set of input values and if each input value is handled differently by the program, identify a valid equivalence class for each input condition and one invalid equivalence class.

4. If an input condition specifies a "must be" condition, identify one valid equivalence class and one invalid equivalence class.

5. If it is suspected that all elements in an equivalence class are not handled identically by the program, split the equivalence class into several smaller equivalence classes.

Several examples of equivalence partitioning are shown in Table 2.

5.4.2.2 Boundary-value Analysis - Boundary conditions are conditions which are directly or, above, or below the edges of input and output equivalence classes (Ref 15:50-55). Boundary-value analysis differs from equivalence partitioning in two respects. First, boundary-value analysis requires that elements selected from an equivalence class be at the edge of the class rather than any element in the class. Second, output and input conditions are
Table 2. Equivalence Classes.

<table>
<thead>
<tr>
<th>INPUT CONDITION</th>
<th>VALID EQUIVALENCE CLASSES</th>
<th>INVALID EQUIVALENCE CLASSES</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMMAND</td>
<td>PERFORMANCE COVERAGE</td>
<td>ANY OTHER WORD</td>
</tr>
<tr>
<td></td>
<td>ERROR</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TRACK</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RWR</td>
<td></td>
</tr>
<tr>
<td></td>
<td>QUIT</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HELP</td>
<td></td>
</tr>
<tr>
<td>OCTAL ADDRESS</td>
<td>0..32767</td>
<td>&gt; 32767</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NON OCTAL DIGIT</td>
</tr>
<tr>
<td>MENU INPUT</td>
<td>1..6</td>
<td>&gt; 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 1</td>
</tr>
</tbody>
</table>

considered, rather than only the input conditions.

5.4.3 System Testing - The specific tests used in validating proper system performance are contained in Appendix G. The test cases were chosen by applying equivalence class analysis and boundary value analysis to the system requirements. The expected response was obtained in all test cases.

5.5 SUMMARY.

This chapter described the implementation and testing of the Data Extraction and Analysis System. The design described in Chapter 4 was followed in the implementation of the DEAS. The language used in the implementation of the
DEAS was Pascal. The main data structures and the major program sections were described. The DEAS was fully tested according to the test plans in Appendix G. No known errors exist in the program.
6.1 **RESULTS.**

This study investigated the requirements for automated tools for test and analysis of embedded computer software. The user requirements along with external requirements were considered in establishing the requirements for the Data Extraction and Analysis System.

Once the requirements for the DEAS were established system design began. A system model was produced using SADT and the detailed system design was done using structure charts combined with a data dictionary.

The DEAS was implemented using Pascal on the VAX 11/780 computer. The highly modular, structured design minimized interfacing difficulties during implementation.
Both black box and white box testing was done. White box testing was done as the modules were developed. Path analysis was the primary technique used during white box testing. Black box testing was done after the entire system was developed. The techniques used for black box testing were equivalence partitioning and boundary value analysis.

Installation and integration of the DEAS with the ISS was not possible because of time constraints. No problems are anticipated with installation since DEC Standard Pascal was used and system calls were minimized.

6.2 RECOMMENDATIONS.

There are two user requirements, identified during this study, which require further study.

The capability to generate input buffers could loosely be thought of as a peripheral simulator. The simulator would replace the RF and A/D portion of the system. This would enable the exact duplication of conditions between tests. This would also allow the simulation of signals beyond the capabilities of the threat generators.

The automated generation of test data would aid the engineer in selecting good test data. The generation of test data for the EID would be simpler than for the OFP, because the EID is constructed using rigid rules.
Bibliography


APPENDIX A

INDEX OF AVAILABLE SOFTWARE TOOLS

This appendix contains four software tools identified in this study which are directly applicable for testing the ALR-46 flight software. The name of the tool is given along with its source and description. The tools are divided into two groups, those used for static analysis and those used for dynamic analysis.
A.1  STATIC ANALYSIS TOOLS.

1. NAME:  EID Tools  
   SOURCE:  Comtek Reasearch Inc.  
   DESCRIPTION:  Examines the EID database for violations of structure rules.

2. NAME:  SCOM  
   SOURCE:  Data General Corp.  
   DESCRIPTION:  Utility which is part of the Advanced Operating System (AOS). Identifies the differences between two source or text files. If the program finds differences, it outputs either a message or the differences. The program will then attempt to resynchronize.

A.2  DYNAMIC ANALYSIS TOOLS.

1. NAME:  ALLADIN  
   SOURCE:  Richard E. Fairley  
   DESCRIPTION:  Assembly Language Assertion Driven Debugging Interpreter.
2. NAME: RWR Simulator  
SOURCE: Comtek Research Inc.  
DESCRIPTION: Simulator for the ALR-46 Radar Warning  
Receiver. The RWR Simulator consists of three  
components: an Environment Simulator, a Receiver  
Simulator, and the operational flight software.
APPENDIX B

DATA EXTRACTION FILE FORMATS

This appendix describes the formats for the event/location file and the extracted data file. The file required by the data extraction subsystem is described first. The file produced by the data extraction subsystem is described second.

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B.1 EVENT/LOCATION SPECIFICATION FILE.

This file contains addresses which specify "event" locations, and "location" address limits. An "event" occurs whenever the data extraction subsystem detects a memory "fetch" on a memory address flagged for extraction. A "location" occurs whenever the data extraction subsystem detects a "memory write" to a address flagged for extraction. The format of the file is as follows (Ref 2: Sec 4, 27):

address of event 1
address of event 2
...
address of event n
0
lower address - upper address of first contiguous data block
lower address - upper address of second contiguous data block
...
lower address - upper address of final contiguous data block

The event addresses are entered first, one per line, and are terminated by a line containing a zero. The zero terminator must be present even if no event addresses are specified. Event addresses are specified by a right-justified, five-digit, octal number.

The data location address limits are entered following the event addresses. The data address location address limits consist of a lower address limit, followed by a space, comma, or a hyphen, then followed by the upper
address limit. One pair of address limits are entered per line. The address limits are right-justified, five-digit, octal numbers as required by the event addresses. If a data block is only one word long, both addresses are set equal to the address of the word. The same address cannot appear as both an event address and be contained a data block defined by a location pair (Ref 2: Sec 4, 27-29). An example of an acceptable event/location file follows:

00537
  745
01243
  0
07775 10003
20105,20105
22351-23200

B.2 EXTRACTED DATA FILE.

The data extracted by a "location" is the address extracted and the value written to that address. The data extracted by an "event" is a -1 marker, followed by its address, followed by the high and low 16 bits of the clock. The formats of the two data extraction sequences are (Ref 5: Sec 3, 9):

1. Location
   ADDRESS
   DATA
2. Event
   -1 MARKER
ADDRESS
CLOCK HIGH (MSBs)
CLOCK LOW (LSBS)

The 32-bit clock free runs at 1MHz, providing a 1 μsec
LSD (Ref 5: Sec 3, 6).
APPENDIX C

SADT DIAGRAMS

This appendix contains the Structured Analysis and Design Technique (SADT) diagrams used in developing the software requirements and data flow for the Data Extraction and Analysis System.

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DO PERFORMANCE ANALYSIS

COVERAGE_DISPLAY

DO COVERAGE ANALYSIS

ERROR_DISPLAY

DO ERROR ANALYSIS

TRACKFILE_DISPLAY

DO TRACKFILE ANALYSIS

RWR_DISPLAY

DO RWR ANALYSIS
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HELP_LEVEL

USER ->
INPUT

BUILD PERFORMANCE DX_FILE

ENTRY+EXIT_ADDRESSES

DX_FILE

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RAW_DATA_FILE

REDUCE PERFORMANCE DATA

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BUILD COVERAGE
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COLLECT COVERAGE
DATA

RAW_DATA_FILE

REDUCE COVERAGE
DATA

USER DISPLAY
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COLLECT ERROR DATA

RAW_DATA_FILE

REDUCE ERROR DATA

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This appendix contains the structure charts used in the detailed design of the Data Extraction and Analysis System.

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- mode

help_level

- Select Mode

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DO TRACKFILE ANALYSIS

DO COVERAGE ANALYSIS

DO ERROR ANALYSIS

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- BUILD COVERAGE DX FILE
- REDUCE COVERAGE DATA
- COLLECT COVERAGE DATA
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- Diagram:
  - Build Coverage Dx file
  - cov_address
  - Get Path Marker Address
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REDUCE COVERAGE RAW DATA

root

total_addr

SORT COVERAGE RAW DATA

COUNT PATH TRAVERSALS
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- help_level
- DISPLAY ERROR HELP
- BUILD ERROR DX FILE
- REDUCE ERROR DATA
- COLLECT ERROR DATA
D.1.5.1 Build Error Dx file -

```
BUILD ERROR
DX FILE

err_address

GET VARIABLE ADDRESS
```
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- REDUCE ERROR RAW DATA
- root
- total_adr
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- DETERMINE MIN & MAX VALUES
APPENDIX E

DATA DICTIONARY

This appendix contains the description of all processes, constants, and variables used in the Data Extraction and Analysis System. The symbols used in describing the data composition will be defined followed by the data dictionary.

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E.1 SYMBOLS AND MEANINGS

1. = is composed of
2. + and
3. | or
4. [ ] choose one of (exclusive or)
5. < > at least one of (inclusive or)
6. x { } y Iterations of the values from x to y times
7. ( ) Optional value
8. * * Comment
9. <= Less than or equal to
10. >= Greater than or equal to
11. <> Not equal to
12. > Greater than
13. < Less Than
E.2 DATA ELEMENTS

1. DATA ELEMENT NAME: bel
   DESCRIPTION: ASCII bell
   COMPOSITION: Character
   ALIASES: None

2. DATA ELEMENT NAME: clock_high
   DESCRIPTION: High 16 MSBs of elapsed time clock
   COMPOSITION: Integer
   ALIASES: None

3. DATA ELEMENT NAME: clock_low
   DESCRIPTION: Low 16 LSBs of elapsed time clock
   COMPOSITION: Integer
   ALIASES: None

4. DATA ELEMENT NAME: column
   DESCRIPTION: Column counter
   COMPOSITION: Integer
   ALIASES: None

5. DATA ELEMENT NAME: convert
   DESCRIPTION: Conversion value for lower to upper case
   COMPOSITION: Integer
   ALIASES: None
6. DATA ELEMENT NAME: entry_text
   DESCRIPTION: Entry address
   COMPOSITION: String
   ALIASES: None

7. DATA ELEMENT NAME: error_address
   DESCRIPTION: Error analysis "location" address
   COMPOSITION: Integer
   ALIASES: None

8. DATA ELEMENT NAME: error_text
   DESCRIPTION: Text form of error_address
   COMPOSITION: String
   ALIASES: None

9. DATA ELEMENT NAME: esc
   DESCRIPTION: ASCII escape
   COMPOSITION: Character
   ALIASES: None

10. DATA ELEMENT NAME: event_address
    DESCRIPTION: Address of an "event"
    COMPOSITION: Integer
    ALIASES: None
11. DATA ELEMENT NAME: event_time
   DESCRIPTION: Time an "event" occurred
   COMPOSITION: Integer
   ALIASES: None

12. DATA ELEMENT NAME: execute_time
   DESCRIPTION: Execution time of a routine
   COMPOSITION: Integer
   ALIASES: None

13. DATA ELEMENT NAME: Exit_text
   DESCRIPTION: Exit address
   COMPOSITION: String
   ALIASES: None

14. DATA ELEMENT NAME: good_address
   DESCRIPTION: Flag
   COMPOSITION: [true, false]
   ALIASES: None

15. DATA ELEMENT NAME: good_input
   DESCRIPTION: Flag
   COMPOSITION: [true, false]
   ALIASES: None
16. DATA ELEMENT NAME: \( I \)
   DESCRIPTION: Column counter
   COMPOSITION: Integer
   ALIASES: None

17. DATA ELEMENT NAME: input_text
   DESCRIPTION: User input
   COMPOSITION: String
   ALIASES: None

18. DATA ELEMENT NAME: invalid_char
   DESCRIPTION: Flag
   COMPOSITION: [true,false]
   ALIASES: None

19. DATA ELEMENT NAME: last
   DESCRIPTION: Flag
   COMPOSITION: [true,false]
   ALIASES: None

20. DATA ELEMENT NAME: last_char
   DESCRIPTION: Column count of last char
   COMPOSITION: Integer
   ALIASES: None
21. DATA ELEMENT NAME: marker
   DESCRIPTION: -1 marker of an "event" record
   COMPOSITION: Integer
   ALIASES: None

22. DATA ELEMENT NAME: menu_input
   DESCRIPTION: Menu selection
   COMPOSITION: Character
   ALIASES: None

23. DATA ELEMENT NAME: new_node
   DESCRIPTION: Pointer to new node in binary tree
   COMPOSITION: Pointer
   ALIASES: None

24. DATA ELEMENT NAME: new_stack
   DESCRIPTION: Pointer to new stack entry
   COMPOSITION: Pointer
   ALIASES: None

25. DATA ELEMENT NAME: next
   DESCRIPTION: Pointer to next linked list record
   COMPOSITION: Pointer
   ALIASES: None
26. DATA ELEMENT NAME: next_time
   DESCRIPTION: Pointer to time stack entry
   COMPOSITION: Pointer
   ALIASES: None

27. DATA ELEMENT NAME: octal_place
   DESCRIPTION: octal_string column count
   COMPOSITION: Integer
   ALIASES: None

28. DATA ELEMENT NAME: octal_string
   DESCRIPTION: Octal representation of decimal number
   COMPOSITION: String
   ALIASES: None

29. DATA ELEMENT NAME: quit_input
   DESCRIPTION: User input for termination
   COMPOSITION: Character
   ALIASES: None

30. DATA ELEMENT NAME: routine
   DESCRIPTION: Linked list element
   COMPOSITION: routinename + entryaddress + exitaddress + link
   ALIASES: None
AUTOMATED TOOLS FOR TEST AND ANALYSIS OF RADAR WARNING RECEIVER SOFTWARE AT AIR FORCE INSTITUTE OF TECHNOLOGY SCHOOL OF ENGINEERING

J.R. ROBERTSON

AFIT/GCS/EE/82D-28

UNCLASSIFIED
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A
31. DATA ELEMENT NAME: stop_comand  
   DESCRIPTION: Flag  
   COMPOSITION: [true,false]  
   ALIASES: None

32. DATA ELEMENT NAME: tab  
   DESCRIPTION: ASCII tab character  
   COMPOSITION: Character  
   ALIASES: None

33. DATA ELEMENT NAME: tail  
   DESCRIPTION: Linked list pointer  
   COMPOSITION: Pointer  
   ALIASES: None

34. DATA ELEMENT NAME: terminate  
   DESCRIPTION: Flag  
   COMPOSITION: [true,false]  
   ALIASES: None

35. DATA ELEMENT NAME: transform  
   DESCRIPTION: Array  
   COMPOSITION: Array[performance..test] of string  
   ALIASES: None
36. DATA ELEMENT NAME: weight

   DESCRIPTION: Weight of a column in an octal digit
   COMPOSITION: Integer
   ALIASES: None

E.3 DATA FLOWS

1. DATA FLOW NAME: address
   DESCRIPTION: Memory address
   COMPOSITION: Integer
   ALIASES: exit_address, entry_address, cov_address, error_address

2. DATA FLOW NAME: address_text
   DESCRIPTION: String representation of a memory address
   COMPOSITION: string
   ALIASES: entry_text, exit_text, cov_text, error_text

3. DATA FLOW NAME: adr_value
   DESCRIPTION: Variable's value
   COMPOSITION: Integer
   ALIASES: None

4. DATA FLOW NAME: decimal
   DESCRIPTION: Decimal number to be converted to octal
   COMPOSITION: integer
   ALIASES: cov_node_adr, error_node_adr, min_value, max_value
5. DATA FLOW NAME: error
   DESCRIPTION: Flag
   COMPOSITION: [true, false]
   ALIASES: last

6. DATA FLOW NAME: father
   DESCRIPTION: Pointer to node in binary tree
   COMPOSITION: Pointer
   ALIASES: None

7. DATA FLOW NAME: head
   DESCRIPTION: Pointer to first linked list record
   COMPOSITION: Pointer
   ALIASES: None

8. DATA FLOW NAME: help_level
   DESCRIPTION: Determine the level of help required
   COMPOSITION: [min, max]
   ALIASES: None

9. DATA FLOW NAME: input_string
   DESCRIPTION: User input
   COMPOSITION: String
   ALIASES: None
10. DATA FLOW NAME: mode
   DESCRIPTION: data extraction mode
   COMPOSITION: [performance, coverage, error track, rwr, quit]
   ALIASES: None

11. DATA FLOW NAME: newaddress
   DESCRIPTION: Pointer to new node to be inserted into binary tree
   COMPOSITION: Pointer
   ALIASES: None

12. DATA FLOW NAME: root
   DESCRIPTION: Pointer to root node of binary tree
   COMPOSITION: Pointer
   ALIASES: None

13. DATA FLOW NAME: stack_top
   DESCRIPTION: Pointer to top of stack
   COMPOSITION: Pointer
   ALIASES: entry_stack_top, time_stack_top

14. DATA FLOW NAME: stack_value
   DESCRIPTION: Value of top of stack
   COMPOSITION: Integer
   ALIASES: entry_time, execute_time
15. DATA FLOW NAME: total_addr
   DESCRIPTION: Total addresses read from rawdatafile
   COMPOSITION: Integer
   ALIASES: None

E.4 FILES

1. FILE NAME: dx_file
   DESCRIPTION: Data extraction specification file
   COMPOSITION: Text
   ALIASES: None

2. FILE NAME: raw_data_file
   DESCRIPTION: Data extraction raw data file
   COMPOSITION: File of integer
   ALIASES: None
APPENDIX F

PASCAL SOURCE LISTING

This appendix contains the source listing for the Data Analysis and Extraction System.

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F.1 PROGRAM DATA_ANALYSIS

******************************************************************************************

PROGRAM data_analysis

******************************************************************************************

VERSION 1.0 DEC 1982

AUTHOR:
Joel R. Robertson

LANGUAGE:
VAX-11 Pascal

PURPOSE:
This program builds the data extraction file, collects data, and reduces the raw data.

REMARKS:
This program was developed as part of the author's masters thesis at the Air Force Institute of Technology.

******************************************************************************************

(*$s- ;suppress nonstandard warnings *)
(*$w- ;suppress variable length warnings *)

program data_analysis(input,output,dx_file,raw_data_file);

type
token = packed array [1..12] of char;
valid_mode = (performance,coverage,error,
track,rwr,quit,test);
help_mode = (min,max);
memory = integer;
address_string = packed array [1..5] of char;
routine_ptr = routine;
stack_ptr = stack;
cov_ptr = cov_node;
err_ptr = err_node;
dx_data = integer;
data_file = file of dx_data;

routine = record
  routine_name : packed array [1..10] of char;
  entry_address : memory;
  exit_address : memory;
  entry_stack_top : stack_ptr;
  time_stack_top : stack_ptr;
  link : routine_ptr
end; {routine}

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stack = record
  stack_time : integer;
  stack_link : stack_ptr
end; {stack}

cov_node = record
  cov_node_adr : memory;
  path_count : integer;
  left,right : cov_ptr
end; {cov_node}

err_node = record
  err_node_adr : memory;
  min_value : integer;
  max_value : integer;
  left,right : err_ptr
end; {err_node}

var
  mode : valid_mode;
  good_input : boolean;
  transform : array [performance..test] of token;
  input_string : token;
  stop_command : boolean;
  help_level : help_mode;
  esc,tab,bel : char;
  dx_file : text;
  raw_data_file : data_file;

value
  stop_command := false;

{end declarations}
F.1.1 Procedure get_input -
******************************************************************************

PROCEDURE get_input
******************************************************************************

VERSION: 1.0 12-SEP-82

PURPOSE:
Inputs a string from the console and converts all lower case characters to upper case.

INPUT: none

OUTPUT: input_string

GLOBALS USED: none

REMARKS:

CALLED BY:
  data_analysis

PROCEDURES AND FUNCTIONS CALLED:
  none

******************************************************************************

procedure get_input(var input_string : token);

var
  I : integer; {column count}
  convert : integer; {upper to lower case conversion}

begin
  convert := ord('a') - ord('A');
  read(input_string);
  for I := 1 to 12 do
    if input_string[I] in ['a'..'z'] then
      input_string[I] := chr(ord(input_string[I]) - convert);
  end; {get_input

******************************************************************************
F,1.2 Procedure help_user -

PROCEDURE help_user

VERSION: 1.0 13-SEP-82

PURPOSE:
This procedure types a menu on the users console and accepts as input a menu selection. Also the help level is set to maximum.

INPUT: none

OUTPUT:
mode help_level

GLOBALS USED:
none

REMARKS:

CALLED BY:
data_analysis

PROCEDURES AND FUNCTIONS CALLED:
one

procedure help_user(var mode : valid_mode;
var help_level : help_mode);

var
menu_input : char;

begin
help_level := max;

{set up menu}
writeln(esc,'[2J');
writeln;
writeln;
writeln(tab,'ALR-46 DATA EXTRACTION AND ANALYSIS SYSTEM');
writeln;
writeln(tab,tab,'**** MENU ****');
writeln;
writeln;
writeln(tab,'1. <PERFORMANCE> ANALYSIS');
writeln(tab,'2. <COVERAGE> ANALYSIS');
writeln;
writeln(tab,'3. <ERROR> CONDITION DETECTION');
writeln;
writeln(tab,'4. <TRACK> FILE DISPLAY');
writeln;
writeln(tab,'5. <RWR> GRAPHICS DISPLAY');
writeln;
writeln(tab,'6. <QUIT> PROGRAM');
writeln;
write('ENTER CHOICE [1..6] => ');
readln;
read(menu..input);
while not (menu-input in ['1'..'6'])
do begin
  write(bel,'ERROR... RE-ENTER => ');
  readln;
  read(menu_input)
end; {while}

{ determine mode }
case menu_input of
  '1' : mode := performance;
  '2' : mode := coverage;
  '3' : mode := error;
  '4' : mode := track;
  '5' : mode := rwr;
  '6' : mode := quit
end; {case}

end; {help_user}
F.1.3 Procedure get_address -
*********************************************************************************

PROCEDURE get_address
*********************************************************************************

VERSION: 1.0 28-SEP-82

PURPOSE: This procedure returns the the address value plus a right justified string representation of the address.

INPUT: none

OUTPUT: address address_text

GLOBALS USED: none

REMARKS:

CALLED BY:
- perf_build_dx
- cov_build_dx
- error_build_dx

PROCEDURES AND FUNCTIONS CALLED: none

*********************************************************************************

procedure get_address(var address : integer;
var address_text : address_string);

var
- last_char : integer;
- column : integer;
- weight : integer;
- good_address, invalid_char : boolean;
- input_text : packed array [1..5] of char;

begin {get address}
- good_address := false;
- repeat
- address_text := ' ';
- invalid_char := false;
- readln(input_text);

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column := 1;
repeat
  last_char := column;
  column := column + 1
until (input_text[column] = ' ') or (column > 5);
for column := last_char downto 1 do
  address_text[5-(last_char-column)]:=input_text[column];
for column := 5 downto (6-last_char) do
  if not (address_text[column] in ['0'..'7']) then
    invalid_char := true;
  if invalid-char then
    write('INVALID ENTRY => ')
  else
    good_address := true;
  until good_address;
{convert octal string into decimal integer}
address := 0;
for column := 1 to 5 do
begin
  if address_text[column] in ['1'..'7'] then
    weight := ord(address_text[column]) - ord('0')
  else
    weight := 0;
  case column of
    1 : address := address + 4096 * weight;
    2 : address := address + 0512 * weight;
    3 : address := address + 0064 * weight;
    4 : address := address + 0008 * weight;
    5 : address := address + weight
  end {case}
end {for}
end; {get address
F.1.4 Procedure octal -
*****************************************************************************

PROCEDURE octal
*****************************************************************************

VERSION: 1.0 01-DEC-82

PURPOSE:
This procedure types on the console the octal representation of the decimal number input

INPUT:
  dec_number

OUTPUT:
  none

GLOBALS USED:
  none

REMARKS:

CALLED BY:
  read_cov_tree
  read_err_tree

PROCEDURES AND FUNCTIONS CALLED:
  none

*****************************************************************************

procedure octal(dec_number : integer);

VAR
  octal_string : packed array [1..6] of char;
  octal_place : integer;

begin
  octal_string := ' ';
  octal_place := 0;

  {build octal string}
  repeat
    octal_place := octal_place + 1;
    octal_string{octal_place} := chr((dec_number mod 8)+48);
    dec_number := dec_number div 8
  until dec_number = 0;

  {type out octal string}
  for octal_place := 6 downto 1 do
    write(octal_string{octal_place})
  end; {octal

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F.1.5 Procedure perf_help -

PROCEDURE perf_help

VERSION: 1.0 13-SEP-82

PURPOSE: This procedure types instructions on the users console if help_level is set to 'max'.

INPUT: help_level

OUTPUT: none

GLOBALS USED: none

REMARKS:

CALLED BY: do_performance

PROCEDURES AND FUNCTIONS CALLED: none

procedure perf_help(help_level : help_mode);

begin
  writeln(esc,'[2J');  {clear screen}
  writeln(tab,'*** PERFORMANCE ANALYSIS MODE ***');
  writeln;writeln;
  if help_level = max then
    begin
      writeln('This mode determines the execution for program');
      writeln('subroutines. An entry and an exit address must be');
      writeln('provided.');
      end;
  end; {perf_help
P.1.6 Procedure perf_build_dx -

PROCEDURE perf_build_dx

VERSION: 1.0 13-SEP-82

PURPOSE: This procedure builds the performance analysis dx file.

INPUT: none

OUTPUT: none

GLOBALS USED: dx_file

REMARKS:

CALLED BY:
do_performance

PROCEDURES AND FUNCTIONS CALLED:
get_address

procedure perf_build dx(head : routine_ptr);
var
  entry_text : address_string;
  exit_text : address_string;
  quit_input : char;
  terminate : boolean;
  tail,next : routine_ptr;

begin
  terminate := false;
  tail := head;
  open(dx_file,'DXFILE',new);
  rewrite(dx_file);
  writeln; writeln;
  repeat
    writeln; writeln;
    writeln('****************************************');
    writeln;
    writeln('ENTER NAME OF SUBROUTINE');
    write('[10 char max] => ');
    readln(tail^.routine_name);
  until terminate
begin
writeln;}
writeln; writeln;
writeln('ENTER ENTRY ADDRESS');
write('[1..77777 octal] => ');
get_address(tail^.entry_address,entry_text);
writeln; writeln;
writeln('ENTER EXIT ADDRESS');
write('[1..77777 octal] => ');
get_address(tail^.exit_address,exit_text);
writeln; writeln;

{initialize stacks}
tail^.entry_stack_top := nil;
tail^.time_stack_top := nil;

writeln(dx_file,entry_text);
writeln(dx_file,exit_text);

write('terminate input [Y/N] => ');
readln(quit_input);
writeln; writeln;
if quit_input in ['Y','y'] then
  begin
    terminate := true;
    tail^.link := nil
  end
else
  begin
    new(next);
    tail^.link := next;
    tail := next
  end;

until terminate;
writeln(dx_file, ' 0.');
close(dx_file)
end; {perf_build_d
PROCEDURE perf_collect_data

VERSION: 1.0 13-SEP-82

PURPOSE: This procedure collects the performance analysis data.

INPUT:

OUTPUT:

GLOBALS USED:
  dx_file
  raw_data_file

REMARKS:
  dummy module - contractor supplied routine

CALLED BY:
  do_performance

PROCEDURES AND FUNCTIONS CALLED:
  none

procedure perf_collect_data;

begin
  writeln;
  writeln('***************************************************************************');
  writeln('*** procedure perf_collect_data called ***');
  writeln('***************************************************************************');
  writeln
end; {perf_collect_data
Procedure push_stack -

PROCEDURE push_stack

VERSION: 1.0 12-OCT-82

PURPOSE: pushes a value on the stack pointed to by stack_top.

INPUT:
stack_top - pointer to top of stack
stack_value - value to be pushed on stack

OUTPUT:
stack_top - new top of stack

GLOBALS USED:
none

REMARKS:

CALLED BY:
perf_reduce_data

PROCEDURES AND FUNCTIONS CALLED:
none

procedure push_stack(var stack_top : stack_ptr;
stack_value : integer);

var
new_stack : stack_ptr;

begin
new(new_stack);
new_stack^.stack_time := stack_value;
if stack_top = nil then
new_stack^.stack_link := nil
else
new_stack^.stack_link := stack_top;
stack_top := new_stack
end; {push_stack
F.1.9 Procedure popstack -
*****************************************************************************

PROCEDURE pop_stack
*****************************************************************************

VERSION: 1.0 11-OCT-82

PURPOSE:
   pops value from top of stack

INPUT:
   stack_top  -pointer to top of stack

OUTPUT:
   stack_value  -value popped from stack
   stack_top  -new top of stack

GLOBALS USED:
   none

REMARKS:

CALLED BY:
   perf_reduce_data

PROCEDURES AND FUNCTIONS CALLED:
   none

*****************************************************************************

procedure pop_stack(var stack_top : stack_ptr;
   var stack_value : integer;
   var error : boolean);

begin
   if stack_top = nil then
      error := true
   else
      begin
         stack_value := stack_top^.stack_time;
         stack_top := stack_top^.stack_link
      end;
end; {pop_stack

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F.1.10 Procedure perf_reduce_data -
***********************************************************************
PROCEDURE perf_reduce_data
***********************************************************************

VERSION: 1.0 21-NOV-82

PURPOSE:
This procedure reduces the performance analysis data.

INPUT:
head - front of linked linked list
raw_data_file - file produced by dx system

OUTPUT:
none

GLOBALS USED:
raw_data_file

REMARKS:

CALLED BY:
do_performance

PROCEDURES AND FUNCTIONS CALLED:
push_stack
pop_stack

***********************************************************************
procedure perf_reduce_data(head : routine_ptr);

var
tail : routine_ptr;
count : integer;
{ 'event' record }
marker : integer;
event_address : integer;
clock_high : integer;
clock_low : integer;
event_time,
entry_time,
execute_time : integer;
next : routine_ptr;
error,last : boolean;
next_time : stack_ptr;

begin
open(raw_data_file,'DXDATA',old);
reset(raw_data_file);
writeln;
while (not eof(raw_data_file)) and (not error) do
begin
  read(raw_data_file,marker,event_address,
   clock_high,clock_low);
  if marker = -1 then
  begin
    next := head;
    event_time := clock_low + 65536 * clock_high;
    repeat
      if next^.entry_address = event_address then
        push_stack(next^.entry_stack_top,event_time);
      if next^.exit_address = event_address then
        begin
          pop_stack(next^.entry_stack_top,event_time,error);
          execute_time := event_time - entry_time;
          push_stack(next^.time_stack_top,execute_time)
        end;
    next := next^.link;
  until next = nil
  end
else
  begin
    error := true;
    writeln('RAW DATA FILE FORMAT ERROR')
  end {else}
end; {while}
close(raw_data_file);

{**************************************************************************}
{* Format and print out the execution times *}
{**************************************************************************}

if error = false then
begin
  writeln(esc,'[2J'); {clear screen}
  next := head;
  repeat
    count := 0; {reset count}
    writeln;
    write(tab,'EXECUTION TIMES FOR SUBROUTINE ');
    writeln(next^.routine_name);
    writeln
    (tab,'-----------------------------------------------');
    next_time := next^.time_stack_top;
    repeat
      last := false; {not end yet}
      pop_stack(next_time,execute_time,last);
      if not last then {stack empty ?}
      begin
        write(execute_time);
        count := count +1
      end
    end
  end
  writeln(esc,'[2J'); {clear screen}
end.
end;
if count > 4 then
begin
  count := 0; \{reset count\}
  writeln \{new line\}
end
until last;
next := next^.link;
writeln;
writeln (tab,'--------------------------------------')
until next = nil;
writeln;
end
end; \{perf_reduce_data
**F.1.11 Procedure do_performance**

*-----------------------------------------------------------------------------*

**PROCEDURE do_performance**

*-----------------------------------------------------------------------------*

**VERSION:** 1.0 13-SEP-82

**PURPOSE:**
This procedure does the subroutine performance analysis

**INPUT:**
help_level

**OUTPUT:**
head

**GLOBALS USED:**
none

**REMARKS:**

**CALLED BY:**
data_analysis

**PROCEDURES AND FUNCTIONS CALLED:**
perf_help
perf_build_dx
perf_collect_data
perf_reduce_data

*-----------------------------------------------------------------------------*

procedure do_performance(help_level : help_mode);

var
    head : ^routine;

begin {do_performance}
    perf_help(help_level);
    {build the performance analysis dx file}
    new(head);
    perf_build_dx(head);
    {call the contractor supplied data extraction routine}
    perf_collect_data;
    {reduce the extracted data}
    perf_reduce_data(head);
end; {do_performance}
procedure covyhelp(help-level : help_mode);
begin
  writeln(esc,'[2J');  {clear screen}
  writeln(tab, '*** COVERAGE ANALYSIS MODE ***');
  if help-level = max then
    begin
      writeln ('This mode counts the occurances of path markers');
      writeln('to determine the testing coverage.');
    end;
  writeln;
  writeln('Enter path marker address <0 to end>')
end; {covyhelp}
P.1.13 Procedure cov_build_dx -
******************************************************************************************

PROCEDURE cov_build_dx
******************************************************************************************

VERSION: 1.0 22-NOV-82

PURPOSE:
This procedure builds the coverage analysis dx file. dx_file will be an 'event' type file.

INPUT: none

OUTPUT: none

GLOBALS USED:
dx_file

REMARKS:

CALLED BY:
do_coverage

PROCEDURES AND FUNCTIONS CALLED:
get_address

******************************************************************************************

procedure cov_build_dx;

var
cov_address : memory;
cov_text : address_string;

begin
open(dx_file,'DXFILE',new);
rewrite(dx_file);
repeat
write('PATH MARKER [1..77777 octal] => ');
get_address(cov_address,cov_text);
writeln(dx_file,cov_text)
until cov_address = 0;
close(dx_file)
end; {cov_build_dx}
F.1.14 Procedure cov_collect_data -
*********************************************************************

PROCEDURE cov_collect_data
*********************************************************************

VERSION: 1.0 27-SEP-82

PURPOSE:
This procedure collects the coverage analysis data.

INPUT:
none

OUTPUT:
none

GLOBALS USED:
dx_file
raw_data_file

REMARKS:
dummy module - contractor supplied routine

CALLED BY:
do_coverage

PROCEDURES AND FUNCTIONS CALLED:
*********************************************************************

procedure cov_collect_data;
begin
  writeln;
  writeln('*********************************************************************');
  writeln('*** procedure cov_collect_data called ***');
  writeln('*********************************************************************');
  writeln
end; {cov_collect_data

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PROCEDURE cov_tree_search

VERSION: 1.0 21-NOV-82

PURPOSE:
This procedure searches the binary tree for an address. If the address is found the path count is incremented, otherwise the address will be inserted into the binary tree.

INPUT:
father
new_address

OUTPUT:
none

GLOBALS USED:
none

REMARKS:
this is a recursive procedure

CALLED BY:
build_cov_tree

PROCEDURES AND FUNCTIONS CALLED:
cov_tree_search

procedure cov_tree_search(var father : cov_ptr;
            new_address : memory);

var
    new_node : cov_ptr;

begin
    if new_address = father^.cov_node_adr then
        {we found it update count}
        father^.path_count := father^.path_count + 1
    else
        if new_address < father^.cov_node_adr then
            begin
                if father^.left = nil then
                    begin
                        new(new_node);
                        father^.left := new_node;
                        with new_node do
                        end
                end
            end
begin
cov_node_adr := new_address;
path_count := 1;
left := nil;
right := nil
end {with}
else
begin
  father := father^.left;
cov_tree_search(father,new_address)
end
end
else
  if father^.right = nil then
  begin
    new(new_node);
    father^.right := new_node;
    with new_node do
      begin
        cov_node_adr := new_address;
        path_count := 1;
        left := nil;
        right := nil
      end {with}
  end
  else
    begin
      father := father^.right;
cov_tree_search(father,new_address)
    end {else}
end; {cov_tree_search
F.1.16 Procedure build_cov_tree -
*******************************************************************************

PROCEDURE build_cov_tree
*******************************************************************************

VERSION: 1.0 21-NOV-82

PURPOSE: This procedure builds the coverage analysis binary tree.

INPUT:
root
total_adr

OUTPUT:
one

GLOBALS USED:
raw_data_file

REMARKS:

CALLED BY:
cov_reduce_data

PROCEDURES AND FUNCTIONS CALLED:
cov_tree_search

*******************************************************************************

procedure build_cov_tree(var root : cov_ptr;
var total_adr : integer);

var
new_address : memory; {address to be inserted in tree}
new_node, {pointers to nodes}
father : cov_ptr;

begin {build_cov_tree}
open(raw_data_file,'DXDATA',old);
{insert the first word in the root node}
reset(raw_data_file); {discard marker}
if not eof(raw_data_file) then
begin
get(raw_data_file); {get address}
new_address := raw_data_file^;
total_adr := 1;
with root^ do
begin
cov_node_adr := new_address;
path_count := 1;

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left := nil;
right := nil
end; {with}
get(raw_data_file); {discard clock high}
get(raw_data_file); {discard clock low}
end
else
root := nil;
{attach each address to its father}
get(raw_data_file); {discard marker}
while not eof(raw_data_file) do
begin
get(raw_data_file); {get address}
new_address := raw_data_file^;
total_adr := total_adr + 1;
father := root; {first father is root}
{insert each path address into tree}
cov_tree_search(father,new_address);
get(raw_data_file); {discard clock high}
get(raw_data_file); {discard clock low}
got(raw_data_file); {discard marker}
end; {while}
close(raw_data_file)
end; {build_cov tree}
F.1.17 Procedure read_cov_tree -
*****************************************************************************

PROCEDURE read_cov_tree
*****************************************************************************

VERSION: 1.0 01-DEC-82

PURPOSE: This procedure does an in order traversal of the binary tree.

INPUT: root

OUTPUT: none

GLOBALS USED: none

REMARKS: recursive procedure

CALLED BY:
    cov_reduce_data

PROCEDURES AND FUNCTIONS CALLED:
    read_cov_tree
    octal

*****************************************************************************

procedure read_cov_tree(root : cov_ptr);
begin
if root <> nil then
begin
  {stopping state not reached - perform recursion}
  read_cov_tree(root^.left);
  write(tab);
  octal(root^.cov_node_adr);
  writeln(' => ',root^.path_count);
  read_cov_tree(root^.right);
end {if}
end; {read_cov_tree

- 117 -
Procedure cov_reduce_data -
*******************************************************************************

PROCEDURE cov_reduce_data
*******************************************************************************

VERSION: 1.0 21-NOV-82

PURPOSE:
This procedure reduces the coverage analysis data. First it builds a binary tree and counts the number of traversals. Second, it does an inorder traversal of the tree and prints out the number of traversals.

INPUT:
none

OUTPUT:
none

GLOBALS USED:
raw_data_file

REMARKS:

CALLED BY:
do_coverage

PROCEDURES AND FUNCTIONS CALLED:
build_cov_tree
read_cov_tree

*******************************************************************************

procedure cov_reduce_data;

var
  total_addr : integer;  \{number of addresses read\}
  root : cov_ptr;  \{root of tree\}

begin
  writeln;
  new(root);  \{create root node\}
  build_cov_tree(root,total_addr);
  if total_addr <> 0 then
    begin
      writeln(esc,'[2J');  \{clear screen\}
      writeln;
      writeln('ADDRESS  NUMBER OF TRAVERSALS');
      writeln('-----------------------------');
      read_cov_tree(root);
      writeln;
    end;
write('TOTAL NUMBER OF PATHS COVERED = ');
writeln(total_addr: 2)
end
else
  writeln('FILE EMPTY')
end; {cov_reduce_data
F.1.19 Procedure do_coverage -
******************************************************************************

PROCEDURE do_coverage
******************************************************************************

VERSION: 1.0 27-SEP-82

PURPOSE: This procedure does the coverage analysis.

INPUT: none

OUTPUT: none

GLOBALS USED: none

REMARKS:

CALLED BY:
data_analysis

PROCEDURES AND FUNCTIONS CALLED:
cov_help
cov_build_dx
cov_collect_data
cov_reduce_data

******************************************************************************

procedure do_coverage(help_level : help_mode);

begin
cov_help(help_level);

{build the coverage analysis dx file}
cov_build_dx;

{call the contractor supplied data extraction routine}
cov_collect_data;

{reduce the extracted data}
cov_reduce_data;

end; {do_coverage}
Procedure error_help -

PROCEDURE error_help

VERSION: 1.0 22-NOV-82

PURPOSE: This procedure types instructions on the users console if help_level is set to 'max'.

INPUT: help_level

OUTPUT: none

GLOBALS USED: none

REMARKS: none

CALLED BY: do_error

PROCEDURES AND FUNCTIONS CALLED: none

begin
 writeln(esc,'[2J'); {clear screen}
 writeln(tab,'*** ERROR ANALYSIS MODE ***');
 if help_level = max then
  begin
   writeln
   ('This mode determines the minimum and maximum');
   writeln
   ('values obtained by a program variable during');
   writeln('a particular test run.');
  end;
 writeln;
 writeln
 ('Enter variable addresses to be extracted in octal');
 writeln('end entry with 0."
end;{error_help

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procedure error_build_dx;

var
  error_address : memory;
  error_text : address_string;

begin
  open(dx_file,'DXFILE',new);
  rewrite(dx_file);
  writeln(dx_file,' 0');
  repeat
    write('ADDRESS [1..77777 octal] => ');
    get_address(error_address,error_text);
    if error_address <> 0 then
      begin
        writeln(dx_file,error_text,' ',error_text)
      end
  until error_address = 0;
  close(dx_file)
end; {error_build_dx}
F.1.22 Procedure error_collect_data -
******************************************************************************

PROCEDURE error_collect_data
******************************************************************************

VERSION: 1.0 27-SEP-82

PURPOSE: This procedure collects the error analysis data.

INPUT: none

OUTPUT: none

GLOBALS USED:
  dx_file
  raw_data_file

REMARKS: dummy module - this routine is contractor supplied

CALLED BY:
  do_error

PROCEDURES AND FUNCTIONS CALLED:
******************************************************************************

procedure error_collect_data;
begin
  writeln;
  writeln('******************************************************************************');
  writeln('*** procedure error_collect_data called ***');
  writeln('******************************************************************************');
  writeln
end; {error_collect_data}
F.1.23 Procedure err_tree_search -
**********************************************************************

PROCEDURE err_tree_search
**********************************************************************

VERSION: 1.0 04-NOV-82

PURPOSE: This procedure searches the binary tree for an address. If the address is found new min and max values will be calculated, otherwise the address will be inserted into the binary tree.

INPUT: father
       new_address
       adr_value

OUTPUT: none

GLOBALS USED: none

REMARKS: this is a recursive procedure

CALLED BY: build_err_tree

PROCEDURES AND FUNCTIONS CALLED:
   err_tree_search

**********************************************************************

procedure err_tree_search(var father : err_ptr;
                          new_address : memory;
                          adr_value : integer);

var
   new_node : err_ptr;

begin
   if new_address = father^.err_node_adr then
      begin
        {we found it, calculate new min and max }
        if adr_value > father^.max_value then
           father^.max_value := adr_value;
        if adr_value < father^.min_value then
           father^.min_value := adr_value
      end
   else
if new_address < father^.err_node_adr then
begin
if father^.left = nil then
begin
new(new_node);
father^.left := new_node;
with new_node^ do
begin
  err_node_adr := new_address;
  min_value := adr_value;
  max_value := adr_value;
  left := nil;
  right := nil
end {with}
end
else
begin
  father := father^.left;
  err_tree_search(father, new_address, adr_value)
end
end
else
if father^.right = nil then
begin
new(new_node);
father^.right := new_node;
with new_node^ do
begin
  err_node_adr := new_address;
  min_value := adr_value;
  max_value := adr_value;
  left := nil;
  right := nil
end {with}
end
else
begin
  father := father^.right;
  err_tree_search(father, new_address, adr_value)
end {else}
end; {err_tree_search}
P.1.24 Procedure build_err_tree -
*******************************************************************************

PROCEDURE build_err_tree
*******************************************************************************

VERSION: 1.0 04-NOV-82

PURPOSE:
This procedure builds the error analysis binary tree.

INPUT:
root
total_adr

OUTPUT:
none

GLOBALS USED:
raw_data_file

REMARKS:

CALLED BY:
err_reduce_data

PROCEDURES AND FUNCTIONS CALLED:
err_tree_search

*******************************************************************************

procedure build_err_tree(var root : err_ptr;
var total_adr : integer);

var
new_address : memory;  {address to be inserted in tree}
adr_value : dx_data;  {value written to a location}

new_node,  {pointers to nodes}
father : err_ptr;

begin {build_err_tree}
open(raw_data_file,'DXDATA',old);
{insert the first word in the root node}
reset(raw_data_file);
if not eof(raw_data_file) then
begin
read(raw_data_file,new_address,adr_value);
total_adr := 1;
with root do
begin
err_node_adr := new_address;

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min_value := adr_value;
max_value := adr_value;
left := nil;
right := nil
end; {with}
end
else
root := nil;
{attach each address to its father}
while not eof(raw_data_file) do
begin
read(raw_data_file,new_address,adr_value);
total_adr := total_adr + 1;
father := root; {first father is root}
{insert each path address into tree}
err_tree_search(father,new_address,adr_value);
end; {while}
close(raw_data_file)
end; {build_err tree}
**F.1.25 Procedure read_err_tree**

*********************************************************************

**PROCEDURE read_err_tree**

*********************************************************************

**VERSION:** 1.0 01-DEC-82

**PURPOSE:**
This procedure does an in order traversal of the binary tree.

**INPUT:**
root

**OUTPUT:**
one

**GLOBALS USED:**
one

**REMARKS:**
recursive procedure

**CALLED BY:**
err_reduce_data

**PROCEDURES AND FUNCTIONS CALLED:**
read_err_tree
octal

*********************************************************************

procedure read_err_tree(root : err_ptr);

begin
  if root <> nil then
    begin
      {stopping state not reached - perform recursion}
      read_err_tree(root^.left);
      write(tab);
      octal(root^.err_nodeadr);
      write(' => ');
      octal(root^.min_value);
      write(' ');
      octal(root^.max_value);
      writeln;
      read_err_tree(root^.right);
    end {if}
  end; {read_err_tree

- 128 -
F.1.26  Procedure error_reduce_data -

************ error_reduce_data

VERSION: 1.0 27-SEP-82

PURPOSE: This procedure reduces the error analysis data.

INPUT: none

OUTPUT: none

GLOBALS USED:
raw_data_file

REMARKS:

CALLED BY:
do_error

PROCEDURES AND FUNCTIONS CALLED:


procedure error_reduce_data;

var
  total_addr : integer; {number of addresses read}
  root      : err_ptr;  {root of tree}

begin
  writeln;
  new(root); {create root node}
  build_err_tree(root,total_addr);
  if total_addr <> 0 then
    begin
      writeln(esc,[2J]; {clear screen}
      writeln;
      writeln (tab,'ADDRESS MIN VALUE MAX VALUE');
      writeln (tab,'-------- --------- ---------');
      read_err_tree(root);
      writeln;
    end
end


write('TOTAL NUMBER OF ADDRESSES READ =');
write(total_addr :2)
end
else
  writeln('FILE EMPTY')
end; {error_reduce_data
PROCEDURE do_error

VERSION: 1.0 27-SEP-82

PURPOSE: This procedure does the error analysis.

INPUT: none

OUTPUT: none

GLOBALS USED:
  error_dx_file

REMARKS: dummy module

CALLED BY:
  data_analysis

PROCEDURES AND FUNCTIONS CALLED:
  error_help
  error_build_dx
  error_collect_data
  error_reduce_data

procedure do_error(var help_level : help_mode);
begin
  error_help(help_level);
  
  {build the error analysis dx file}
  error_build_dx;
  
  {call the contractor supplied data extraction routine}
  error_collect_data;
  
  {reduce the extracted data}
  error_reduce_data
end; {do_error}
F.1.28 Procedure do_trackfile -
*****************************************************************************

PROCEDURE do_trackfile
*****************************************************************************

VERSION: 1.0 12-SEP-82

PURPOSE:
This procedure displays the contents of the emitter track file.

INPUT: none

OUTPUT: none

GLOBALS USED: none

REMARKS:
Dummy module -
Code for this module from previous thesis

CALLED BY:
data_analysis

PROCEDURES AND FUNCTIONS CALLED:
*****************************************************************************

procedure do_trackfile;

begin
  writeln;
  writeln('*****************************************************************************');
  writeln('*** not implemented in thesis version ***');
  writeln('*****************************************************************************');
  writeln
end; {do_trackfile
F1.29 Procedure do_rwr -
*****************************************************************************

PROCEDURE do_rwr
*****************************************************************************

VERSION: 1.0 12-SEP-82

PURPOSE:
This procedure displays a simulation of the RWR CRT on the color graphics terminal.

INPUT: none

OUTPUT: none

GLOBALS USED: none

REMARKS:
Dummy module - Code for this module from previous thesis

CALLED BY:
data_analysis

PROCEDURES AND FUNCTIONS CALLED:
*****************************************************************************

procedure do_rwr;

begin
  writeln;
  writeln('*************************** i*************S)');
  writeln('*** not implemented in thesis version ***');
  writeln('*****************************************');
  writeln;
end; {do_rwr

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F.1.30 Main Executive -  
--------------------------------------------------------------------------------

THIS IS THE MAIN EXECUTIVE ROUTINE  
--------------------------------------------------------------------------------

begin {data_analysis}
  esc := chr(27);  {ASCII ESCAPE}
  bel := chr(7);   {BEEP}
  tab := chr(9);   {ASCII TAB}
  writeln(esc,'[2J'); {clear_screen}
  writeln  
          (tab,'*** ALR-46 DATA EXTRACTION AND ANALYSIS SYSTEM ***');
  writeln  
  writeln('Type <help> for menu');
  writeln  
  {initialize the transformation array}
  transform[performance] := 'PERFORMANCE ',
  transform[coverage] := 'COVERAGE ',
  transform[error] := 'ERROR ',
  transform[track] := 'TRACK ',
  transform[rwr] := 'RWR ',
  transform[quit] := 'QUIT ',
  repeat
      help_level := min;
      good_input := false;
      {loop until valid command}
      while not good_input do begin
          write ('ENTER COMMAND -> ');
          get_input(transform[test]);
          { select mode from menu or command }
          if transform[test] = 'HELP ' then begin
              help_user(mode,help_level);
              good_input := true
          end else begin
              mode := performance;
              {search the transformation array for a match}
              while transform[mode] <> transform[test] do begin
                  mode := succ(mode);
              {check for invalid input}
              if mode = test then begin
                  writeln(bel,'INVALID COMMAND... try again')
              end else begin
              good_input := true
          end (else)
  end {else}

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end; {while}

{command has been converted into an enumeration type}
case mode of
    performance : do_performance(help_level);
    coverage : do_coverage(help_level);
    error : do_error(help_level);
    track : do_trackfile;
    rwr : do_rwr;
    quit : stop_command := true
end; {case}
until stop_command
end. {analysis}
This appendix contains the test plans used in validating the proper operation of the Data Extraction and Analysis System. Test cases were derived from the software requirements using equivalence partitioning and boundary value analysis.

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2. Test Data ......................................... 140
### G.1 TEST PLANS

<table>
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<tr>
<th>TEST CASE</th>
<th>INPUT</th>
<th>EXPECTED OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Command PERFORMANCE</td>
<td>Enter performance analysis mode</td>
</tr>
<tr>
<td>02</td>
<td>Command COVERAGE</td>
<td>Enter coverage analysis mode</td>
</tr>
<tr>
<td>03</td>
<td>Command ERROR</td>
<td>Enter error analysis mode</td>
</tr>
<tr>
<td>04</td>
<td>Command TRACK</td>
<td>Enter trackfile analysis mode</td>
</tr>
<tr>
<td>05</td>
<td>Command RWR</td>
<td>Enter RWR analysis mode</td>
</tr>
<tr>
<td>06</td>
<td>Command HELP</td>
<td>Print menu</td>
</tr>
<tr>
<td>07</td>
<td>Command QUIT</td>
<td>Exit to operating system</td>
</tr>
<tr>
<td>08</td>
<td>Command INVALID</td>
<td>Print error message</td>
</tr>
<tr>
<td>09</td>
<td>Menu selection #1</td>
<td>Enter performance analysis mode</td>
</tr>
<tr>
<td>10</td>
<td>Menu selection #2</td>
<td>Enter coverage analysis mode</td>
</tr>
<tr>
<td>11</td>
<td>Menu selection #3</td>
<td>Enter error analysis mode</td>
</tr>
<tr>
<td>12</td>
<td>Menu selection #4</td>
<td>Enter trackfile analysis mode</td>
</tr>
<tr>
<td>TEST CASE</td>
<td>INPUT</td>
<td>EXPECTED OUTPUT</td>
</tr>
<tr>
<td>-----------</td>
<td>--------------------------------------------</td>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>13</td>
<td>Menu selection #5</td>
<td>Enter RWR analysis mode</td>
</tr>
<tr>
<td>14</td>
<td>Menu selection #6</td>
<td>Exit to operating system</td>
</tr>
<tr>
<td>15</td>
<td>Menu selection #7</td>
<td>Print error message</td>
</tr>
<tr>
<td>16</td>
<td>Performance mode: Entry address = 1..32767</td>
<td>'DXFILE.DAT' contains right justified 5 char entry and exit addresses</td>
</tr>
<tr>
<td></td>
<td>Exit address = 1..32767</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Performance mode:</td>
<td>Print error message</td>
</tr>
<tr>
<td></td>
<td>Entry address &gt; 32767</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Performance mode: Exit address &gt; 32767</td>
<td>Print error message</td>
</tr>
<tr>
<td>19</td>
<td>Performance mode:</td>
<td>Execute data collection Print module name and execution times</td>
</tr>
<tr>
<td></td>
<td>terminate input</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Performance mode: Empty data file</td>
<td>Print module name with no execution times</td>
</tr>
<tr>
<td>21</td>
<td>Coverage mode: Path address 1..32767</td>
<td>'DXFILE.DAT' contains right justified 5 char path address</td>
</tr>
<tr>
<td>22</td>
<td>Coverage mode: Path address &gt; 32767</td>
<td>Print error message</td>
</tr>
<tr>
<td>23</td>
<td>Coverage mode: Path address = 0</td>
<td>Execute data collection Print path address and # times executed</td>
</tr>
<tr>
<td>24</td>
<td>Coverage mode: Empty data file</td>
<td>No data printed</td>
</tr>
<tr>
<td>TEST CASE</td>
<td>INPUT</td>
<td>EXPECTED OUTPUT</td>
</tr>
<tr>
<td>-----------</td>
<td>--------------------------------------------</td>
<td>------------------------------------------------------</td>
</tr>
<tr>
<td>25</td>
<td>Error mode: Variable address = 1..32767</td>
<td>'DXFILE.DAT' contains right justified 5 digit text of addresses</td>
</tr>
<tr>
<td>26</td>
<td>Error mode: Variable address &gt; 32767</td>
<td>Print error message</td>
</tr>
<tr>
<td>27</td>
<td>Error mode: Variable address = 0</td>
<td>Execute data collection Print variable addresses with min and max values</td>
</tr>
<tr>
<td>28</td>
<td>Error mode: Empty data file</td>
<td>No data printed</td>
</tr>
</tbody>
</table>
G.2 TEST DATA AND RESULTS

G.2.1 Performance Analysis - This section contains the test data used to validate the "performance analysis" mode of the Data Extraction and Analysis System.

G.2.1.1 Input Data -

<table>
<thead>
<tr>
<th>Subroutine Name</th>
<th>Entry Address</th>
<th>Exit Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEST1</td>
<td>1</td>
<td>77777</td>
</tr>
<tr>
<td>TEST2</td>
<td>400</td>
<td>1000</td>
</tr>
<tr>
<td>TEST3</td>
<td>2000</td>
<td>4000</td>
</tr>
</tbody>
</table>

G.2.1.2 Data Reduction Simulation Data - The following data is data used to simulate the operation of the data extraction subsystem. This data is in the internal decimal representation used by the DEAS. The format of the data is described in Appendix B.

```
-1
1
0
0
-1
32767
0
```
G.2.1.3 **Dx file Produced** - The following is the data extraction specification file to be used by the data extraction subsystem. The file is a text file and is verified by visual comparison with the input data.

1
77777
400
1000
2000
4000
0

G.2.1.4 **Console Output** - The following is the display generated by the DEAS when supplied with the previously described data.

**EXECUTION TIMES FOR SUBROUTINE TEST1**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>50</td>
<td>10</td>
</tr>
</tbody>
</table>

**EXECUTION TIMES FOR SUBROUTINE TEST2**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>30</td>
<td>10</td>
</tr>
</tbody>
</table>

**EXECUTION TIMES FOR SUBROUTINE TEST3**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>
G.2.2 **Coverage Analysis** - This section contains the test data used to validate the "coverage analysis" mode of the Data Extraction and Analysis System.

G.2.2.1 **Input Data** -

PATH MARKER #1 1
PATH MARKER #2 400
PATH MARKER #3 1000
PATH MARKER #4 2000
PATH MARKER #5 4000
PATH MARKER #6 77777

G.2.2.2 **Data Reduction Simulation Data** - The same simulation file used for the "performance analysis" mode was used for this mode.

G.2.2.3 **Dxfile Produced** - The following is the data extraction specification file to be used by the data extraction subsystem. The file is a text file and is verified by visual comparison with the input data.

```
1
400
1000
2000
4000
77777
0
```
G.2.2.4 Console Output - The following is the display generated by the DEAS when supplied with the previously described data.

<table>
<thead>
<tr>
<th>ADDRESS</th>
<th>NUMBER OF TRAVERSALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 =&gt;</td>
<td>3</td>
</tr>
<tr>
<td>400 =&gt;</td>
<td>3</td>
</tr>
<tr>
<td>1000 =&gt;</td>
<td>3</td>
</tr>
<tr>
<td>2000 =&gt;</td>
<td>3</td>
</tr>
<tr>
<td>4000 =&gt;</td>
<td>3</td>
</tr>
<tr>
<td>77777 =&gt;</td>
<td>3</td>
</tr>
</tbody>
</table>

TOTAL NUMBER OF PATHS COVERED = 18

G.2.3 Error Analysis - This section contains the test data used to validate the "error analysis" mode of the Data Extraction and Analysis System.

G.2.3.1 Input Data -

VARIABLE ADDRESS #1 66
VARIABLE ADDRESS #2 504
VARIABLE ADDRESS #3 1733
VARIABLE ADDRESS #4 3720
VARIABLE ADDRESS #5 1
VARIABLE ADDRESS #6 77777
VARIABLE ADDRESS #7 13055

- 144 -
G.2.3.2 Data Reduction Simulation Data - The following data is data used to simulate the operation of the data extraction subsystem. This data is in the internal decimal representation used by the DEAS. The format of the data is described in Appendix B.

```
1
0
1
456
1
32767
32767
32767
5677
3455
987
6546
54
786
324
4000
2000
400
987
20
5677
0
54
32767
```

G.2.3.3 Dxfile Produced - The following is the data extraction specification file to be used by the data extraction subsystem. The file is a text file and is verified by visual comparison with the input data.

```
0
66, 66
504, 504
1733, 1733
3720, 3720
1, 1
77777, 77777
```
G.2.3.4 Console Output - The following is the display generated by the DEAS when supplied with the previously described data.

<table>
<thead>
<tr>
<th>ADDRESS</th>
<th>MIN VALUE</th>
<th>MAX VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>77777</td>
</tr>
<tr>
<td>66</td>
<td>1422</td>
<td>77777</td>
</tr>
<tr>
<td>504</td>
<td>7640</td>
<td>7640</td>
</tr>
<tr>
<td>1733</td>
<td>24</td>
<td>14622</td>
</tr>
<tr>
<td>3720</td>
<td>620</td>
<td>620</td>
</tr>
<tr>
<td>13055</td>
<td>0</td>
<td>6577</td>
</tr>
<tr>
<td>77777</td>
<td>77777</td>
<td>77777</td>
</tr>
</tbody>
</table>

TOTAL NUMBER OF ADDRESSES READ = 12
VITA

Mr. Joel R. Robertson was born on January 24, 1952, in Huntsville, Alabama. In 1969, he graduated from John Marshall High School in Glendale, West Virginia. He attended West Liberty State College from which he received an Associate of Science degree in Electronics Technology in 1971. He then attended West Virginia University from which he received a Bachelor of Science degree in Electrical Engineering in 1975. Following graduation, he accepted a position with the Federal Aviation Administration in Atlanta, Georgia. He was employed with the FAA as an electrical engineer installing radar systems until 1979 when he accepted employment with the Electronic Warfare Division of the United States Air Force at Robins AFB, Warner Robins, Georgia, as a civilian electronic engineer working in the Radar Warning Receiver Section. He entered the Air Force Institute of Technology at Wright Patterson AFB, Ohio in June 1981.

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