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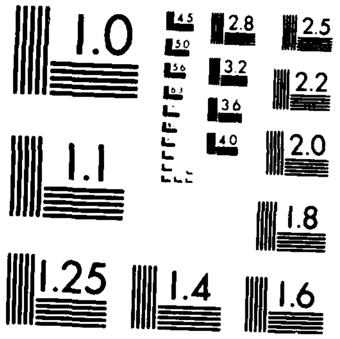

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MODIFICATION, IMPLEMENTATION, AND EVALUATION OF A REMOTE TERMINAL EMULATOR AS A SOFTWARE VALIDATION AND STRESS TESTING TOOL

THESIS

Craig J. Riesberg, B.S.
Captain, USAF

AFIT/GCS/MA/87D-5

AFIT/GCS/MA/87D-5

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THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

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Requirements for the Degree of

Master of Science in Computer Systems

Craig J. Riesberg, B.S.

Captain, USAF

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Preface

The purpose of this study was to provide the sponsor with a new tool to be used in improving the reliability of their software. In the past, the sponsor was limited to using an internal test driver to exercise their software. This effort allowed the system test director to expand beyond the world of single-threaded validation testing, opening a new window for them in the area of software validation.

In preparing my thesis, I have received considerable help from others. I am very grateful to my thesis advisor Dr. Panna B. Nagarsenker, for her support and guidance during the entire effort. I would also like to thank my committee members, Dr. Brahmanand N. Nagarsenker and Major Duard S. Woffinden for their assistance. A word of thanks also goes to the sponsor's personnel, who aided me in the development and evaluation of the test scenario. Finally, I would like to thank my family, my wife Gail, for her loving support during graduate school, and my daughter Dawn, who understood why her dad could not attend all of her athletic events.

Craig J. Riesberg

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Abstract

This project involved the modification, implementation and evaluation of a remote terminal emulator (RTE) as a software validation and stress testing tool. The work, sponsored by the Directorate of Integration and Standardization, Military Airlift Command, utilized a Honeywell DPS-6 Model 95 minicomputer as the host for the RTE application package.

Considerable background information is provided about the sponsor's release environment to show the sponsor's need for a reliable testing tool. Information is also presented about acceptance and validation testing.

The emphasis of this research centered on a RTE made available by the Joint Data System Support Center. This software package, capable of emulating multiple users, needed major modifications before implementation on the sponsor's equipment. After successful implementation, the study examined two areas of use for the sponsor.

The modified package was found to be a very good tool for software validation. Comparisons are made between the RTE and the sponsor's internal test driver in the areas of scenario collection and management. The two tools are also compared during the emulation phase of software validation.

The RTE package was also examined as a stress testing tool. Several problems in the RTE application software which inhibit its use as a stress testing tool are discussed.

MODIFICATION, IMPLEMENTATION AND EVALUATION OF A REMOTE TERMINAL EMULATOR AS A SOFTWARE VALIDATION AND STRESS TESTING TOOL

I. Introduction

Background

The implementation of this remote terminal emulator is the continuation of an effort in software and hardware configuration management which began at the Military Airlift Command in 1982. At that time, the Configuration Management Board in charge of hardware and software for the 1500 Computer Services Squadron, tasked the Directorate of Integration and Standardization with preparing a way to adequately control the organization's computer resources. The directorate designed the MAC Automated Release Facility (MARF) to serve as an overall automated tool to manage the hardware and software of a distributed processing network. MARF was built to control equipment and code for the Consolidated Aerial Ports Subsystem (CAPS) which in 1982 was being prototyped at Travis AFB, Dover AFB, McGuire AFB, and Rhein Mein AB, Germany. With the system development units located at Scott AFB, Ill, the entire distributed network appeared as shown in Figure 1. The system currently runs at eighteen operational sites worldwide as shown in Figure 2.

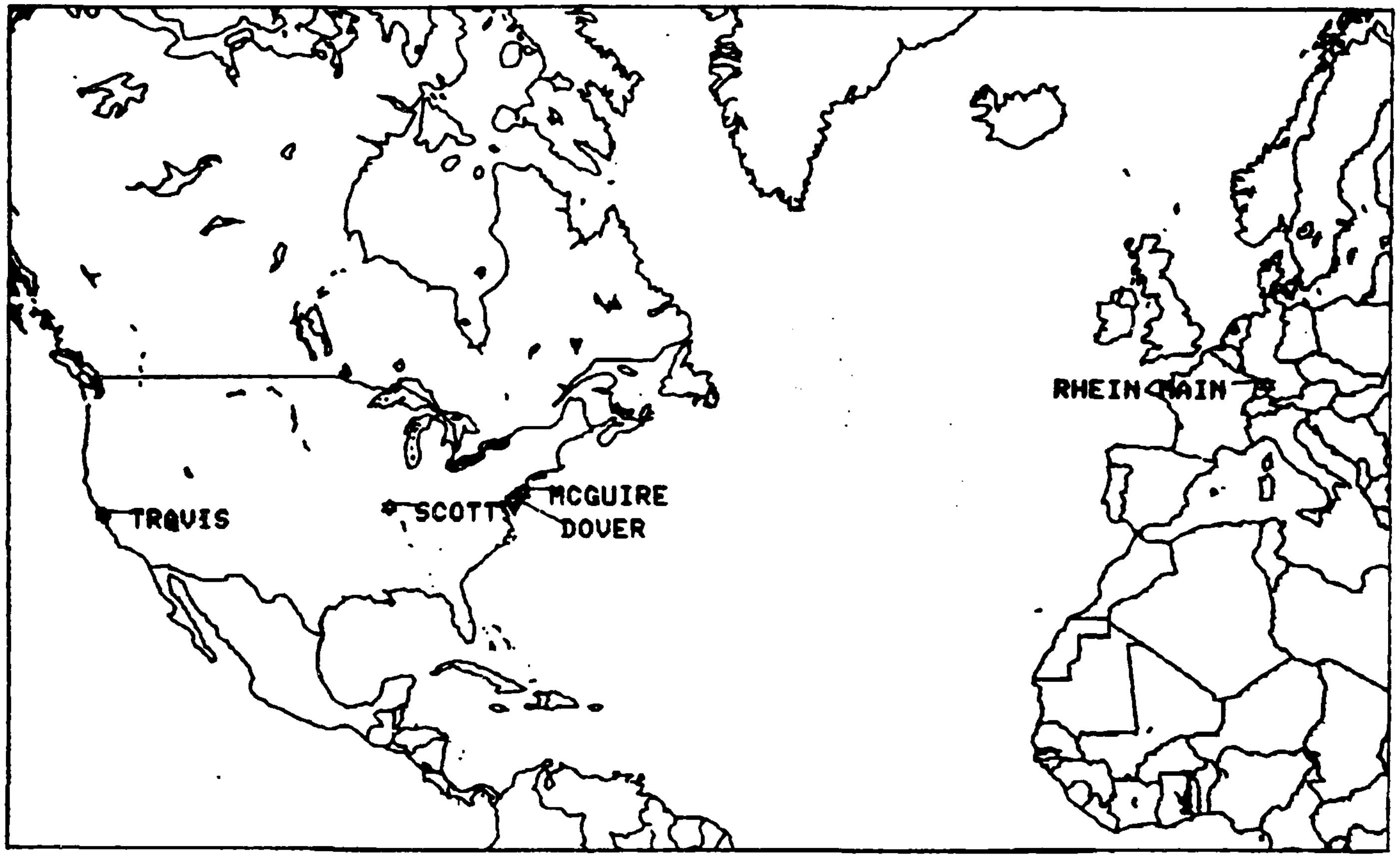


Figure 1. CAPS Operational Sites During Prototyping

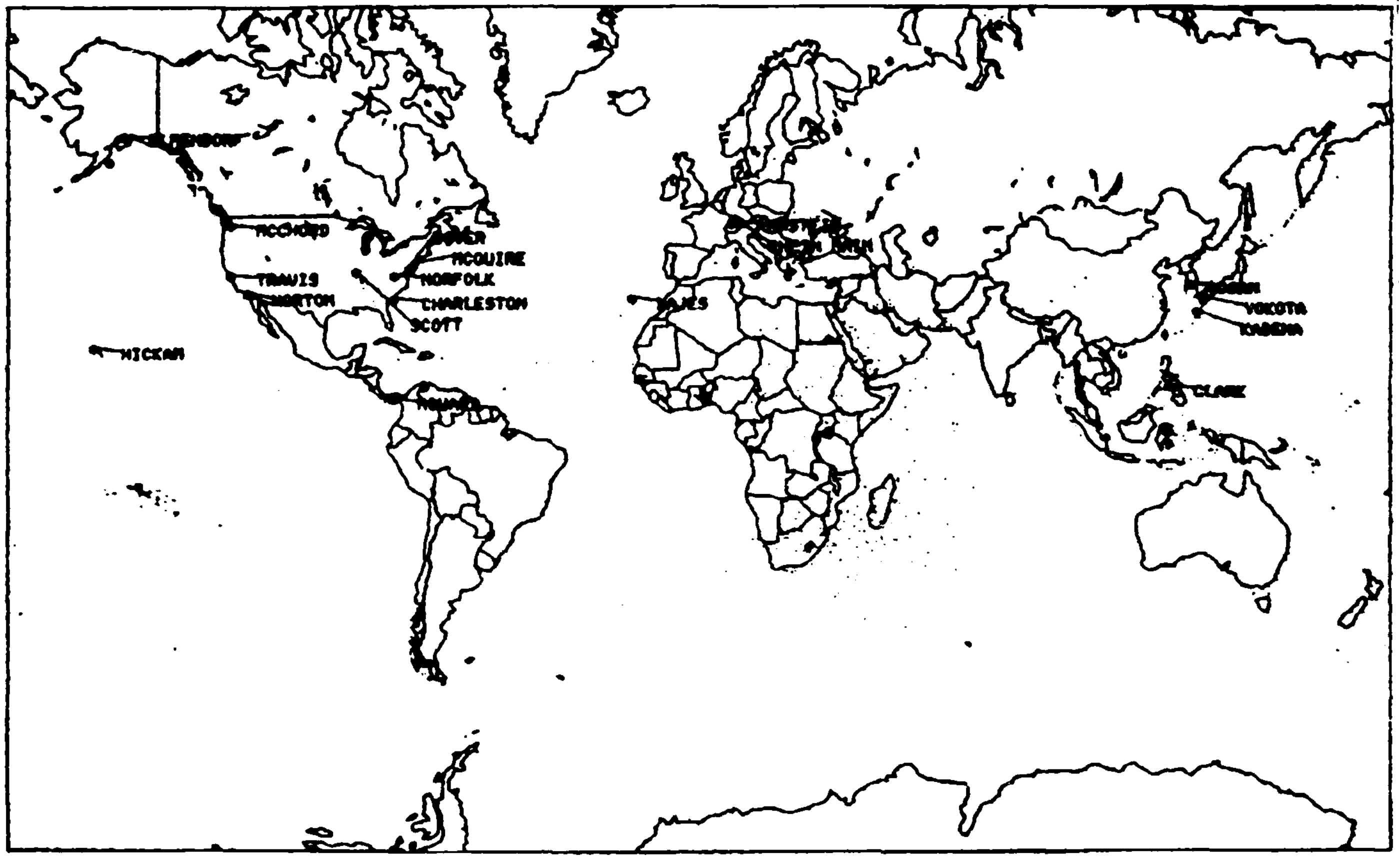


Figure 2. Current CAPS Operational Sites

At least three other factors significantly contributed to the software configuration management problem of this network: 1. the number of releases, 2. the size of the modules and 3. the location of the processing nodes.

The first factor is the sheer number of releases which are being sent to the individual sites. In an effort to keep the software identical at all operational sites, each release must be distributed throughout the network, regardless of which site requested the change. The system went straight from a prototype environment to full implementation. This meant that the system was still in a state of change when it went operational in 1984. A 'try it and see' mentality had been encouraged among the software developers during the prototype phase. As the system went operational and the number of sites increased, the software developers were being asked to revert to more traditional test and distribution techniques.

Data taken from the release control log books of the sponsor shows 68 software releases in 1984, 50 in 1985, 45 in 1986 and 34 in the first half of 1987. The actual release information, divided by system, can be found in Appendix A. The decrease in the number of releases has occurred both because of the maturity of the system as well as the realization by the configuration manager that the system's software could not be adequately tested as fast as it was being released.

The second contributing factor is the size of the software modules being sent to the sites. Without even considering the Honeywell operating system, which is updated quarterly, the user has written 196 different executable modules. The modules are built from 2,765 different source code files. Fifteen of these modules are very large. The module size can best be described by example. The modules are composed of a root which can be up to 32K words, and an addressable overlay area of 32K words. Many of the functional code modules would not fit into a single overlay area and had to be divided into two or more overlays. The largest of the modules has over 200 of these overlays. The module must be delivered in a complete package with all overlays included.

The third and final factor is the limited means of distribution available to the configuration manager. Physical distribution of a release tape to the European, Pacific and Asian theater of operations was found to take up to three weeks. In addition to the unacceptable delay, tapes never arrived at all sites. As long as a single site did not receive the tape, all sites had to wait until the releases was redistributed to the single site. For physical distribution, no commercial overnight or second day delivery system could be found to most overseas sites. Military aircrew members traveling to the sites are not used to distribute tapes unless the tapes contain classified information. The release tapes do not contain classified information, so that type of distribution is not available to the sponsor.

An electronic transfer system is available in the distributed net, but it has two severe limitations, neither of which can be reasonably eliminated. The first limitation is that all distributions go through a central host. A message sent to this host can only be directed to six different nodes. To send to 18 sites requires the message to be sent to the host three times. The host also has a limitation of six files per message. Therefore, to send 24 of the 196 modules to all 18 sites would require 12 (4 times 3) transmissions to the host.

The second severe limitation of the electronic transfer is the speed of the transfer. The message is broken into packages called unit-blocks and the system is capable of transferring one unit-block per second. When coupled with the size of the bound units discussed as the second factor, the limitation is created. The largest bound unit is broken into 1600 unit-blocks. To transfer it requires over 26 minutes (1600 / 60). Messages to the nodes are not interleaved, so a single release transmission can tie up the communication channel of an operational site for hours.

All of these distribution problems quickly pointed to the need for a good configuration management system. The emphasis was soon to be placed on insuring the quality of the released software. It was hard enough to release the software once; if it had to be corrected after release, the problem was doubled.

Hardware for both the operational sites and the automated release facility are the same. Current operational sites have from one to three systems consisting of Honeywell DPS-6 model 95's with at least two tape drives, three disk drives with removable packs, two megabytes of memory, and a commercial instruction code processor. All system security measures have been removed from the operating system including passwords for files and logon requirements.

The sole purpose of the operational systems is to provide either passenger reservations service (PACS), cargo management service (CARGO) or enhanced airlift report service (EARLO), or any combination of these services. The need for more than one set of hardware is dictated by the capacity of the machine that is currently providing the service. The operational sites have no compilers, linkers, or any other means to modify or create software. These sites have no computer programmers or analysts assigned to manage or control software. All software comes from the central release facility at Scott AFB, through the automated release facility.

Captain Enrique G. DeJesus introduced the MARF system as a configuration management tool at the Computer Related Information Systems Symposium, sponsored by The Department of

Computer Sciences, US Air Force Academy in February, 1983.(3:3.1-3.22) A refined model of the system was again presented at the Computer Performance Evaluation User's Group 19th meeting in San Francisco, California in 1983.(4:187-196) Final first cut modifications to the system were completed in 1983 and the final product was presented at the 14th international conference of the Computer Measurement Group, 8 December, 1983, in Crystal City, Virginia.(5:222-230)

The system addresses four elements of configuration management: change control, validation testing, inventory management, and software distribution. The remote terminal emulator will be an important addition to the validation testing module. Figure 3 shows the position of the remote terminal emulator in reference to other elements of the validation testing module.(3:3.13)

Problem Statement

The validation testing leg of the MARF system uses an internal test driver to pass precollected screen faces to application bound units whenever a system is tested. This internal test driver is only able to pass one transaction at a time to the system under test (SUT). After passing an input screen, it must wait for the output from the SUT to verify that the output is correct, before proceeding to the next transaction. Therefore, the internal test driver will not allow tests of two individual bound units (application programs) running simultaneously. While path testing in an

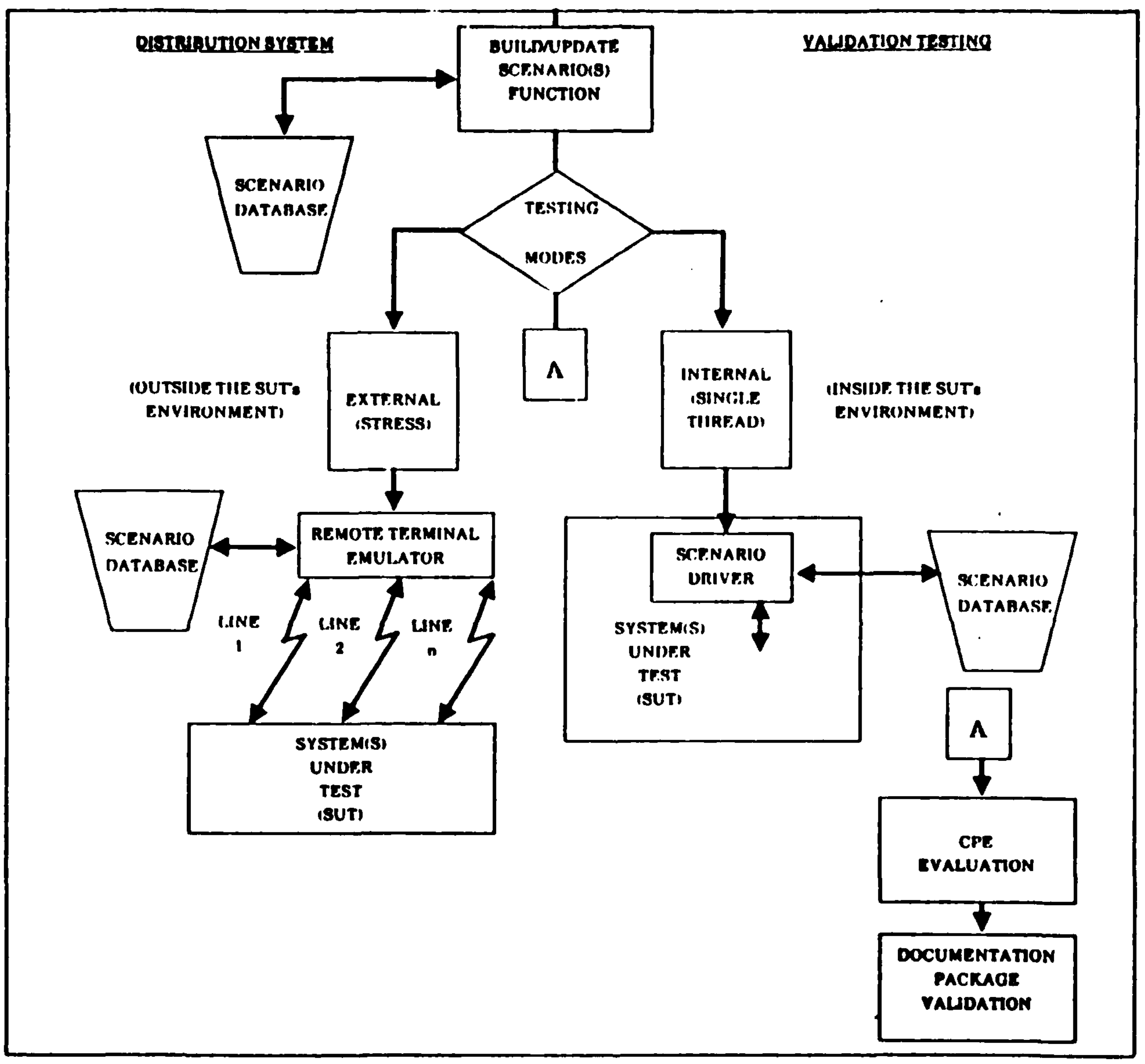


Figure 3. Validation Testing

isolated mode is better than no testing at all, the internal test driver still leaves a large margin for error. The remote terminal emulator allows the system test director to feed inputs to more than one application unit at the same time.

The main problem in integrating the RTE into the MARF system concerns the length of the inputs and outputs. The only RTE which operates on the system hardware is limited to inputs and outputs of 72 characters each. The system needs a RTE which will operate with full screen faces or 1968 characters (24 lines x (80 characters + 2 control characters)). The screen size is the same for both input and output. In addition to the need to modify for input and output sizes, the RTE and the driving system are currently built for different versions of the operating system.

The problem for this study is to implement the RTE and evaluate its use as a validation tool for these systems. If the RTE is an acceptable tool, how does it compare to the internal test driver for use during the different phases of software development, and are there other uses for the RTE?

Scope

This effort consisted of implementing the RTE in the full screen face mode and evaluating its usefulness after implementation. This required updating the RTE package into a system which would operate under the currently running operating system. The connections between the two systems

(RTE implemented system and the system under test) were operated with at least four terminals being simulated. This required either four different lines or some type of alternate polling on a physical line.

The initial implementation was not expected to do data collection in full screen mode, relying instead on the information from the internal test driver as the starting test data base. In addition, the collection scenario which was used in testing the RTE was limited to entries which do not change the corporate data base on the system under test. This was to insure that the collection scenario could be run repeatedly without restoring the data base of the SUT. If the stimulus transactions change the data base, then the data base would have needed to be restored prior to a repetition of the stimulus.

This effort was intended to show and evaluate the use of the RTE as a validation and testing tool, not to do actual software validation for the sponsor. Every effort was made to leave the sponsor with a tool that they could use to test and evaluate their systems. To achieve this goal, some elementary training of the sponsor's personnel was required after implementation.

Assumptions

It was assumed that the people using the RTE package were more than familiar with the concepts of software validation. More emphasis was placed on the correct operation of the RTE package than on the ease of interaction with the system user. User's manual documentation changes were implemented by pen and ink changes to the current contractor supplied manual. It was also assumed that the RTE users would be familiar with the application software being used on the SUT.

Approach

The implementation and evaluation of the RTE package took place in four phases. The first phase was the physical connecting of the two machines, coupled with the implementation of the 72 character RTE with the latest operating system. The second and third phase was the evaluation of the package for its intended use of validation and stress testing. The final phase was training the sponsor's personnel.

The first phase was evaluating what lines on the two hardware systems needed to be connected to enable the two DPS-6's to communicate with each other. Extensive changes were needed in the Configuration Line Manager (CLM) User's file. This is the file that determines the input and output channel speeds and the establishment of which unit will be the host and which will act as the slave. Considerable work was necessary to cross the lines between the machines so that the output from A becomes the input to B. Data scopes were necessary to monitor the lines.

After the lines were connected, the phase continued with implementing the RTE package using the 72 character software and the latest versions of the operating system. This phase of the implementation was the largest unknown. The conversion over several versions of the operating system could have been as easy as recompiling all of the source code and relinking using the latest operating system version. This was not the case. The sponsor's experience with COBOL over the same span of operating systems showed that extensive work was going to be required. To convert the three systems running at the operational sites (PACS, CARGO and EARLO) to the current version, from the version that the RTE is in, took a team of analysts from each system close to six months of work. The RTE is written mostly in FORTRAN and the sponsor had no FORTRAN experience. In addition, the latest version of the operating system uses a different structure of memory pools which generated problems for the RTE package.

The second phase was the evaluation of the package as a full screen software validation tool. During this phase the primary focus was on the software's capability to capture and retransmit inputs and outputs of up to 1,968 characters. It was also during this phase that the software was evaluated to determine if the response from the SUT was identical to a previously accepted response.

The third phase determined if the RTE package was an acceptable stress testing tool. For this work, stress testing is defined as the ability to determine the correct execution of software when it is placed under heavy load. To fulfill this requirement, the tool needed to collect inputs and outputs from more than terminal simultaneously and be able to retransmit stimuli at least fast enough and to enough terminals to load the SUT.

The final phase of this effort, was to insure that the sponsor was left with trained personnel, qualified to continue the research without 'reinventing the wheel'. To achieve this goal, all of the preliminary work needed to implement and test the system was not only briefed, but thoroughly explained to the sponsor's workers.

Materials and Equipment

The work required two Honeywell DPS-6 Model 95 computers, side by side, with a minimum of 4 input-output ports that could be connected. The equipment is currently in place at Scott AFB and was made available by the sponsor for this work. TDY funds for the work were also supplied by the sponsor. A one week TDY, early in the work, to the RTE developers in Reston, Virginia was used to evaluate the original RTE package to determine what modifications would be needed. Data scopes were available for the equipment and the lines to cross input to output were manufactured during the TDY at Reston. These lines were taken to Scott AFB, Ill and were left with the sponsor for future use.

Other Support

Limited programming support was supplied by the sponsor, especially for the output verification phase. The sponsor also requested support and cooperation from the contractor currently responsible for maintenance of the RTE. Because of the lack of a Fortran compiler on the sponsor's machine, all of the RTE modifications had to be coordinated and made by the contractor's personnel on their equipment.

II. Literature Review

Need for Testing

There are four major elements of configuration management: change control, validation testing, inventory management, and software distribution. This discussion is limited to the areas which cover software validation testing. Software validation concerns itself with the final usefulness of the software product.

Software validation is the most critical leg in the configuration management scheme. With the current impetus toward distributed processing, changing bundled software at remote processing sites becomes an ever increasing problem. Not only is it necessary to transfer new software to the geographically separated locations, it is important that the software performs as expected. Software validation is the final chance for the releasing authority to insure that the product fulfills its intended use.

Definitions of what testing actually is, are almost as varied as the number of books or articles read. One overall explanation of current software testing was presented by Plessey MicroSystems in a product introduction booklet. They stated:

> The testing of software in a large system is a inexact science at best. Current testing methods are laborious, imprecise, and expensive. These methods usually include single-threaded functional testing and perhaps a more formal verification and validation effort.(15:1.1)

Not knowing or understanding exactly what testing is would not be an insurmountable hindrance if we could be sure of the final result of that testing. They continued in their explanation:

> Overall system testing is usually done in a benign environment with a relatively light load. The connection between a system's test results and its performance in its real environment is tenuous. As it is usually accomplished, the performance testing of software is analogous to testing an aircraft by reviewing its blueprints. Would the reader want to fly in such a machine? (15:1.1)

While everyone agrees that testing is a necessary evil, there are different views as to how important it is and consequently how much effort and system resources should be expended towards adequate testing. In his book on software engineering and design, Zelkowitz says:

> Verification and validation (module and integration testing) of a system occupies about half of the development time of a project. Many debugging aids were developed to lessen this effort; most are implemented as programs to test some feature of a system.(17:27)

What is truly needed for an organization is a tool which is useful not only during the development of a particular software system, but one that is useful over the entire life of the system hardware and beyond.

Just as the system controller can decide how many resources will be devoted to thorough testing, he also must decide within those resource limits, what type of effort he is willing to accept. Often what is considered to be a correct execution depends on the stage of the software in the life cycle. Zelkowitz referenced Conway in his book, and the subject was called correctness instead of testing.

> ...the term "correct" can have many interpretations. Conway lists eight different meanings for a correct program:
>
> 1. A program contains no syntactic errors.
>
> 2. A program contains no compilation errors or failures during program execution.
>
> 3. There exists test data for which the program gives correct answers.
>
> 4. For typical sets of test data, the program gives correct answers.
>
> 5. For difficult sets of test data, the program gives correct answers.
>
> 6. For all possible sets of data which are valid with respect to the problem specification, the program gives correct answers.
>
> 7. For all possible sets of valid test data and all likely conditions of erroneous input, the program gives correct answers.
>
> 8. For all possible input, the program gives correct answers.(17:27-28)

The level of testing, then depends not only on the resources that are available to test the software, but on the need for correct execution.

Validation of software can be divided into two areas. The validation that occurs on a new system, after design and coding, but prior to or in conjunction with its first implementation, is usually referred to as acceptance testing. While this area is obviously important, this review also covers the continued validation of operational systems. This validation occurs after a change to the baseline software.

This chapter presents different views of software validation represented in current literature. Examined first are those views applying to acceptance testing and then those that deal with continued software validation of operational software.

Acceptance Testing

> The crucial stage in any procurement is the moment when the vendor offers the product to the buyer for inspection to determine whether or not the contract has been satisfied. This process is known as acceptance testing.(1:295)

This definition can apply to the acceptance of software both from a software developer under contract to your organization, as well as software which is developed in house. Regardless of the source of the software, there must be some method to determine if the software is performing correctly.

This problem of determining whether software is acceptable is complicated in the Department of Defense environment by the multitude of vendors who have contributed to a complete system. When hardware is being developed in conjunction with the software, the final software criteria may not be determined until the limitations of the hardware are manifested. Pressman states:

> The deliverable that is developed as part of the requirements analysis is the Software Requirements Specification. The specification extends scope by establishing a complete information description, a detailed functional description, appropriate validation criteria and other data pertinent to requirements.(16:116)

All classical design models have requirements analysis and specification as one of the earliest steps in the design process. The two do not seem compatible.

It is a well known assumption, called the 80/20 rule, that in recent years the total cost of systems has moved to 20% for the hardware and 80% for the software(9:22). Brannigan stated:

> As computer hardware has become much less expensive, it has become obvious that acceptance testing of the software is the critical stage.(1:295)

In an article concerning the legal problems involved with acceptance testing he says:

> In legal theory, there is no problem with acceptance testing. The contract specifies what tests are to be performed, the tests are run, and the software either passes or fails.(1:295)

But he goes on to state: "In practice that is not the case"(1:295). Often the buyer contracts for software and the vendor modifies an existing package and installs it. It has fulfilled the contractual requirements, but is nowhere close to what the buyer wanted.

Acceptance testing is complicated even further when the user is inexperienced in the use of the package he wishes to buy. In effect he is bargaining at a severe disadvantage. The vendor knows exactly what his product will do and what its capabilities are. He probably knows from reading the contract if he can meet the contract specifications before the testing ever begins. The buyer on the other hand, has just decided that he cannot economically develop the software system in house and is looking for help. This is the same buyer who now has to write a contract and define the acceptance test criteria. One method is to:

> . . . form a series of inputs to the software and test the program's major requirements. All program statements should be tested at least once.(2:437)

Validation Testing

After the acceptance testing has taken place and the software is installed and in use, it is natural to expect that changes will need to be made by the software developer. "The problem is compounded because programmers constantly have to update software to keep it from becoming obsolete"(14:66). In most cases these changes will actually be requested by the user. The system that was originally defined is not likely to fulfill the user's needs forever. With every subsequent release of software, some type of acceptance testing needs to be initiated. This is referred to as validation testing.

> The reliability of software can play an important role in determining when a system should be released, whether it should be accepted by the user, and the degree of user satisfaction once the system is operational.(13:338)

This is true not only in the case of acceptance testing but also for validation testing. There are several different situations requiring the need for a new release and consequently a new validation. If the software is not providing any new capabilities, the original acceptance test may be repeated as a good method to revalidate the package. If new paths are opened in the execution of the code, then these paths must be tested to revalidate the package.

"In software testing the main statistical emphasis is on estimating the number of errors remaining in the system"(13:338). But the main problem is not in determining the number, but in finding the errors before the system goes back into operation.

One of the best methods for validation testing is to use a third party to conduct the validation, just as a third party is the best method for original acceptance testing. But this can quickly become costly. To protect the user, software must be revalidated for the smallest change that affects the baseline of the system. Even the load of a different operating system or the use of a different compiler by the software developer, calls for a validation by the releasing authority. If a third party cannot be hired for each of these validations, what are the choices?

Two good strategies for validating the software involve the use of either a remote terminal emulator (RTE) or an internal test driver. The internal test driver is generally the tool of choice for in house software validation because the internal driver can run on a single machine and seldom requires additional resources. Software validation, especially path verification, can be done in a single threaded mode which is ideal for an internal driver. In an editorial, Ralph Evans contends:

> Sequential tests are hailed as great savers of resources in reliability testing. . . . Rarely is a system rejected because its test path touches the reject line. What happens is that . . . the faults found in the test are fixed and the system is issued.(8:337)

Sequential testing and path traversals always have one large deficiency; they only execute the paths or code, one at a time. What is needed is the same type of a load as the operations system encounters. This is where the remote terminal emulator surfaces as a software validation tool. The RTE can collect an actual work situation and then when connected to another machine, resubmit these identical transactions to the system under test. The resubmission feed can occur at the original collection rate, slower or faster. In the case of a faster feed, the rate can be increased until the system under test either backlogs or has an overload fault in the software under test.

Summary

The purpose of this literature review was to present information in other sources pertaining to the testing of software systems, especially acceptance and validation testing. In order to fully understand why a remote terminal emulator can be such a useful tool to a software configuration manager, it is necessary to realize the broad scope of software testing. This chapter gives the reason for the implementation and evaluation chapters which follow.

III. Modification and Implementation

History

The remote terminal emulator package chosen for this implementation was originally designed by the Computer Sciences Corporation (CSC) under contract to the Computer Services Directorate of the Joint Data Systems Support Center (JDSSC). Support for the maintenance of the software was originally also supplied by CSC for the Computer Performance Evaluation Branch of JDSSC.

The original request for full screenface emulation was presented to JDSSC for their consideration. A preliminary attempt to transmit and receive full screenfaces occurred at Scott AFB, Ill. in December 1984. The installation of the RTE package under the direction of CSC used asynchronous communications channels. The evaluation of the implementation showed that characters of the transmissions were being lost with no indication that an error had occurred.

The contract for the maintenance and technical support of the RTE was subsequently awarded to Advanced Technology Systems of Vienna, Virginia, still under the direction of the Computer Performance Evaluation Branch of JDSSC. It was with their support and efforts that the modification necessary for this implementation took place.

Three distinct areas had to be addressed to make this implementation successful: 1. the RTE software had to be brought up to the current operation system used by the sponsor's machines, 2. the RTE application software had to be modified for full screenface stimulus and response as well as full screenface response verification, and 3. the physical connections had to be accomplished with cables instead of through a patch panel. The order of discussion of these three entities in this chapter is not intended to order their importance. If any of the areas had failed, the result would have been a failed implementation.

Modifications Due to Systems Software

Considerable effort and examination was originally directed to the difference in the operating systems installed on the hardware systems. The DPS-6 Model-95's at Scott AFB, run on a commercially procured operating system. The currently supplied version of this operating system is labeled as version 3.1. In addition to being the most current operating system available, the operating systems on these machines are updated quarterly with an update package supplied by the vendor. These update packages include the latest modifications and corrections that are available. The contractor supporting the RTE software is supplied computer time on two different systems at the Deery Engineering Building in Reston, Virginia. One of the machines is a Level-6 Model-43, which was running under a Worldwide

Military Command and Control System (WWMCCS) released operating system. This is a version of Honeywell's operating system 2.1. The other machine is a DPS-6 Model-95, which also was running operating system version 2.1.

The sponsor's experience in converting their COBOL applications from version 2.1 to version 3.0 led them to believe that the conversion of the RTE software would be a long and arduous task. It was not. The only problem encountered was on an early visit to the Reston, Virginia site, when the Polled VIP Emulator software was not yet in place on the DPS-6 machine. No problems attributed to the operating system were encountered when transporting the software to Scott AFB. The implementation would have been easier if the SUT application software could have been loaded at the development site, but because the application software runs the commercial 3.1 operating system, it could not be loaded on the development machine to test prior to implementation.

Because the implementation of the RTE was on systems used daily by the sponsor, it was necessary to convince their users that there would be no impact or disruption of their normal service. The solution was to totally isolate the RTE test from the users. Block time was scheduled on the machines for the RTE test team's exclusive use. To complete the isolation, both the operating system and the SUT application software was transferred to a removable pack. A smaller version of the data bases needed by the application software was duplicated on a second removable pack. This allowed the RTE application software to be loaded at implementation time without fear of disrupting normal operations. At the beginning of test block time, the machine was booted off of the removable packs and rebooted off of the normal system packs at the end of the test time. During the test time, the user's packs were write protected.

A release of the SUT application software and data bases occurred during the months of testing. The disk packs we created were not upgraded to the new software. As noted in Chapter 1, the intent was to evaluate the RTE as a tool, not do actual testing for the sponsor.

The actual implementation at Scott AFB required the changing of the file used to cold boot the system. No attempt will be made to explain the changes necessary to the file or to explain how the software was actually loaded. The RTE Configuration Manual (6), devotes the first 32 pages to these changes. Several of the operating system manuals are required to understand the approach in addition to the configuration manual. They are: 1. System Building and Administration (12), 2. System Concepts (10) and 3. System Messages.(11)

Modifications to RTE Software

After the initial test of the full screenface transmission in December 1984, several changes were made to the software in order to implement the full screenface mode. These changes were all targeted toward implementation on asynchronous lines. The original contractor was not able to deliver a successful full screenface product to the sponsor.

This implementation was aimed at implementing synchronous terminals. There were two reasons for the synchronous choice. First, if a collection of actual data at an operational site is contemplated, the RTE software must be able to collect and retransmit on the types of devices in the field. Most of the operational sites of the sponsor have both PACS and CARGO terminals running on synchronous lines. Second, the contractor felt that the ability to detect the completion of a transmission on a synchronous line would help solve the problem of lost characters.

After the move to synchronous lines, there were two key problems to solve in order to implement the full screenface package. The first involved the sizes of the stimuli and responses; both were limited to 72 characters in the original package. The second was the ability of the RTE software to verify on five characters of the response against a previously collected response. In solving each of these problems, another problem was generated.

Expanding the size of the stimuli from 72 characters to full screenfaces could have drastically changed the size of the bound units. When adjusting the size of the stimulus and response from 72 to 1968 characters, the number of terminals to be emulated was dropped from a possible 128 to 4. The size of ASCII text for the stimulus alone for 128 terminals would have been 245,760 (128 times 1920). An equal amount of space was needed for the responses.

By dropping the number of terminals during the emulation phase, the sizes of the buffers to support those lines was kept to a reasonable limit. In its emulation phase, the RTE uses 120K words of memory to perform an emulation on four terminals. It is likely that the sponsor will ultimately request or build two different versions of the RTE emulation module. One for software validation, where four terminals would be sufficient, and a larger module needed to emulate additional terminals for stress testing. For software validation a single hardware system approach would be used and memory would be limited. For stress testing, the RTE application software would reside on its own hardware system and memory would not be a problem. Each of these concepts will be addressed in Chapter 4 (Software Validation) and Chapter 5 (Stress Testing).

The second problem area was expanding the response verification from 5 to a maximum of 1920 text characters. The original package was limited to 5 because the speed of the emulation was severely degraded when the length of the comparison was increased. This was due in part to the way Fortran generates its storage blocks on the DPS-6 at execution time and in part to the speed of the memory to memory compare. The sponsor determined total response verification was a mandatory requirement and that during the software validation phase of testing, speed was not a critical component. If verification is needed in conjunction with stress testing, the verification module may need to be converted to the assembler language level.

Hardware Implementation Details

The physical cabling on the RTE implemented machines was accomplished at Scott AFB, without any previous tests. The channel ports on the Level-6 machine at the contractor's development site are wired directly into a patch panel. This panel connection can then be routed to a terminal or a port on another machine. The sponsor does not have a patch panel to connect the two systems. The ports on the sponsor's machine were directly connected.

Two cables were necessary to connect the sponsor's DPS-6's. The most important cable was manufactured during the initial software testing at Reston, Virginia. This cable transfers the stimulus data from the RTE implemented machine to the SUT. It also accepts the response from the SUT on the return lines. Figure 4 shows the suggested diagram for wiring a cable to be used with a patch panel. Figure 5 shows how the direct connected cable was constructed. During the initial testing through the patch panel at the development site, it appeared that the timing signal was not strong enough to drive three lines tied together. In Figure 5 there is no line that drives more than two.

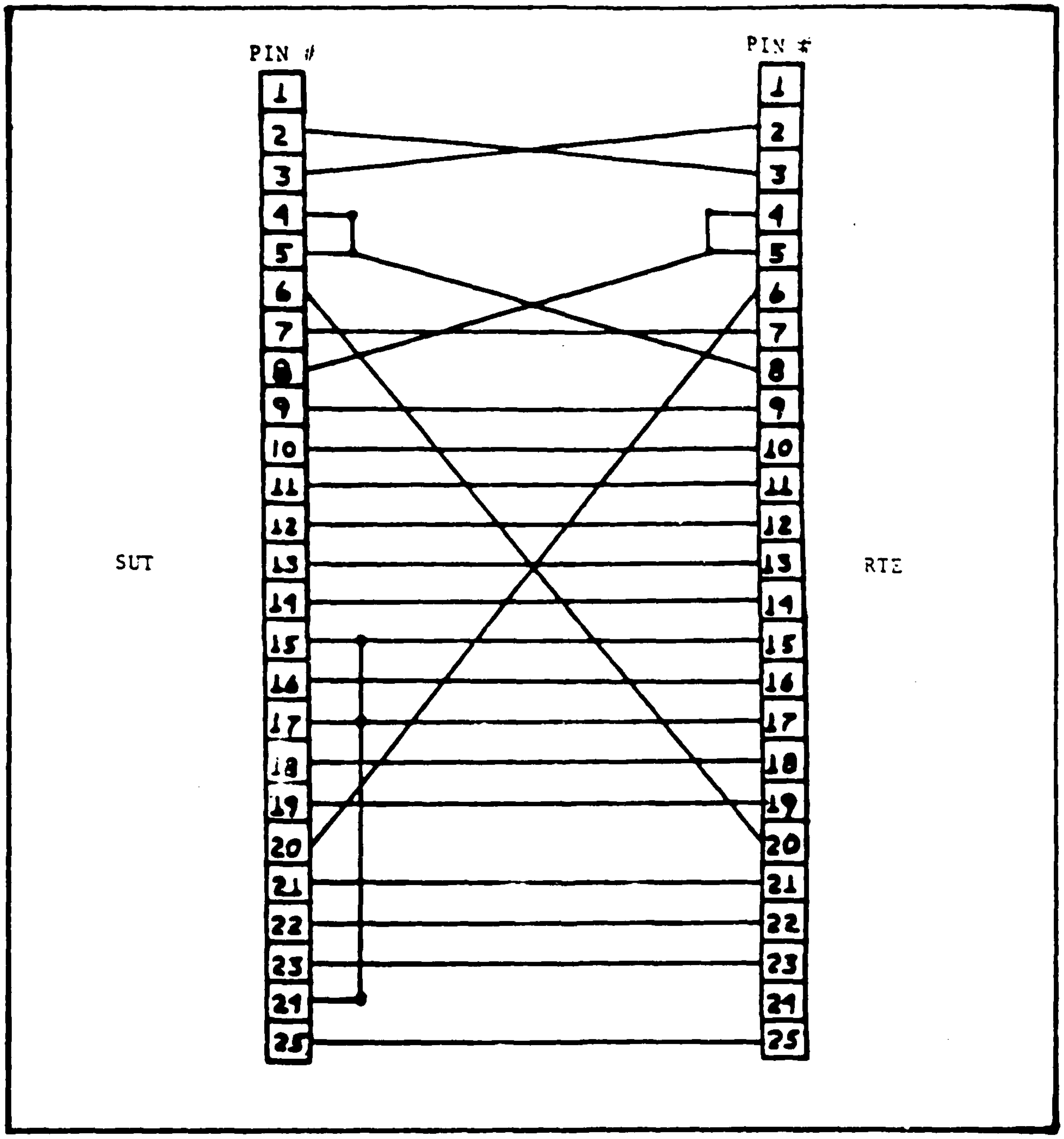


Figure 4. Patch Cable Schematic (6:2-148)

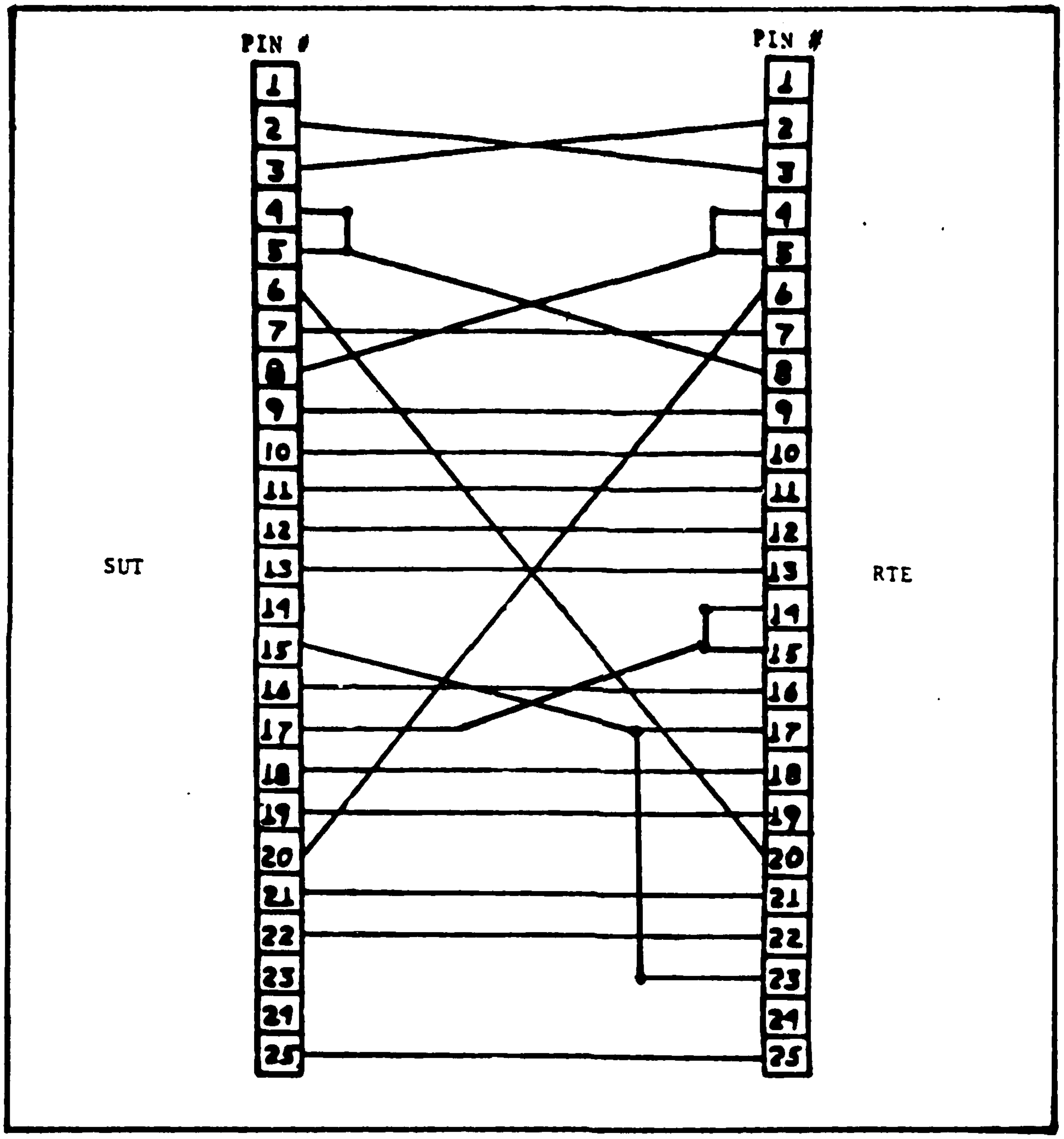


Figure 5. Revised Crossover Cable Schematic

Up to 32 different terminals could be emulated with this cable and two ports on the DPS-6 if the RTE emulation software was expanded beyond four terminals. During the implementation, the machine was configured with four logical terminals on a single physical line. The Configuration Line Manager (CLM) User's file entries to support two lines are shown in Figure 6. The stimulus flows on the PVE01 line to the STD04 line and the response from the SUT application software returns on the STD04 to the PVE01. The SUT is unaware that it is being fed by another line instead of an actual terminal.

It is immaterial whether the PVE lines are configured on the SUT or another DPS-6 machine. In the initial implementation, both ports were configured on the same machine. This was to allow the other machine to be used by the sponsor. For the stress test evaluation, the RTE software and the PVE lines were moved to the second DPS-6. This required a second cable. A 25 foot cable with RS-232 connections was used to connect the PVE port of the RTE machine to the STD port of the second machine. In order to include the crossover cable of Figure 5, it became necessary to continuously route the signals through a data scope. Both cables had male ends and a coupler with two female ends could not be found. For future work, either a coupling cable or another 25 foot cable with different ends should be found.

```
PVE 201,10,X'C900',0,0,QA        TEST ENTRY
DEVICE PVE01,201,10,X'C900',,2500
PVE 202,10,X'C900',0,1,QA        TEST ENTRY
DEVICE PVE02,202,10,X'C900',,2500
*PVE 203,10,X'C900',2,2,QA        TEST ENTRY
*DEVICE PVE03,203,10,X'C900',,1970
STDLN 10,X'C980',0,2400,W4       TEST ENTRY
STD 204,0,,'7814S',PB                 TEST ENTRY
STD 205,1,,'7814S',PB                 TEST ENTRY
*STD 206,2,,V7700                 TEST ENTRY
POLIST 1                         TEST ENTRY
STAPOL 0,1
DEVICE STD04,204,10,X'C980',,2500     TEST ENTRY
DEVICE STD05,205,10,X'C980',,2500     TEST ENTRY
```

Figure 6. CLM User File Entries for Two Terminals

A significant implementation factor was the ability of the sponsor's personnel to attach the cables and hardware to the physical machine. During the period of the RTE test, all test personnel had physical access to the cables and ports. At the Reston, Virginia development site, the test director had to request cabling support from the field engineer which often took considerable time. At the sponsor's site, the DPS-6's are located across the base from where the field engineers work, which would increase the time needed to recable. If the RTE was to be used daily, it would be reasonable to have at least the STD port on the SUT permanently cabled.

Testing

After loading the RTE application software, rebooting the system and cabling the ports, the actual implementation was examined. The testing was divided into two phases: 1. checking out the physical hardware and 2. evaluating the RTE software.

The physical connections were evaluated using a DLM IV Data Line Monitor. The DLM IV was very easy to use and the operator's manual (7) was well written. The disadvantage of the DLM IV was that it had no capability to print the collection. An even better package for the sponsor to examine is a utility which tracks data coming across the channels. This utility was available for previous versions of the operating system. Several loose connections caused problems during the initial evaluation. It is important to not only plug in the connections but to tighten the mounting screws, leading to the recommendation that the port attachment on the SUT be permanent.

The evaluation of the RTE software progressed from simple to more complicated. It ranged from a stimulus of 10 characters ($LOG-ON;CI) and a response of 14 characters (INVALID LOG-ON), to a full screenface input and output. No serious errors were noted in the way the system was configured to run, but several minor modifications of the CLM file were required. Two errors were noted in the collection and building of the data base necessary for an emulation session. Both concerned a single precision counter in a Fortran program. As the character count exceeded 32K the counter reset and data was lost. Both programs were later modified to eliminate this problem.

Summary

It must be noted that the sponsor acted as a test site for the software developers. Most of the software was specifically written to help the sponsor in his test package. In the initial evaluation of the package, several minor problems were found. These problems were quickly corrected, sometimes patched within the hour. This initial package performed much better than the sponsor had anticipated.

IV. Evaluation as a Software Validation Tool

Introduction

Chapter III described the modification and implementation of the RTE on the sponsor's machines. The final stage of the implementation insured that the RTE application software and the hardware connections could function as indicated in the accompanying documentation. The second phase of this thesis was to evaluate the RTE as a software validation tool. In other words, how well could the RTE software determine if an application program or system under test, was returning an erroneous response to a predetermined stimulus? For the purpose of this effort, response verification is defined as a character by character compare of the original response versus the emulation response.

To be considered a viable software validation tool, the RTE had to adequately perform three different functions. They were: 1. collect stimuli and responses going to and from the SUT application software, 2. combine those collections into matched sets, and 3. retransmit the stimuli and verify the responses from the SUT to the ones previously collected. The sponsor was interested in not only evaluating the RTE as a software validation tool, but also in comparing its use to that of his current internal test driver (ITD).

Consequently, the focus of this chapter is examining how well the RTE does its primary task of validation. If it is useful in software validation, does it do it better or faster than the internal test driver? Is it easier to learn and use?

In order to insure comparability of the data, the same stimuli and responses were used for both the RTE and the ITD. The terms inputs and outputs will be substituted for stimuli and responses occasionally. They refer to the same transactions. Also, in order to insure no compromise of official passenger data if or when the results were turned over to the RTE contractor, all social security numbers and names are fictitious. The passenger system data bases contained no actual data. Examples of the inputs and outputs are found in Appendix L. They are printed in a format generated by the ITD.

Stimulus and Response Collection

The input-output collection of the RTE package is done by a program called Autogen. Figure 7 shows how the RTE collects inputs and outputs. At initialization time, the Autogen program asks the user which line the inputs will be sent out on. PVE01 is used in the diagram. After this PVE line has been entered, the user establishes the STD line as a valid terminal. In the diagram it is STD04. At this point, any system log-on message is sent out the STD line, through the PVE line, received by Autogen, written to the response

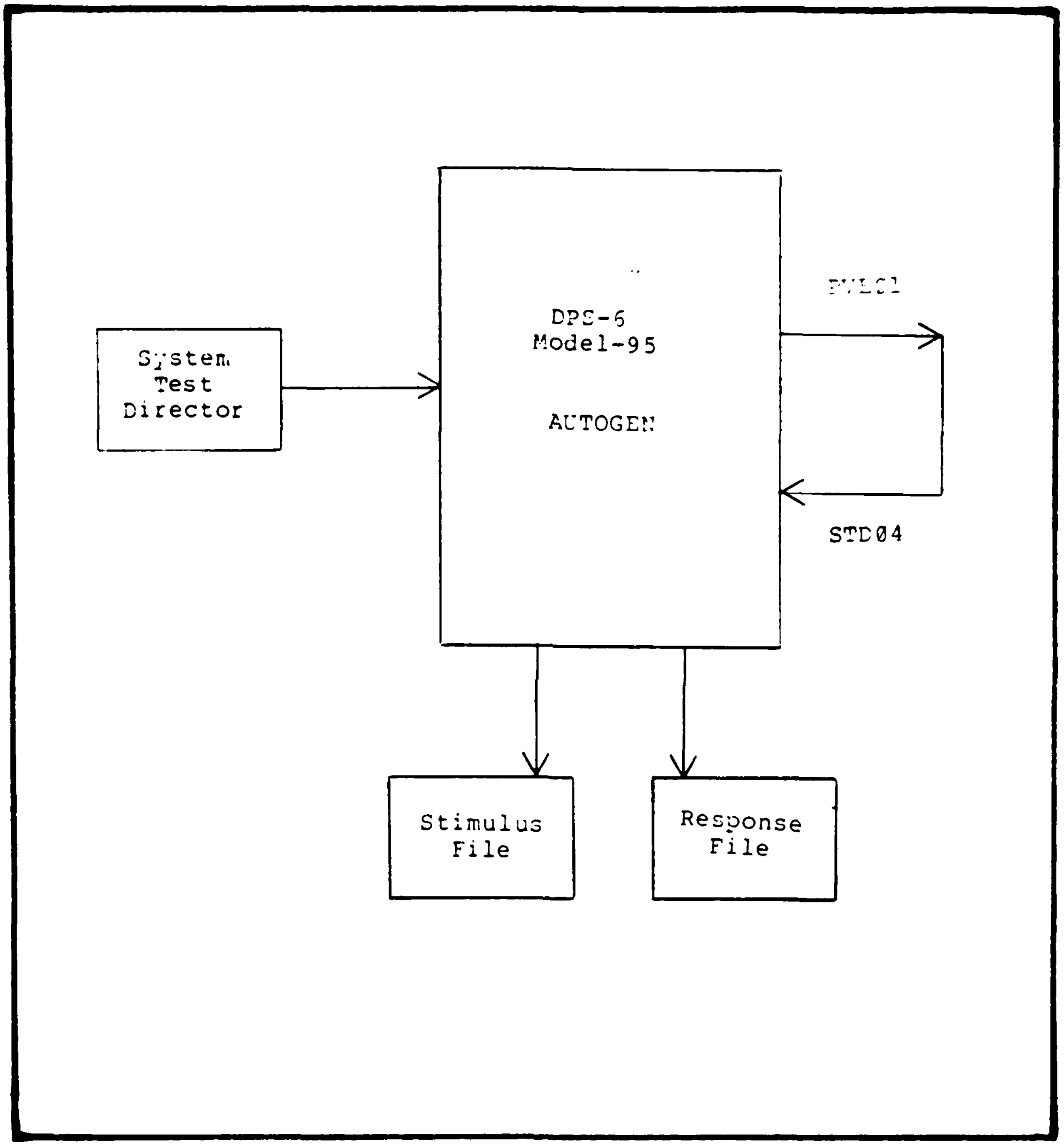


Figure 7. Diagram of Remote Terminal Emulator's Data Flow

file as response number zero, and transferred to the original terminal. The connection is now complete and any inputs entered on the original terminal are logged by Autogen in the stimulus file and processed by the SUT after being passed to STD04. Responses are collected in the return circuit. Examples of the stimulus and response files are found in Appendix C.

The collection software is easy to use. The user needs to be told, by the configuration manager, what line the RTE uses and what line to bring up as a system terminal. The RTE user enters his own name for the collection files when prompted by Autogen. At that point, he is unaware that the collection is happening. He ends the collection by transmitting '&&&&'. '&&&&' was chosen by the RTE's initial developer as a terminating character string, because it was not expected to occur in a normal input string. At that time, the Autogen software acknowledges the end of a collection session. Appendix C gives a file dump of both stimulus and response files for a part of a collection.

The evaluation of the RTE collection program found it to be easy to use and totally accurate in its collection. Due to its double buffered files, there was no noticable delays when receiving or sending screenfaces. The Autogen program required only 67 kilobytes of memory on a 2 megabyte machine. The only noticable drawback was the file space necessary to store the files. If a number of terminals were being collected in an operational environment, available file space would be quickly exhausted.

The sponsor's internal test driver uses a computer performance evaluation package to log inputs and outputs to a journal tape. It collects data as it is transferred to and received from the input-output handlers. Previous studies had shown a five to six percent degradation of response times when a collection is occurring. In the case of the ITD, the user is totally unaware of a collection. Therefore, there is no real difference to the user in the collection of the RTE or the ITD.

Script Assembly

The packaging of the inputs and outputs into matched pairs that can be retransmitted to the SUT is referred to as building and assembling a script by the RTE manual and labeled scenario management by the ITD and the sponsor. Regardless of the terminology, the aim is to generate a continuous combination of inputs and outputs to pass to the SUT.

The RTE uses two different modules to generate the script for the emulation phase: 1. the Build function of Autogen, and 2. the module called ASMB. Both are menu driven, or question and answer oriented and very easy to use. It is at this point that the RTE and the ITD begin to differ drastically.

The Build function of Autogen provides a level of capability not supplied by the ITD. This level is the ability of the RTE to reprocess transactions at the speed in which they were collected. In other words, if the user waited 20 seconds between the receipt of a response and the transmission of the next stimulus, then the RTE collects that wait time and makes it available for the retransmission. In some literature, this is referred to as think time. It is in the Build function that the RTE allows the system test director to specify either a default wait time, or an actual wait time.

If actual wait times are not selected, then the default wait time is used. Consequently, to run an emulation without wait times requires either eliminating the wait times and changing the default time to zero or changing all of the wait times to zero during the build function. This is a very tedious procedure, especially for a long scenario. The test director found it much easier to build the scenario file, then read the file into an editor and globally change all the wait times to zero. An example of the completed script file is in Appendix C. While this function supplies an option not available in the ITD, the RTF process is slow and monotonous. Some type of global change should be supplied in future releases.

It is also in the Build function of Autogen that the groundwork is laid for response verification. This is a function that the ITD supplies automatically, since the ITD was written specifically for the purpose of response validation. It should be noted at the beginning of this critique that the contractor already plans a modification allowing global response verification much like the ITD of the sponsor.

The method to establish response verification is very cumbersome. The actual screenfaces for a single transaction are included in Appendix D. After specifying either default or actual wait time, the Autogen software displays stimulus number one on the screen. At this command level, the user enters 'R' to signify response verification. Autogen displays the response on the terminal and asks if the starting point for the verification is on that page. The RTE only displays 9 of the 24 lines per screenface. After arriving at the correct screen, it prompts for the desired starting line. To establish the actual response verification starting point, it displays an 80-column scale and prompts for the starting column. Autogen reiterates this procedure to find the ending test line and column. It terminates the building of one response verification transaction by reprinting the original stimulus information plus the response to be verified.

This method of specifying the response is very slow. At a minimum, it takes six screenfaces and eight responses by the user to flag one transaction for verification. Even a

300 input scenario would take longer than this writer would care to spend. It is in this utility that the RTE lags far behind the sponsor's ITD. Perhaps the future release with global response verification will eliminate this problem.

To prepare for the actual emulation session, both the RTE and the ITD use a simple utility. To assemble a script in the RTE, the user enters the utility ASMB which queries the user for the data base name, a name given to the actual prepared script, and the script name from the previous Build function. The results are data base files needing only the appropriate line and channel numbers. The ITD assembles its script by querying the user for a start transaction number. It then strips the journal tape matching the inputs and outputs in an indexed file. Both systems are well documented, easy to use, build about the same size of files and execute at roughly the same speed.

One severe disadvantage of the RTE is its lack of utilities to merge scripts and to enter individual stimuli and responses after the script has been completed. There is no reasonable way to enter a single transaction in the middle of a previous script, other than building a script of one transaction. With the one transaction script, the user could divide the original into two scripts at the point of addition, then combine all three back into a single script. The sponsor's ITD allows additions at any point and the RTE software needs this modification to improve its usefulness.

Emulation

Evaluating how well the RTE does its primary job of response verification or software validation is best done by walking through the steps to begin an emulation session and comparing the results with the sponsor's ITD. To begin a session, the scripts must be prepared as described earlier in this chapter and the lines must be configured and matched to the scripts in a utility called Config. To begin an emulation session, the test director (user of the RTE) enters the utility called RTE. RTE queries the user for the data base (script) and then asks the user how many iterations of the script he wishes to run. This is a most useful tool and will be discussed in more detail in Chapter V. The only direct need in software validation, for this capability, is if the test director is looking for an error that occurs after an extended period of time. Our test scenario was designed for repeatability and a test was conducted with five iterations with response verification. The ITD has no corresponding capability and while it is not a primary need for software validation, it is just the thing that may enable a system test director to find a tricky time-caused error.

The RTE next asks for the number of errors allowed in the script emulation. If the RTE discovers an error, it means that a response from the SUT is not identical to the previously collected response in the data base. It then counts the number of errors that have occurred so far in the emulation and examines to see if the total has been reached. If so, it ends the emulation. If not, it writes the incorrect response to a report file (XLOG) and continues the emulation.

This allows the system test director to test a scenario and examine the errors after the completion of the test. The ITD stops a scenario as soon as it finds the first error and transmits the incorrect response to the terminal of the test director. It then waits for the test director to provide instructions to continue, stop, or repeat the offending stimulus.

Which system is the better is really a matter of choice. The RTE does allow a hands off approach for software validation, but the sponsor found that with stimuli that change the data base, if one response is wrong, chances are that all subsequent responses will also be wrong. Therefore, for the sponsor at least, this would not be a strong advantage.

The third step in emulating the script is to start the actual transmissions. This is the area where the RTE surpasses the ITD. Providing the scripts have been collected correctly, the individual lines can be used to exercise different application programs at the same time. The ITD is limited to supplying one stimulus and waiting for the corresponding response. It can then send another stimulus which could be targeted toward a different application program. The RTE can execute four different application programs at the same time. This can easily uncover data base contention errors or other errors caused by resource contention.

The RTE allows the test director to actually exercise the communication line handlers used by the system under test. The ITD is totally within the system and does no communication with the terminals or terminal drivers. For the sponsor, this is a large concern since the input-output handlers are user written. The RTE also allows the test director to perform computer performance evaluation on the actual transmissions.

Summary

The RTE surpasses the ITD as a software validation tool. While the RTE is not as versatile in scenario management as the sponsor's ITD, the addition of a global response verification capability would make the RTE just as easy to use as the ITD. The RTE is extremely easy to operate. It does a better job of software validation than any tool the sponsor currently has. It not only exercises the SUT application software, but also exercises the communication channels and the communication oriented application software.

V. Evaluation as a Stress Testing Tool

Introduction

Chapter IV examines the use of a RTE as a software validation tool, by evaluating how well it is able to verify the correctness of responses which are being returned by the system under test. This type of software validation testing is most often done in a very controlled environment, often with predetermined scenarios which were constructed from an acceptance testing plan. This thesis effort continued beyond the evaluation of the RTE as a primary software validation tool. Chapter V evaluates the RTE as a stress testing tool.

The presentation of this chapter is divided into four areas. They are: 1. the concepts of RTE stress testing and how it is needed by the sponsor, 2. the method of collection for multiple terminal emulation, 3. the emulation of multiple terminals on a single machine, including results of sample runs, and the emulation of terminals from one machine to another, and 4. the problems uncovered with the RTE during the sample runs.

Concepts of Stress Testing

To be considered as a viable stress testing tool, the RTE must be able to feed stimuli and receive responses from the SUT in such a manner as to approximate different levels of use or a different number of users. The sponsor found that software which was validated by the internal test driver would often fail after being loaded at an operational test site. These failures were often due to the interaction of application software after it had been placed under a specific load of users. These load related failures were extremely difficult to diagnose because the operational sites have no on-site programmers or analysts. In addition, the load could not be duplicated on the sponsor's machines. The ITD was capable of only single-threaded input and the sponsor does not have enough terminals to generate the load, even if he could find knowledgeable users. To further complicate the problem, the software failure often occurred only with a precise mix of transactions. The result was generally a programming team sent to the site.

The capability to emulate multiple terminals is the area where the RTE would far surpass the ITD. Emulation of multiple terminals would allow the sponsor to load test the new software to determine if it had stress related errors. In addition to the software test under load, the RTE would allow the system configuration manager to test the hardware configuration at each site to determine if it had the processing power to insure adequate user response times. Coupled with the sponsor's computer performance evaluation subsystem, stress testing the SUT would allow the manager to evaluate the effect of additional users and additional loads on the SUT. This need for capacity planning data is a natural by-product of the stress testing phase.

The RTE also would allow another avenue of testing, never before used by the sponsor. Each operational site generally contains at least two sets of hardware. As described in Chapter I, the sponsor runs three different operational systems on the two sets of hardware. PACS and EARLO usually run on one hardware set with CARGO on the other. In the case of a catastrophic hardware failure which disables one machine, the data base from one system is transferred to the other. This is possible because the data base is stored on removable packs. In the cases of a disk crash, the previous save is used and a journal tape recovery brings it up to date. Application software for all three systems is always current on both sets of hardware. By transferring selected physical terminal lines, the backup configuration allows both systems to run in a degraded mode. After collecting scenarios on a PACS and CARGO system for software validation, the RTE can be used to simultaneously feed PACS and CARGO stimuli to the SUT on different logical lines, thereby evaluating the feasibility of a backup configuration.

Collection for Stress Testing

The type of testing, or more importantly the focus of testing, will generally determine the method for the collection of stimuli and responses. Chapter IV discussed in detail the procedures to capture the stimuli and responses going from one terminal into the SUT. If the stimuli and responses are a repeatable scenario, then the collection from a single terminal is a valid collection method. An example of this type of collection, would be a normal user's session from a software developer's terminal. These types of stimuli, such as compiles, editor work, lists of directors, etc., are generally repeatable regardless of the order. Because they give similar results, a single session can be collected and repeated over several terminals. Chapter IV described how the single script could be assembled into a data base for emulation over several lines. However, even in the simple case just described, things can go wrong. A compiler invoked from two different terminals, using the same source file, may each try to establish an object file with the same name, or a source listing file with the same name. This leads to a file contention problem during emulation.

While the test scenario was repeatable, it was designed and constructed that way specifically for testing the RTE package. Part of the intent of this chapter, is to show that the RTE is capable of multiple collection from different terminals. Figure 8, when compared to Figure 7, shows the additions necessary to collect stimuli and responses from two different terminals. The collection in this study was limited to two different terminals. This was due to a hardware limitation on the sponsors machine. Both DPS-6's available for this study had only one synchronous terminal. Since the current version of the RTE was limited to

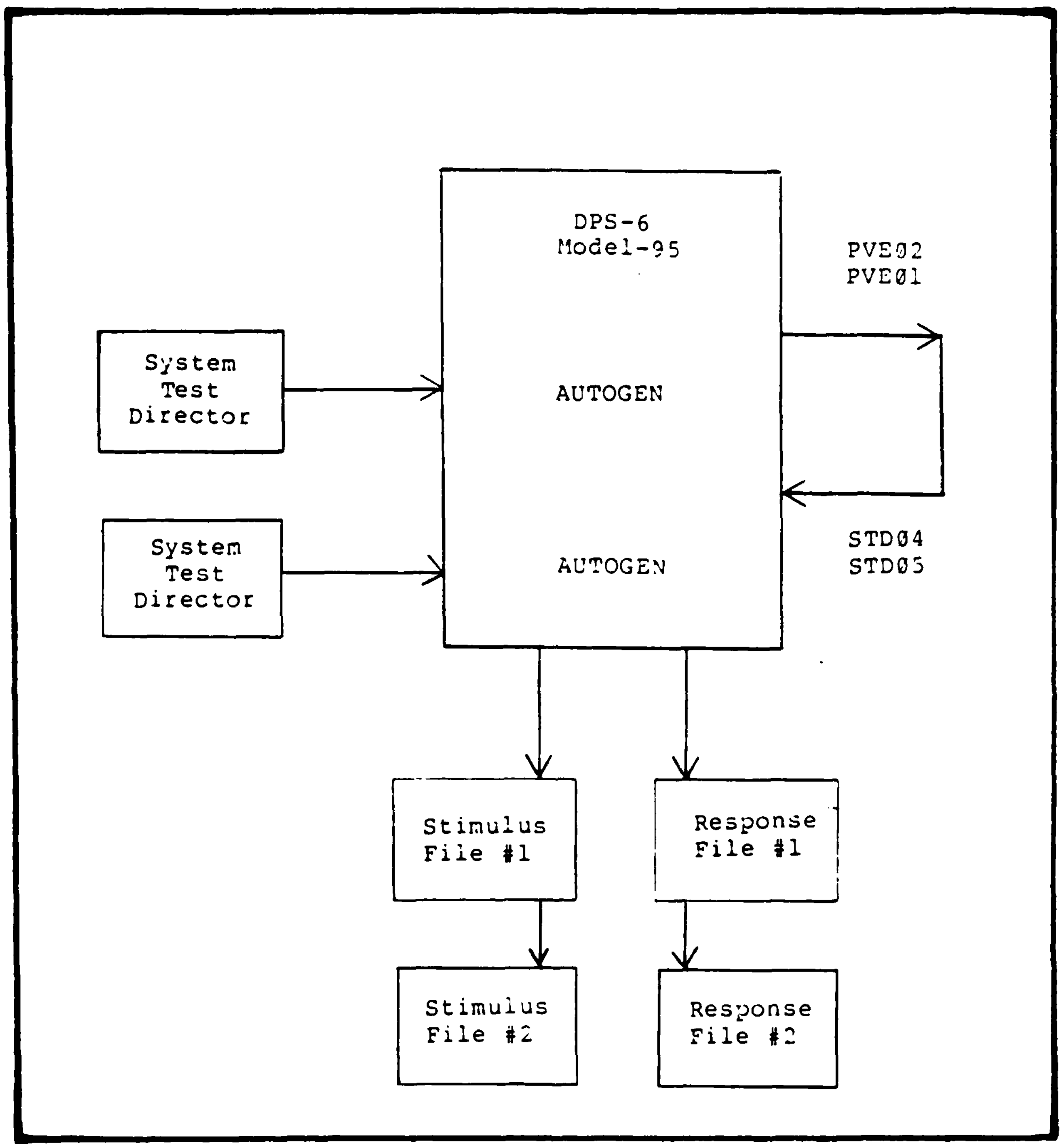


Figure 8. Diagram of Data Flow for Two Terminals

synchronous terminals, one asynchronous terminal was converted to a synchronous mode. This required changes to the CLM user's file, recabling to a synchronous channel, and resetting of internal switches on the terminal. After configuring the second synchronous terminal, the collection was accomplished as diagrammed in Figure 8.

An important point of this diagram is that the diagram shows only one physical line going from the PVE to STD port. In the test, the first control terminal was directed out of PVE01 and into STD04; the second out of PVE02 and into STD05. The DPS-6 is able to handle 32 different logical lines on a physical line. To further test the RTE stress test collection capability, two synchronous test director's terminals and four asynchronous terminals were configured through Autogen. The system had no trouble handling the physical requirements, but a collection through synchronous lines from an asynchronous terminal is not possible.

Each Autogen module requires 67 kilobytes of memory, so a potential memory problem exists at an operational site if all terminals are used for a collection. Most of the operational systems do have 2 megabytes of memory to cover the backup configuration requirement, so a reasonable choice of terminals should give adequate coverage. A larger problem might be the funnelling of all the logical lines into a single physical connection. The sponsor does have 32 hand-held terminals, routed through a micro-computer into a single physical line. They have noticed severe degradation of response times when traffic from the hand-held terminals is high. The same situation would likely occur with a concentration of terminals going into a single channel.

It was the intent of this study to evaluate the feasibility of the stress test collection, and to determine if the RTE application software could handle the collection. The RTE software was capable of adequate collection from more than one terminal. Because two machines are available at most sites, it was also suggested that both machines could be utilized as in the emulation phase. This isolation of the RTE software on the other machine also worked without error. In summary, while the entire package performed without error, before traveling to an operational site for a full site collection, considerable preparation would be required.

Stress Test Emulation

Often the effort the system test director can devote to testing is limited by the resources that he has available to him. For this reason, even the stress testing of software would be broken into two distinct phases. First, the new application software would be driven with the RTE software on the same hardware systems and second, a final test would be run with the RTE software split from the SUT. This single machine test allows the test director to discover most of the load errors without the use of both machines; the two machine test allows a full and final test with computer performance evaluation data being generated.

To evaluate the stress testing capability of the RTE on a single machine, four separate runs were conducted. Each run used the same repeatable scenario initially generated during the software validation testing. As stated earlier in Chapter IV, the intent of this study was to evaluate the use of the tool, not to do actual testing. The sponsor's application software for the SUT is single-threaded. For this study, single-threaded is defined as being able to handle only one input at a time. In other words, they are not reentrant. The RTE software needed to be able to handle the situation where software is queued, awaiting entry into the application program.

Full use was made of the sponsor's Computer Performance Evaluation (CPE) subsystem, and it was with the CPE data that a major flaw was discovered in the RTE package. This flaw, a time delay problem, is discussed later in the chapter. Appendix E gives an example of the RTE report generated by a utility called XLOG and the corresponding CPE printouts.

Table 1 gives the condensed data for three of the four runs as generated by the CPE subsystem. To understand the data in Table 1 requires a knowledge of how the sponsor's CPE subsystem collects and generates the data. Figure 9 gives a graphic view of the CPE data collection. Three different record types can be collected for each stimulus and response sent and received by a terminal. Each of these record types has two time stamps, one indicating the start of the transaction and one at the completion. Type 10 records are

Table 1. Results from Stress Test Emulation

Test	Application	Total Stimuli	Number Queued	Percent Queued	Average for Queued	Average for Total
4-Line	IA	77	21	27	6.275	1.711
	IC	9	1	11	11.292	1.254
	ID	44	11	25	7.816	1.954
3-Line	IA	58	8	13	3.227	Ø.445
	IC	7	Ø	Ø	-	-
	ID	33	7	21	3.932	Ø.834
2-Line	IA	42	Ø	Ø	-	-
	IC	5	Ø	Ø	-	-
	ID	22	Ø	Ø	-	-

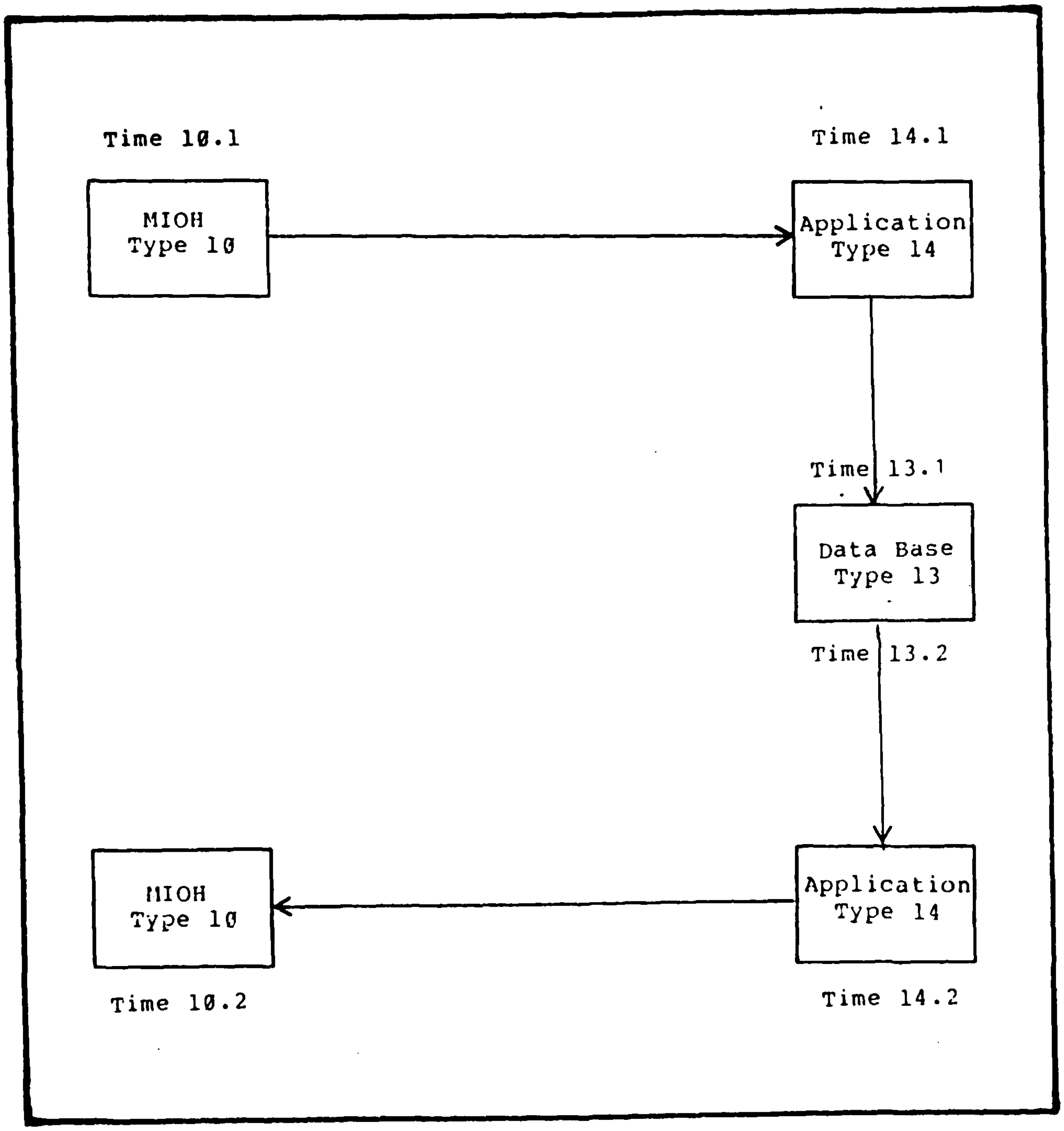


Figure 9. Diagram of Sponsor's Computer Performance Evaluation Subsystem

collected from the input-output handlers. Type 14 records are collected inside the individual application programs and type 13 records are generated by the data base system used by the application software. For the purpose of this study, type 13 records are not needed and will not be explained. The other two records will be described by explaining when the time stamps are taken in relation to the collection.

When the input-output handler receives the last character from the terminal, it generates a request for system time. The time is held and later journalized as time 10.1. It is important to note that the system time call is generated at the completion of the transmission from the terminal. The input-output handler releases the transmission to the appropriate application program, which issues a system time call that is later journalized as time 14.1. Upon completion of the application task, time 14.2 is generated, a type 14 record containing time 14.1 and 14.2 is journalized, and a response is given to the input-output handler for transmission to the terminal. The input-output handler requests a physical output to the terminal, waits for the completion of that output, generates a system time call, and writes the type 10 journal record with time 10.1 and 10.2.

In summary, a single type 10 and type 14 record is generated for each stimulus and response received from and sent to the terminal. The type 10 record includes one half of the terminal communication time, that half being the output of the terminal screenface. The type 14 record gives the application service time for the user's request.

Because the input-output handler module is reentrant, with a separate buffer for each terminal, it is capable of serving multiple terminals simultaneously. The application program modules, on the other hand, are not reentrant and must serve the screenface requests in a single-threaded mode. After receiving a stimulus from the terminal, it completes all of the requested work, issuing an output screen for that terminal, before accepting the next input.

If requests for the application program arrive faster than the application can service them, then the requests are queued. To determine if a stimulus has been queued, involves comparing the time 10.1 of a record, with the time 14.2 of the previous record for the same application. If the 10.1 is lower than the 14.2, it means that a second or subsequent stimulus arrived before the application program was free to process it. If a stimulus must wait in a queue for the application program, then the time between record time 10.1 and record time 14.1 is a good estimate of queue time.

To be considered as a viable stress testing tool, the RTE must be able to transmit stimuli and receive responses faster than the SUT application software can generate the response screenfaces. In other words, it must be able to generate queued transactions. Table 1 does not include data for the single line transmission. At the single line level, the RTE acts much like the sponsor's ITD, transmitting the next stimulus only after receipt of a response. There is no possibility of a queued transaction. The table results also show that a two line transmission does not generate queued transactions. The three and four line transmissions both generated queued transactions, showing that even with a simple test scenario, and with the limited number of lines available in this version of the RTE software, the RTE can be used as a stress testing tool. The four line test generated a queue for each of the application programs at least once, with over 25% of the transactions being queued on the two larger units.

It is noteworthy that with only four lines, the RTE generated an average queue time on the two programs of over six seconds for a stimulus that entered a queue. With a larger number of lines available in future releases, the sponsor will be able to stress test the SUT at will. By using a larger number of terminals, and adjusting the user think time between stimuli, he can achieve any level of use he desires to simulate.

Because of the limited availability of both machines at the same time, most of the data collection was done on a single machine. Additional runs were conducted, with one set of hardware as the RTE system, and the other as the SUT containing the application programs. There was no significant difference in the results of the one or two machine runs. This is partly because response verification was not included as part of the stress test, and therefore, the RTE software did not consume significant CPU time. The single machine results were presented in the table due to the timing problem discussed in the next section.

Problems Encountered

There were three significant problems identified during the stress testing. They are presented in this section based on their level of importance in affecting the sponsor's stress testing capability. Where possible, potential solutions are offered.

As stated in the previous section, a timing problem exists when using two different machines to conduct a stress test. If the RTE is loaded on one machine and the application software, including the CPE system, is loaded on another, each issues a call for time to their respective system. It is almost impossible to set the two system clocks to within a second of each other. The clocks are accurate to eight millesecond intervals. If the clocks are not reasonably synchronized, the RTE report can show a stimulus sent from the RTE after the SUT has received it. A potential solution would be to have one machine request the time from the other when setting the clock, but the delay of communication from one machine to the other would also affect the time set.

A second, and more significant problem, was the RTE's tendency, during the stress test, to drop one of the logical lines being emulated over the physical line. When it dropped one of the logical lines being emulated, there was no notification to the test director by the RTE software. The loss of a line was not discovered until either the SUT issued a timeout warning message at the operator's console, or the RTE report was examined at the end of the session. Even when the warning message indicated the loss of a line; the line could not be restarted. Several attempts were needed to get valid results for the four terminal emulation. Expanding the software to more than four terminals is likely to increase the occurrence of lost lines.

No valid reason was discovered during the testing to explain the loss of the line. The DLM IV data scope used by the test team did not have a print capability or an extensive memory to store a complete test. By utilizing a different data scope, the reason for the loss of a line should become apparent.

The largest problem discovered during the stress test evaluation was a significant time delay between the transmission of the stimulus by the RTE and its receipt by the SUT. This delay occurred both during the one machine and two machine emulations. For example, the XLOG report (page E-2) shows the transmission of the first stimulus at

12:35:26. The type 10 record from the CPE report (page E-5) shows the stimulus arrived at 12:35:42, a delay of 16 seconds. The second stimulus gives a 14 second delay. All stimuli appear to be delayed between 14 to 16 seconds. Evaluation of the stress test data did not provide the reason for this delay. It is expected that a wait state is occurring in one of the programs.

Summary

While several problems were discovered, only the final one would severely impact the RTE's ability to conduct a valid stress test. The evaluation showed that the RTE could emulate terminals faster than the SUT application software could handle the requests. It also allowed the system test director to simulate the system with both CARGO and PACS terminals in any combination of four terminals. Further refinements of the RTE software, expanding beyond four terminals and eliminating the time delay, will allow the sponsor to stress the application software at will.

VI. Conclusions and Future Studies

Conclusions

This research effort combined the modification of software designed by a civilian contractor with the hardware of the sponsor to determine if the combination would result in an effective tool for software validation and stress testing. The effort was a continuation of concepts in configuration management originally presented by the sponsor in 1982.

The sponsor is determined to find a tool which, when incorporated into his automated release facility, will enable him to improve the reliability of software sent to the operational sites. This study showed that the remote terminal emulator, supplied by the Service Directorate of the Joint Data Systems Support Center, is just the tool they need. It is individually tailored for their type of equipment and the hardware necessary for extensive testing is already in place. The RTE application software package is small enough to reside on the sponsor's hardware with the SUT application software. The cabling connections necessary to utilize the RTE are simple enough to be done without the help of a hardware engineer.

The evaluation of the RTE package, as a software validation tool, showed that the RTE was superior to the sponsor's internal test driver. The RTE software is so easy to use that the package should be considered as a tool for development testing as well as release testing. While the RTE is deficient in the area of scenario management, it makes up for the deficiency by exercising all the software in the SUT, including the communication handlers.

The evaluation of the RTE package, as a stress testing tool, pointed out that this package allows the sponsor to conduct tests not currently available with his internal test driver. The RTE application software can transmit stimuli faster than the sponsor's SUT application modules can generate the responses, thereby causing a queue of stimuli waiting to enter the SUT application programs. The RTE also allows the system test director to load the SUT with stimuli from more than one of his application systems concurrently. This provides him with an excellent means to test his backup configurations. Elimination of minor problems with the RTE software package will allow the system test director to perform computer performance evaluation studies on the application software before release to the field.

Future Studies

The RTE package was shown to be a quality tool for use by the system test director in releasing software to his operational sites. Just by using the tool in day to day activities of software configuration management, the sponsor will no doubt find many new uses for the RTE package. Possible areas of use for the sponsor include capacity planning for future sites, hardware acceptance testing for sites with dual machines located in the same area, and benchmark testing for future hardware acquisitions. The Joint Data Systems Support Center briefed the availability of a full screenface emulator at the 1987 Level-6 Terminal User's Conference. The proliferation of this software to other DPS-6 users is bound to open new areas of study which utilize the RTE.

The possible area of study which would constitute a follow-on thesis, however, is not in the use of the RTE package with other DPS-6 machines. The future focus of RTE study, should be directed at using the DPS-6 as the RTE resident machine to emulate and stress other pieces of hardware.

The sponsor, for example, has several configurations which currently could benefit from the use of the RTE. Figure 10 shows a group of current systems which could be driven by the RTE. By loading the RTE software on a DPS-6 which resides before the Datanet Frontend, or on the Datanet, if it is a DPS-6, the system manager could exercise each individual system. Most of these systems are located in the same general area so hardware connections would not be a large problem. By exercising the individual systems, the test director could also exercise the data bases connected to those systems.

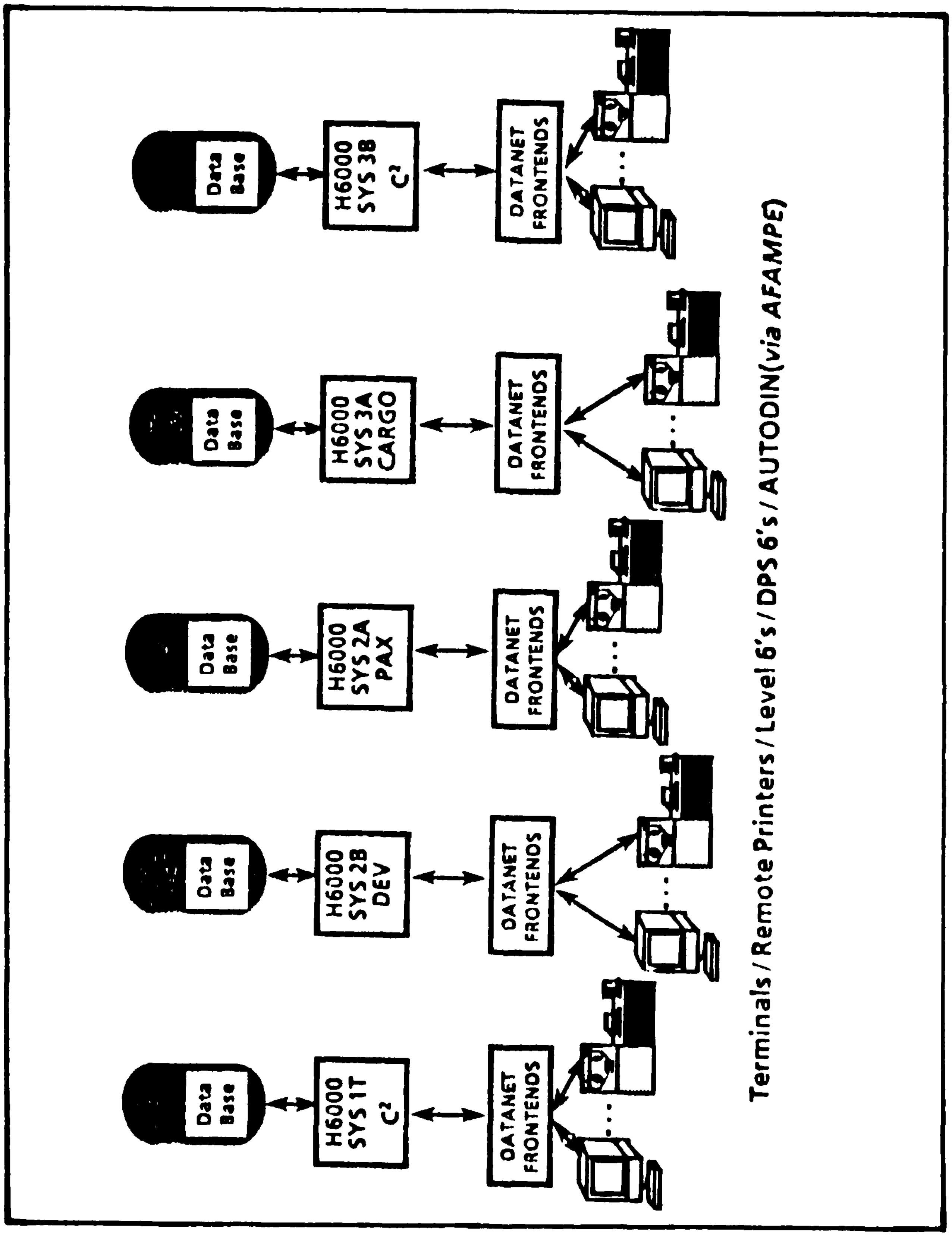


Figure 10. Current System Configuration

Figure 11 shows a future configuration, using a high speed bus to connect computer systems with a general data base. A potentially rewarding study would be the integration of a RTE loaded DPS-6 as one of the 'other hosts' connected to the high speed bus. In this configuration, the RTE could load each of the individual systems, as well as loading the data access processor without use of the individual hosts.

In summary, future studies using the RTE are limited only by the desire of the researcher, the availability of the hardware for research, and the need for the information in respect to the funds made available by the sponsor.

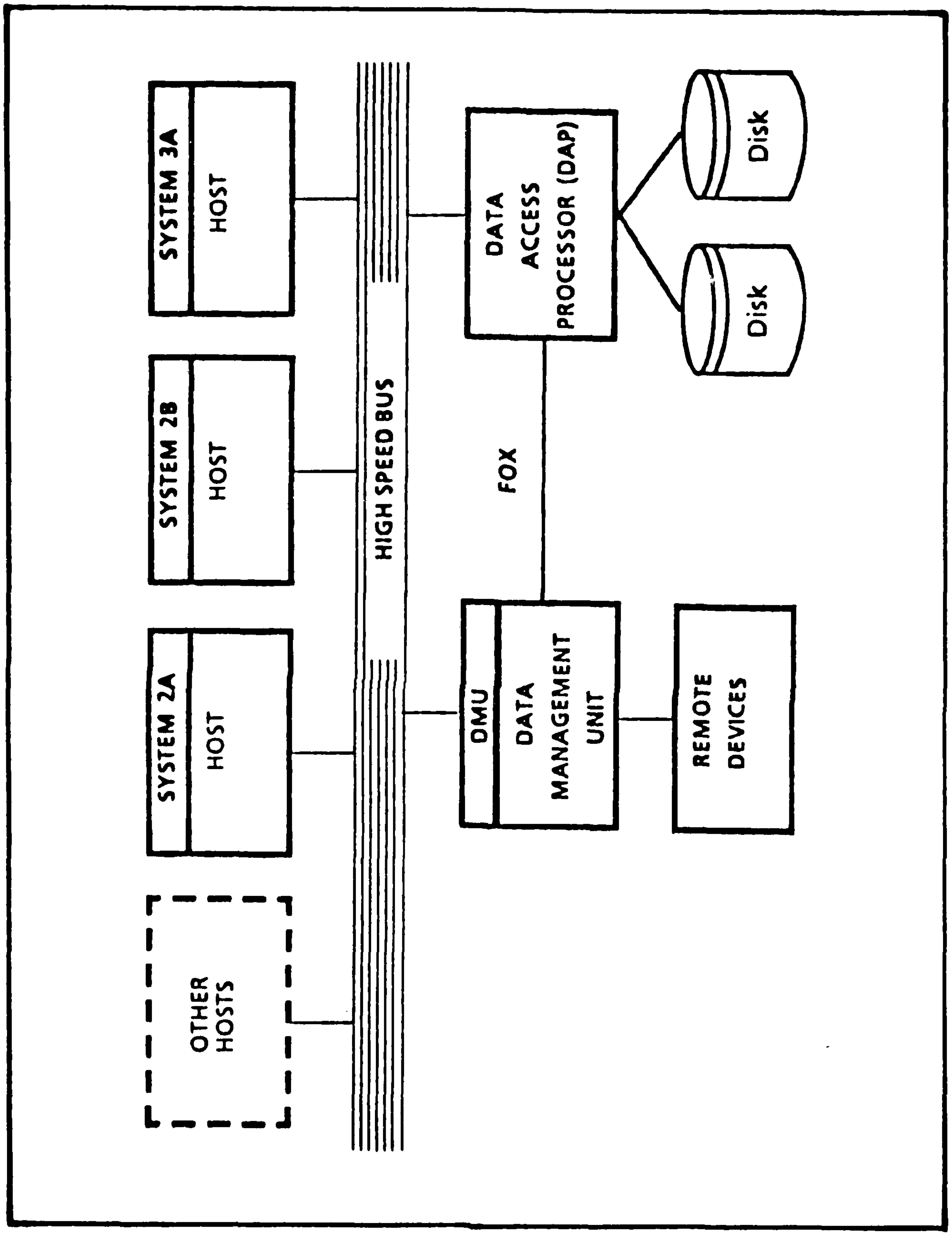


Figure 11. Potential Future System Configuration

Appendix A: Sponsor's Release Data 1984 - 1986

RELEASES FOR 1984

JANUARY

BASIC	CARGO	PACS	EARLO
322			
321	320		
319	318		

FEBURARY

BASIC	CARGO	PACS	EARLO
326			
325			
324	323	323	

MARCH

BASIC	CARGO	PACS	EARLO
	336		
	335		
337	333		
334	332		
331	329		
330	327	328	

APRIL

BASIC	CARGO	PACS	EARLO
342	340	341	
339	336	338	

MAY

BASIC	CARGO	PACS	EARLO
350			
346		349	
344		347	
343	348	345	

JUNE

BASIC	CARGO	PACS	EARLO
354			
353			
351		352	

JULY

BASIC	CARGO	PACS	EARLO
361			
359			
358		360	
357	356	355	

AUGUST

BASIC	CARGO	PACS	EARLO
	367		
	365		
	364	366	
	363	362	

SEPTEMBER

BASIC	CARGO	PACS	EARLO
		369	
371	370	368	

OCTOBER

BASIC	CARGO	PACS	EARLO
374			
373	372		

NOVEMBER

BASIC	CARGO	PACS	EARLO
379			
378			
376	377	375	

DECEMBER

BASIC	CARGO	PACS	EARLO
	381		
382	380	383	

RELEASES FOR 1985

JANUARY

BASIC	CARGO	PACS	EARLO
385			
384		386	

FEBURARY

BASIC	CARGO	PACS	EARLO
	394		
	393		
	392		
390	388		
387	389	391	

MARCH

BASIC	CARGO	PACS	EARLO
400			
397			
396			
395	398	399	

APRIL

BASIC	CARGO	PACS	EARLO
408			
407			
406	402		
405	401	403	404

MAY

BASIC	CARGO	PACS	EARLO
411	777	410	

JUNE

BASIC	CARGO	PACS	EARLO
413			
412	414		

JULY

BASIC	CARGO	PACS	EARLO
418			
415	416		

AUGUST

BASIC	CARGO	PACS	EARLO
453	452		451

SEPTEMBER

BASIC	CARGO	PACS	EARLO
	457		
	454	456	

OCTOBER

BASIC	CARGO	PACS	EARLO
463			
462			
458	460	461	459

NOVEMBER

BASIC	CARGO	PACS	EARLO
465		464	

DECEMBER

BASIC	CARGO	PACS	EARLO
		466	467

RELEASES FOR 1986

JANUARY

BASIC	CARGO	PACS	EARLO
474			
468			469

FEBURARY

BASIC	CARGO	PACS	EARLO
	470	472	

MARCH

BASIC	CARGO	PACS	EARLO
475			
474			
473	476		

APRIL

BASIC	CARGO	PACS	EARLO
480		481	
478	479	477	482

MAY

BASIC	CARGO	PACS	EARLO
483	487		

JUNE

BASIC	CARGO	PACS	EARLO
486	487		

JULY

BASIC	CARGO	PACS	EARLO
491			
490	493	489	492

AUGUST

BASIC	CARGO	PACS	EARLO
501			
499			
497			500
496	498	494	495

SEPTEMBER

BASIC	CARGO	PACS	EARLO
502			

OCTOBER

BASIC	CARGO	PACS	EARLO
505			
504	503		506

NOVEMBER

BASIC	CARGO	PACS	EARLO
		513	
509		511	
507	512	508	510

DECEMBER

BASIC	CARGO	PACS	EARLO

Appendix B: Examples of Inputs and Outputs

This appendix contains two examples of PAX input transacions (B - 2 and B - 4) followed by their output transactions (B - 3 and B - 5).

```
PLTLUP;WRIFRF;360;1200
```

```
************************************************************************************
************************************************************************************
**                                                                                **
**FLTLUP;WRIFRF;360;1200                                                          **
**                                                                                **
**FLT            DEPARTURE C  FLT  TOT     ------------------APOD-----------------**
**CD  MISSION-ID  DAY TIME S  STAT ACL     -1- -2- -3- -4- -5- -6- -7- -8- -9- -10**
**                                                                                **
**AA AAA1112  365 360 1200 B CLSED 030     FRF                                    **
**                                    ACL  030                                    **
**                                    OPEN 023                                    **
**                                    OVBK 000                                    **
**                                                                                **
**AC AAA4321  365 365 1200 A CLSED 090     FRF                                    **
**                                    ACL  090                                    **
**                                    OPEN 067                                    **
**                                    OVBK 000                                    **
**                                                                                **
**                                                                                **
**                                                                                **
**                                                                                **
**                                                                                **
**                                                                                **
**                                                                                **
**                                                                                **
**                                                                                **
************************************************************************************
************************************************************************************
```

```
SBOW;AD;0000
```

```
**************************************************************************
**************************************************************************
**                                                                      **
**SHOW;AD;0000                                                          **
**                                                                      **
**LINE STS                                                              **
**NBR  REQ NAME--------- RIC- GRD --------------SEATS ASSIGNED--------------  **
**                                                                      **
**0601 001 LIMA          +3332 CPT                                      **
**0602 001 MURRAY        +4333 AMN                                      **
**0701 002 TEST POSTONE +0111 SGT                                       **
**0703 002 TEST POSTTWO +0222 SSG                                       **
**0705 001 TEST POSTTHR +0333 SGT                                       **
**0706 001 TEST POSTFOUR+0444 TSG                                       **
**0707 005 TEST POSTFIVE+0555 SRA                                       **
**0712 002 TEST POSTSIX +0666 LTG                                       **
**0714 001 TEST POSTSEV +0777 MAJ                                       **
**0716 001 TEST POSTNIN +0999 SGT                                       **
**0718 002 TEST POSTEIG +0888 A1C                                       **
**0720 002 TEST POSTTEN +1010 SSG                                       **
**                                                                      **
**                                                                      **
**                                                                      **
**                                                                      **
**                                                                      **
**                                                                      **
**************************************************************************
**************************************************************************
```

Appendix C: Printouts of RTE Generated Files

This appendix contains file dumps of a stimulus file (C - 2 and C - 3), file dumps of a response file (C - 4 and C - 5) and a print of the generated script file (C - 6 and C - 7).

```
LD  PATH= ^SYSPKO>MARF>RTE>PAX1.S
86/12/25 1256:23.8                                              PAGE 0CC1

001 0018 2020 2031 3132 3130 3432 2020 3130 244C 4F47 2D4F 4E38 4941                          1121042  10SLOG-CN;IA

002 00AE 2C20 2032 3132 3131 3136 2031 3630 2C20 2C20 2020 202C 2C20 2C20 202C 202C 2C20      2121116 160
         2020 2020 202C 2020 2020 2020 2020 2C20 2C20 2020 202C 2C20 2020 202C 202C 2C20
         2C20 202C 2020 2C20 2020 2020 2020 2020 2C20 2020 2020 2C20 2020 202C 202C 5348            SM
         4F57 3B41 4138 3C30 3C30 202C 2020 2C20 2C20 2020 202C 2C20 2020 202C 202C 2C20      OW;AA;0000
         2020 202C 202C 2C20 2020 202C 2020 2020 2C20 2020 202C 2C20 202C 2020 202C 2C20
         2020 202C 2020 2C20 2020 2020 2020

003 0016 2020 2033 3132 3131 3530 2020 2038 244C 4F47 2D4F 4646                               3121130   8SLOG-OFF

004 0018 2020 2034 3132 3132 3C39 2020 3130 244C 4F47 2D4F 4E38 4944                          41212C9  10SLOG-ON;ID

005 00AE 2020 2035 3132 3132 3330 2031 3630 2C20 2C20 2020 202C 2C20 2020 202C 202C 2C20      5121230 160
         2C20 2020 202C 2C20 2020 2020 2020 2020 2C20 2020 202C 2C20 2C20 202C 202C 2C20
         2C20 202C 2020 2C20 2020 2020 2020 2C20 2C20 2020 202C 2C20 2C20 202C 202C 4745            GE
         543B 4D41 5246 2054 5454 3B41 4120 2C20 2C20 2020 202C 2C20 2C20 2020 202C 2C20      T;MARF TTT;AA
         2C20 2020 202C 2C20 2020 2020 2020 2020 2C20 2020 202C 2C20 2020 2020 202C 2C20
         2020 202C 202C 2020 2020 2020 2020

006 0018 2020 2036 3132 3132 3436 202C 3130 244C 4F47 2D4F 4E38 4941                          6121246  10SLOG-CN;IA

007 00AE 2020 2037 3132 3132 3539 2031 3630 2C20 2C20 2020 202C 2C20 2C20 202C 202C 2C20      7121259 160
         2020 202C 2020 2C20 2020 2020 2020 2C20 2C20 202C 202C 2C20 2020 202C 202C 2C20
         2020 2020 2020 2C20 2020 2020 2020 2C20 2C20 2020 202C 2C20 2C20 2020 202C 5348            SM
         4F57 3B41 4438 3030 3C30 2020 2020 2020 2C20 2020 202C 2C20 2C20 202C 202C 2C20      OW;AE;00C0
         2C20 2020 202C 2C20 2020 202C 2020 2020 2C20 2020 202C 2C20 2020 202C 202C 2C20
         2C20 202C 2020 2C20 2020 202C 2020

008 0018 2C20 2038 3132 3133 3533 2020 3130 244C 4F47 2D4F 4E38 4944                          8121353  10SLOG-ON;ID

009 00AE 2C20 2039 3132 3134 3230 2031 3630 2020 2C20 2020 202C 2C20 2020 202C 202C 2C20      9121420 160
         2020 202C 2020 2020 2020 202C 2020 2020 2C20 2020 202C 2C20 2020 202C 2020 2C20
         2020 202C 202C 2020 2C20 2020 2020 2C20 2C20 2020 202C 2C20 2020 202C 202C 4243            BC
         4B50 4158 3B4C 494D 4138 4144 2020 2020 2C20 2020 202C 2C20 2020 202C 202C 2C20      KPAX;LIMA;AD
         2C20 202C 2020 2C20 2020 2020 2020 2020 2C20 2020 202C 2C20 2020 202C 202C 2C20
         2020 2020 2020 2020 2020 2020 2020

00A 0018 2020 3130 3132 3134 3431 2020 3130 244C 4F47 2D4F 4E38 4941                          10121441  10SLOG-ON;IA

00B 00AE 2C20 3131 3132 3135 3132 2031 3630 2C20 2C20 2020 202C 2C20 2020 202C 202C 2C20      11121512 160
         2C20 2020 2020 2C20 2020 2020 2020 2C20 2C20 2020 202C 2C20 2020 202C 202C 2C20
         2020 202C 2020 2C20 2020 2020 2020 2C20 2020 2020 202C 2C20 2C20 202C 202C 4E49            FI
         4E44 3B41 4138 5341 3B4E 4320 2020 2C20 2C20 2020 202C 2C20 2020 202C 202C 2C20      ND;AA;SA;NC
         2020 2020 2020 2C20 2020 2020 2020 2C20 2C20 2020 202C 2C20 2020 2020 2020 2C20
         2C20 202C 2020 2020 2020 202C 2020

00C 0C5E 2C20 3132 3132 3137 3031 2020 3830 2C20 2C20 2020 202C 2C20 2020 202C 202C 2C20      121217C1  80
         2020 202C 202C 2C20 2C20 2020 2020 2C20 2C20 2020 202C 2C20 2020 202C 202C 2C20
         2020 2020 202C 2C20 2020 202C 2020 2020 2020 202C 202C 2C20 2020 202C 2020

0CD 00AE 2C20 3133 3132 3137 3238 2031 3630 2C20 2C20 2020 2020 2C20 2020 2020 202C 2C20      13121728 160
         2C20 202C 2020 2C20 2020 2020 2020 2020 2C20 2020 202C 2C20 2C20 2020 2020 2C20
         2C20 2020 2020 2C20 2020 2020 2020 2C20 2C20 2020 2020 2C20 2C20 202C 202C 4243            BC
         3B55 5341 2020 2C20 2020 202C 2020 2020 2C20 2020 202C 2C20 2020 2045 5252 4F52      ;USA      ERROR
         2049 4E2C 434F 4D4D 414E 4420 464F 5220 4941 2020 2020 2C20 2C20 202C 202C 2C20       IN COMMAND FOR IA
         2C20 2020 2020 2020 2020 2020 2020
```

```
LD  PATH= ^SYSPKO>MARF>RTE>PAX1.S
86/12/25 1256:23.8                                              PAGE 0002

00E 00AE 2020 3134 3132 3138 3233 2031 3630 2020 2020 2020 202C 2C20 2020 2020 202C 2C20     14121823 160
         2020 202C 2020 2C20 2C20 2020 2020 2020 2C20 2020 202C 2C20 2020 2020 202C 2C20
         2C20 2020 202C 2C20 2020 2020 2020 2C20 2C20 2020 2020 2C2C 2C20 2020 202C 4649                    FI
         4E44 3B41 413B 5042 3B4E 432C 2020 2020 2020 2020 202C 2C20 2020 202C 202C 2C20    ND;AA;PB;NC
         2C20 202C 202C 2C20 2C20 2020 2020 2C20 2C20 2070 202C 2C20 2020 202C 202C 2C20
         2020 2020 202C 2C20 2C20 2020 2020

00F 023E 2020 3135 3132 3138 3532 2035 3630 2020 2C20 2020 202C 2C20 2020 202C 2020 2C20     15121852 560
         2C20 202C 2030 2C20 2C20 2020 2020 2020 2C20 2020 202C 2C20 2020 2020 2020 2C20
         2C20 2020 2020 2C20 2C20 2020 2020 2020 2C20 2020 202C 2C20 2020 202C 202C 464C                    FL
         5444 4953 3B53 544C 3B4E 4320 2020 2C20 2C20 2020 202C 2C20 2020 202C 202C 2C20    TDIS;STL;NC
         2C20 202C 2020 2C20 2020 2020 2020 2020 2C20 2020 202C 2C20 2020 202C 202C 2C20
          ....      0002 LINES
         2020 202C 202C 2C20 2020 2020 202C 2C20 2C20 2020 202C 2C20 2020 2020 202C 4C49                    LI
         4E45 2053 5453 2C20 2020 202C 2020 2020 2C20 2C20 2020 2C20 2020 2020 202C 2C20    NE STS
         2C2C 202C 2020 2C20 2020 202C 2020 2C20 2C20 2020 202C 2C20 2020 202C 202C 2C20
         2C2C 202C 2020 2C20 2020 202C 2020 4E42 5220 2052 4551 2C4E 414D 452D 2D2D 2C20              NBR  REQ NAME-----
         2D2D 2D2D 2052 4943 2D20 4752 4420 2D2D 2D2D 2D2D 2D2D 2D2D 2D2D 2D2D 5345 4154    ---- RIC- GRD ----------------SEAT
         5320 4153 5349 474E 4544 2D2D 2D2D 2D2D 2D2D 2D2D 2D2D 2D2D 2D2D 202C 202C 2C20    S ASSIGNED-----------------
         2C20 202C 202C 2C20 2020 2020 2020 2C20 2C20 2020 202C 2C20 2020 202C 2020 2C20
          ....      0001 LINES
         2020 202C 2020 2C20 2020 2020 2020 3036 3035 2043 3031 204D 4152 4620 4646 4620              0605 C01 MARF FFF
         2020 202C 2035 3535 3520 4350 5420 2C20 2C20 2020 202C 2C20 2020 2020 202C 2C20          5555 CPT
         2020 202C 202C 2C20 2C20 2020 2020 2020 2C20 2020 202C 2C20 2020 202C 202C

010 014E 2C20 3136 3132 3139 3139 2033 3230 2020 2C20 2020 202C 2C2C 2020 202C 2020 2C20     16121919 320
         2C20 202C 202C 2C20 2C20 2020 2020 2C20 2C20 2020 2020 2C20 2C20 202C 202C 2C20
         2C20 2020 202C 2C20 2020 2020 2020 2C20 2C20 202C 202C 2C20 2020 202C 202C 464C                    FL
         5444 4953 3B57 5249 2C20 2020 2020 2C20 2C20 202C 202C 2C20 2020 202C 202C 2C20    TDIS;WRI
         2C20 202C 2020 2C20 2C20 202C 2020 2020 2C20 2020 202C 2C20 2020 2020 202C 2C20
          ....      0002 LINES
         2C20 2020 202C 2C20 2020 2020 2020 2C20 2020 202C 202C 2C20 2020 2020 202C 4F50                    OP
         454E 2046 4C54 2C20 4445 5054 2F44 4154 4520 2054 494D 4520 2047 4154 452C 2C44    EN FLT  DEPT/DATE  TIME  GATE  D
         4553 5449 4E41 5449 4F4E 532C 2020 2C20 2C20 2020 202C 2C20 2020 202C 2020 2C20    ESTIMATIONS
         2C20 2020 2020 2C20 2020 2020 2020

011 023E 2C20 3137 3132 3230 3231 2035 3630 2020 2C20 2020 202C 2C20 2020 2020 202C 2C20     17122021 560
         2020 202C 202C 2C20 2C20 2020 2020 2C20 2020 2020 202C 2C20 2020 202C 202C 2C20
         2020 2020 2020 2C20 2020 202C 2020 2C20 2C20 2020 202C 2C20 2020 2020 202C 464C                    FL
         544C 5550 3B57 5249 4652 463B 3336 303B 3132 3030 202C 2C20 2020 202C 202C 2C20    TLUP;WRIFRF;360;1200
         2C20 202C 2020 2C20 2020 2020 2020 2C20 2C20 2020 202C 2C20 2020 202C 202C 2C20
          ....      0002 LINES
         2020 202C 2020 2C20 2020 202C 2020 2020 2C20 2020 202C 2C20 2020 202C 2020 4F50                    OP
         454E 2046 4C54 2C20 4445 5054 2F44 4154 4520 2054 494D 4520 2C47 4154 452C 2C44    EN FLT  DEPT/DATE  TIME  GATE  D
         4553 5449 4E41 5449 4F4E 532C 2020 2C20 2C20 202C 202C 2C20 2C20 202C 2020 2C20    ESTIMATICNS
         2C20 202C 2020 2C20 2020 202C 2020 2C20 2C20 2020 202C 2C20 2C20 2020 202C 2C20
          ....      0001 LINES
         2C20 202C 202C 2C20 2020 202C 2020 2C20 2020 2020 202C 2C20 2020 2020 202C 5553                    US
         3333 202C 4144 2C20 2032 3820 4A41 4E20 2C20 2031 3030 3020 2020 4131 202C 2046    33  AD   28 JAN   1000   A1   F
         5246 2020 202C 2C20 2C20 2020 2020 2C20 2C20 2020 202C 2C20 2020 2020 202C 2C20    RF
         2C20 202C 2020 2C20 2020 202C 2020 3132 3334 2020 4142 2C20 2033 3020 4445 4320              1234  AB   30 DEC
         2C20 2031 3130 3020 2020 4232 2020 2C42 4C56 2020 202C 2C20 2020 2020 202C 2C20      1100   B2   BLV
         2C20 2020 202C 2C20 2020 202C 2020 2C20 2020 202C 202C 2C20 2020 2020 202C

012 048E 2C20 3138 3132 3230 3439 3132 3030 2020 2C20 2020 202C 2C20 2020 2020 202C 2C20     181220491200
         2C20 202C 2020 2C20 2020 2020 2020 2C20 2C20 2020 202C 2C20 2020 2020 202C 2C20
         2C20 202C 2020 2C20 2020 2020 2020 2C20 2C20 2020 202C 2C20 2020 202C 2020 4C49                    LI
         5354 3B41 5052 3B41 4352 463B 3336 303B 3132 3030 202C 2C20 2020 202C 202C 2C20    ST;APR;ACRF;360;1200
```

```
LD  PATH= *SYSPKO>MARF>RTE>PAX1.R
86/12/25 1257:31.9                                          PAGE 0CC1

001 0C0E 2020 2030 3132 3036 3338 2020 3139 1845 1858 4C18 3855 1E58 4218 5864 1872 087F    0120658  19.E.CL.CU.CB.CD.R..
         7F20 2020 2020 2C20 2020 2020 2020 2C20 2020 2020 202C 2C20 2020 202C 202C 2C20  .
         2020 2020 2020 2C20 2020 2020 2020 2020 2C20 2020 202C 2C20 2020 2020 202C 2C20
          ****     0001 LINES
         2020 2020 202C 2C20 2020 2020 2020
002 0C0E 2020 203C 3132 3C34 3338 2020 3137 1840 1848 1858 4ECC 1E58 4100 1871 087F 7F20    0120658  17.8.M.CN..CA..0...
         2020 202C 2020 2C20 2020 2020 2020 2C20 2C20 2020 2020 2C20 2020 202C 202C 2C20
          ****     0004 LINES
         2C20 202C 2020 2020 2020 2020 2020
003 0C0E 2020 2030 3132 3C34 3339 2020 3239 2032 4341 4439 2044 4F52 2C43 4F4E 5452 4F4C    C120659  29 READY FOR CONTROL
         2049 4E50 5554 2C20 C87F 7F20 2020 2020 2020 2020 202C 2C20 2020 202C 202C 2C20  INPUT ....
         2020 2020 2020 2020 2020 2020 2020 2C20 2C20 2020 202C 2C20 2C20 2020 202C 2C20
          ****     0003 LINES
         2020 2020 2020 2020 2020 2020 2020
004 0C0E 2020 2031 3132 3130 3436 2020 3137 1840 1848 1858 4ECC 1E56 4100 1871 087F 7F20    1121044  17.8.M.CN..CA..0...
         2020 202C 2020 2C20 2C20 2020 2020 2C20 2C20 202C 202C 2C20 2C20 202C 2020 2C20
          ****     0004 LINES
         2020 2020 202C 2020 2020 2020 2020
005 0C0E 2020 2031 3132 3130 3435 2031 3039 2C20 2C20 2020 202C 2C20 2020 202C 2020 2C20    1121045 1C9
         2020 2020 2020 2C20 2020 2020 2020 2C20 2C20 2020 202C 2C20 2C20 202C 202C 2C20
         2C20 2020 2020 2C20 2020 2020 2020 2C20 2C20 2020 202C 2C20 2C20 202C 0D0A 5C52                                ..PR
         4F47 5241 5020 4941 2052 4541 4459 2046 4F52 2049 4E50 5554 CD7F 7F2C 202C 2C20  OGRAP IA READY FOR INPUT...
         2020 2020 2020 2C20 2020 2020 2020 2020 2020 2020 202C 2C20 2020 2020 202C 2C20
          ****     0001 LINES
         2020 2020 2020 2020 2020 2920 2020
006 0C0E 2020 2032 3132 3131 3231 2020 3137 1840 1848 1858 4ECC 1858 4100 1871 C87F 7F20    2121121  17.8.M.CN..CA..0...
         2020 2020 2020 2020 2020 2020 2020 2C20 2C20 2020 2020 2C20 2020 2020 202C 2C20
          ****     0004 LINES
         2020 202C 2020 2020 2020 2020 2020
007 0C0E 2020 2032 3132 3131 3233 3139 3233 2020 2C20 2020 202C 2C20 2023 2020 2020 2C20    21211231923
         2020 2020 2020 2020 2020 2020 2020 2C20 2020 2020 202C 2C2C 2C20 2020 202C 2C20
         2020 2020 2020 2020 2020 2020 2020 2C20 2C20 2020 202C 2C20 2020 202C 0D0A 5348                                ..SN
         4F57 3841 4138 3C30 3030 2020 2020 2020 2C20 2020 202C 2C20 2C20 202C 202C 2C20  OW8AA800CO
         2020 2020 2020 2C20 2020 2020 2020 2020 2C20 2020 202C 2C20 2020 202C 202C 2C20
          ****     0002 LINES
         2020 2020 2020 2020 2020 2020 2020 2C20 2020 2020 202C 2C20 2C20 2020 202C 4C49                                  LI
         4E45 2053 5453 2020 2020 2020 2020 2020 2C20 202C 202C 2C20 2C20 2020 202C 2C20  NE STS
         2020 2020 2020 2020 2020 2020 2020 2020 2020 2020 202C 2C20 2020 2020 202C 2C20
         5020 5020 5020 2C20 2020 5020 2020 4E42 5220 2052 4551 2C4E 414D 4520 2D2D 2D2D                  NBR  REQ NAME-----
         2D2D 2D2D 2052 4943 2D20 4752 4420 2D2D 2D2D 2D2D 2D2D 2D2D 2D2D 2D2D 5345 4154  ---- RIC- GRD ---------------SEAT
         5320 4153 5349 474E 4544 2D2D 2D2D 2D2D 2D2D 2D2D 2D2D 2D2D 202C 202C 2C20  S ASSIGNED---------------
         2020 2020 2C20 2C20 2020 2020 2020 2020 2C20 2020 202C 2C20 2020 2020 202C 2C20
          ****     0001 LINES
         2020 202C 2020 2C20 2020 2020 2020 3036 3C31 2030 3031 2C4D 4152 4620 5457 4F20                0601 001 MARF TWO
         2C20 2020 2B33 3434 3420 4350 5420 2020 2020 2020 202C 2C20 2020 2020 202C 2C20      +3444 CPT
         2020 2020 2020 2C20 2C20 2020 2020 2C20 2C20 2020 202C 2C20 2020 202C 202C 3C36                                  06
         3032 203C 3031 204D 4152 4620 5448 5245 4520 4520 2B34 3333 3320 414C 4E20 2C20  02 001 MARF THREE    +4333 AMN
         2020 2020 2020 2C20 2020 2020 2020 2C20 2C20 2020 202C 2C20 2C20 2020 202C 2C20
         2020 202C 2020 2C20 2020 2020 2020 3036 3033 2030 3031 2C4D 4152 462C 464F 5552                0603 001 MARF FOUR
         2020 2020 2B32 3232 3220 434F 4C20 2C20 2C20 2020 202C 2C20 2C20 2020 202C 2C20      +2222 COL
         2020 2020 2020 2020 2020 202C 2020 2C20 2C20 2020 2020 2C20 2C20 2020 2020 3C36                                  06
         3035 2030 3031 204D 4152 4620 4646 4620 2020 2020 2035 3535 3520 435C 5420 2C20  05 C01 MARF FFF       5555 CPT
```

```
LD  PATH= ^SYSPKO>MARF>RTE>PAX1.R
86/12/25 1257:31.9                                                  PAGE 0CC2

         2020 2020 2020 2C20 2020 2020 2020 2C20 2C20 2020 202C 2C20 2C20 202C 202C 2C20            0606 C00 PET ONE
         [illegible]                                                                               RB
                                                                                                                          07
                                                                                        01 0C3 MARF NONE      9090 CCL
                                                                                                         0704 001 MARF OLD
                                                                                              +7664 CPT
                                                                                                                          07
                                                                                        05 0C1 MARF PPP       +4777 CPT
                                                                                                         0706 C01 MARF 000
                                                                                              +2983 CPT
                                                                                                                          07
                                                                                        07 001 MARF TTT       4565 CPT
                                                                                                         07C8 C01 TEST A
                                                                                              +8555 CPT
         2C20 2020 202C 2C20 2020 2020 2020 2020 2C20 2020 202C 2C20 2020 2020 202C 2C20
          ****      0017 LINES
         2020 2020 202C 2C20 2020 2020 2020 0D7F 7F20 2020 202C 2C20 2020 202C 202C 2C20                    ...
         2020 202C 2020 2020 2020 2020 2020 2020 2C20 2020 202C 2C20 2020 202C 202C 2020
          ****      0034 LINES
         2020 202C 2020 2C20 2020 2020 2020

008 0C0E 2020 2033 3132 3131 3533 202C 3137 1860 1840 1858 4ECC 1E58 4100 1871 0D7F 7F20      3121153  17.8.M.CN..CA..0...
         2020 2020 2020 2C20 2020 2020 2020 2020 2C20 2020 202C 2C20 2020 2020 202C 2C20
          ****      0094 LINES
         2020 202C 2020 2020 2020 2020 2020

009 0C0E 2020 2031 3132 3131 3536 2031 3032 2C20 2C20 2020 202C 2C20 2020 202C 202C 2C20      3121154 1C2
         3020 3020 2020 2C20 3020 3020 2020 2C20 3C20 2020 202C 2C20 2020 202C 202C 2C20
         2C20 2020 2020 2C20 2020 2020 2020 2C20 2C20 2020 202C 2C20 2020 202C 0D0A 5349                                ..SI
         474E 204F 4646 2053 5543 4345 5353 4655 4C0D 7F7F 202C 2C20 2020 2C2C 202C 2C20    GN OFF SUCCESSFUL...
         2020 2020 2020 2020 2020 2020 2020 2C20 2C20 2020 2020 2C20 2020 202C 202C 2C20
          ****      0091 LINES
         2C20 202C 2020 2020 2020 2020 2020

00A 0C0E 2020 2034 3132 3132 3132 2020 3137 1860 1840 1858 4ECC 1E58 4100 1871 0D7F 7F20      4121212  17.8.M.CN..CA..0...
         2020 202C 2020 2C20 2020 2020 2020 2020 2C20 2020 202C 2C20 2020 202C 202C 2C20
          ****      0094 LINES
         2020 2020 2020 2C20 2020 2020 2020

00B 0C0E 2020 2034 3132 3132 3133 2031 3039 2020 2C20 2020 202C 2C20 2020 2020 202C 2C20      4121213 109
         2020 2020 2020 2C20 2020 2020 2020 2C20 2C20 2020 202C 2C20 2020 2020 202C 2C20
         2020 202C 2020 2020 2020 2020 2020 2C20 2C20 2020 202C 2C20 2020 202C 0D0A 5052                                ..PR
         4F47 5241 4D20 4944 2052 4541 4459 2046 4F52 2049 4E5C 5554 CD7F 7F2C 202C 2C20    OGRAM ID READY FOR INPUT...
         2020 2020 2020 2C20 2C20 2020 2020 2C20 2C20 2020 202C 2C20 2020 2020 202C 2C20
          ****      0091 LINES
         2020 2020 2020 2020 2020 2020 2020

00C 0C0E 2020 2035 3132 3132 3333 2020 3137 1860 1840 1858 4ECC 1E5E 4100 1871 0D7F 7F20      5121233  17.8.M.CN..CA..0...
         2C20 202C 202C 2C20 2020 2020 2020 2C20 2C20 2020 2020 2C20 2C20 202C 2020 2C20
          ****      0096 LINES
         2020 202C 2020 2020 2020 202C 2020

00D 0C0E 2020 2035 3132 3132 3335 3139 3233 2C20 2C20 2020 202C 2C20 2C20 2020 202C 2C20      51212351923
         2020 2020 2020 2C20 2020 202C 2020 2C20 2C20 2020 202C 2C20 2C20 202C 202C 2C20
```

```
D         "
W         #
O         REPORT

DT  12C
DW   15
S         "$LOG-ON;IA"
L     3
W    31
C         "IGNORE"

S         "                                                             "
SC        "            SHOW;AA;COOC                                     "
SC        "
L    25
W    27
C         "IGNORE"

S         "$LOG-OFF"
L     3
W    15
C         "IGNORE"

S         "$LOG-ON;ID"
L     3
W    17
C         "IGNORE"

S         "                                                             "
SC        "            GET;MARF TTT;AA                                  "
SC        "
L    25
W    11
C         "IGNORE"

S         "$LOG-ON;IA"
L     3
W    11
C         "IGNORE"

S         "                                                             "
SC        "            SHOW;AD;COOC                                     "
SC        "
L    25
W    69
C         "IGNORE"

S         "$LOG-ON;ID"
L     3
W    23
C         "IGNORE"

S         "                                                             "
SC        "            BCKPAX;LIMA;AD                                   "
SC        "
L    25
W    17
C         "IGNORE"
```

```
S        "$LOG-ON;IA"
L      7
W     29
C        "IGNORE"

S        "                                                                    "
SC       "          FIND;AA;SA;NC                                             "
SC       "
L     25
W     99
C        "IGNORE"

S        "                                                                    "
SC       "          "
L     25
W     21
C        "IGNORE"

S        "                                                                    "
SC       "          BC;LSA                       ERROR IN COMMAND FCR IA      "
SC       "                 "
L     25
W     49
C        "IGNORE"

S        "                                                                    "
SC       "          FIND;AA;PB;NC                                             "
SC       "
L     25
W     18
C        "IGNORE"

S        "                                                                    "
SC       "          FLTDIS;STL;NC                                             "
SC       "                                                                    "
SC       "                            LINE STS                                "
SC       "                                  NBR  REQ NAME--------- RIC- CRD ---"
SC       "------------SEATS ASSIGNED---------------                           "
SC       "                                                  06CS OC1 MARF FFF"
SC       "       5555 CPT
L     25
W     24
C        "IGNORE"

S        "                                                                    "
SC       "          FLTCIS;WRI                                                "
SC       "                                                                    "
SC       "                            OPEN FLT "DEPT/CATE  TIME  GATE  DESTINATION"
SC       "S
L     25
W     58
C        "IGNORE"

S        "                                                                    "
SC       "          FLTLUP;WRIFRF;360;1200                                    "
SC       "                                                                    "
SC       "                            OPEN FLT  DEPT/DATE  TIME  GATE  DESTINATION"
SC       "S                                                                   "
SC       "                                           LS33  AD   28 JAN    10CG "
SC       "  A1   FRF                                 1234  AB   30 DEC"
```

Appendix D: Screenfaces for Response Verificaion

This appendix contains examples of screenfaces generated by the response verification command of the Autogen module.

```
                                                      DW=  15
TRANSACTION:    1
LABEL: NONE
STIMULUS TEXT:
$LOG-ON;IA
LENGTH OF RESPONSE:   2
WAIT TIME:   31
CONTINGENCY ACTION: IGNORE
COMMAND:
```

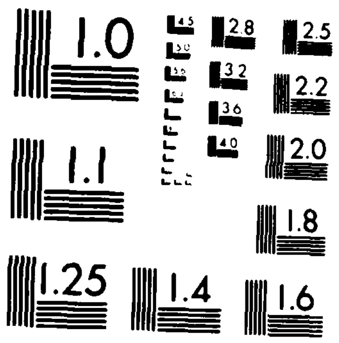
```
   1: _`_M_[N__[A__q___

   2:                    __PROGRAM IA READY FOR INPUT___
IS DESIRED STARTING LINE ON THIS PAGE? (Y/N)
ENTER STARTING LINE NUMBER:
```

```
1...+....1....+....2....+....3....+....4....+....5....+....6...
_`_M_[N__[A__q___
START OF RESPONSE TEXT:
```

```
   1: _`_M_[N__[A__q___

   2:                    __PROGRAM IA READY FOR INPUT___
IS DESIRED ENDING   LINE ON THIS PAGE? (Y/N)
ENTER ENDING LINE NUMBER:
```


1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

```
1...+....1....+....2....+....3....+....4....+....5....+....6...
_`_M_[N__[A__q___
END OF RESPONSE TEXT:
```

```
                                                    DW=  15
TRANSACTION:    1
LABEL: NONE
STIMULUS TEXT:
$LOG-ON;IA
LENGTH OF RESPONSE:   2
RESPONSE TEXT:
_`_M_[N__[A__q___
WAIT TIME:   31
CONTINGENCY ACTION: IGNORE
COMMAND:
```

Appendix E: Reports Generated During Stress Test

This appendix contains examples of reports generated by the RTE report generator (E - 2 and E - 3) and reports from the sponsor's computer performance evaluation systeem (E - 4 through E - 7).

```
**************   REMCTE TERMINAL EMULATOR -LOG EXPANSION   *************
CODE LINE SCRIPT          TRANSACTICN DESCRIPTION                      TIME
-------------------------------------------------------------------------------

 T      1 -   1    TRANSPISSION OF STIPULUS    1                      12:35:26
 R      1 -   1    RESFCNSE TO STIPULUS  1 RECEIVEC                   12:35:43
                 --  NCT CCMPARED  --
 V      1 -   1    RESFONSE TO STIPULUS   1 VERIFIED                  12:35:43
 T      1 -   1    TRANSMISSION OF STIPULUS    2                      12:35:44
 R      1 -   1    RESPCNSE TC STIPULUS  2 RECEIVED                   12:36: 2
                 --  NOT CCMPARED  --
 V      1 -   1    RESPCNSE TO STIPULUS   2 VERIFIEC                  12:36: 2
 T      1 -   1    TRANSMISSION OF STIPULUS    3                      12:36: 2
 R      1 -   1    RESPCNSE TO STIPULUS  3 RECEIVEC                   12:36:19
                 --  NCT CCMPARED  --
 V      1 -   1    RESPCNSE TO STIPULUS   3 VERIFIEC                  12:36:19
 T      1 -   1    TRANSPISSION CF STIPULUS    4                      12:36:19
 R      1 -   1    RESFCNSE TO STIPULUS  4 RECEIVED                   12:36:35
                 --  NCT CCMPARED  --
 V      1 -   1    RESPCNSE TO STIPULUS   4 VERIFIED                  12:36:35
 T      1 -   1    TRANSMISSION OF STIPULUS    5                      12:36:36
 R      1 -   1    RESPCNSE TO STIPULUS  5 RECEIVED                   12:36:53
                 --  NCT COMPARED  --
 V      1 -   1    RESPCNSE TO STIPULUS   5 VERIFIEC                  12:36:53
 T      1 -   1    TRANSMISSION OF STIPULUS    6                      12:36:53
 R      1 -   1    RESPONSE TO STIPULUS  6 RECEIVED                   12:37:10
```

```
                      --  NCT CCMPARED  --
V       1 - 1    RESPONSE TO STIPULUS   6 VERIFIED          12:37:1C
T       1 - 1    TRANSPISSICN OF STIPULUS    7              12:37:11
R       1 - 1    RESPCNSE TO STIPCLUS  7 RECEIVEC           12:37:29
                      --  NOT COMPARED  --
V       1 - 1    RESPONSE TO STIPULUS   7 VERIFIEC          12:37:29
T       1 - 1    TRANSMISSION OF STIPULUS    8              12:37:3C
R       1 - 1    RESPCNSE TO STIPULUS  8 RECEIVED           12:37:4C
                      --  NOT CCMPARED  --
V       1 - 1    RESPONSE TO STIPULUS   8 VERIFIED          12:37:4C
T       1 - 1    TRANSMISSION OF STIMULUS    9              12:37:47
R       1 - 1    RESPCNSE TO STIPLLUS  9 RECEIVED           12:38: 4
                      --  NOT CCMPARED  --
V       1 - 1    RESPONSE TO STIMULUS   9 VERIFIED          12:38: 4
T       1 - 1    TRANSMISSION OF STIMULUS   1C              12:38: 4
R       1 - 1    RESPCNSE TO STIPULUS 10 RECEIVEC           12:38:2C
                      --  NOT COMPARED  --
V       1 - 1    RESPCNSE TO STIPULUS  10 VERIFIED          12:38:2C
T       1 - 1    TRANSMISSION OF STIMULUS   11              12:38:21
R       1 - 1    RESPONSE TO STIPULUS 11 RECEIVED           12:38:44
                      --  NCT CCMPARED  --
V       1 - 1    RESPCNSE TO STIPULUS  11 VERIFIED          12:38:44
T       1 - 1    TRANSMISSION OF STIPULUS   12              12:38:45
R       1 - 1    RESPCNSE TO STIPULUS 12 RECEIVED           12:39: 2
```

```
                          COMPUTER PERFORMANCE EVALUATION - QUEUE TIME ANALYSIS

SYS-ID      TX-NUM        PGM-ID  DEVICE-ID      TIME-1          TIME-2      EXECUTION-TIME      QUEUE-TIME

  40       0000000001       IA       LC        1217:49.766     1217:57.766     0000:08.000       0000:00.650
  40       0000000001       IA       LL        1218:06.766     1218:33.233     0000:26.467
  40       0000000001       IA       LN        1218:16.766     1218:36.400     0000:15.634
  40       0000000001       IA       LP        1218:26.841     1218:41.775     0000:14.934
THIS APPLICATION CAUSED A QUEUE                1218:27.058     1218:35.675
  40       0000000001       IA       LC        1218:29.766     1219:09.450     0000:35.684       0000:09.909
  40       0000000001       IA       LL        1218:50.275     1219:07.366     0000:17.091
  40       0000000001       IA       LP        1219:03.175     1219:12.850     0000:09.675
THIS APPLICATION CAUSED A QUEUE                1219:03.405     1219:04.000
  40       0000000001       IA       LN        1219:00.100     1219:12.858     0000:12.758       0000:03.900
  40       0000000001       IA       LL        1219:22.900     1219:47.941     0000:24.941
  40       0000000001       IA       LN        1219:32.900     1219:55.833     0000:22.933
  40       0000000001       IA       LP        1219:42.975     1219:52.758     0000:09.783
  40       0000000001       IA       LC        1219:46.100     1219:56.000     0000:09.900
  40       0000000001       IA       LL        1220:05.100     1220:29.641     0000:26.541
  40       0000000001       IA       LP        1220:25.175     1220:43.741     0000:18.566
THIS APPLICATION CAUSED A QUEUE                1220:25.408     1220:47.158
  40       0000000001       IA       LN        1220:15.100     1220:43.750     0000:28.650       0000:12.058
THIS APPLICATION CAUSED A QUEUE                1220:28.016     1220:28.575
  40       0000000001       IA       LC        1220:27.900     1220:43.750     0000:15.850       0000:00.675
  40       0000000001       IA       LL        1220:32.891     1221:26.000     0000:33.105
  40       0000000001       IA       LP        1221:12.708     1221:26.008     0000:13.300
THIS APPLICATION CAUSED A QUEUE                1221:12.958     1221:13.308
  40       0000000001       IA       LN        1221:01.633     1221:26.008     0000:24.375       0000:11.675
THIS APPLICATION CAUSED A QUEUE                1221:16.508     1221:18.141
  40       0000000001       IA       LC        1221:16.100     1221:38.123     0000:22.025       0000:02.041
  40       0000000001       IA       LL        1221:44.783     1222:05.883     0000:18.500
  40       0000000001       IA       LP        1221:45.633     1222:03.966     0000:16.333
  40       0000000001       IA       LN        1221:57.650     1222:05.958     0000:08.075
THIS APPLICATION CAUSED A QUEUE                1221:58.066     1221:58.875
  40       0000000001       IA       LC        1221:56.633     1222:07.600     0000:10.967       0000:02.242
  40       0000000001       IA       LL        1222:19.700     1222:45.375     0000:25.675
  40       0000000001       IA       LP        1222:19.800     1222:49.283     0000:05.483
THIS APPLICATION CAUSED A QUEUE                1222:40.025     1222:40.358
  40       0000000001       IA       LN        1222:29.708     1222:49.958     0000:20.250       0000:10.617
THIS APPLICATION CAUSED A QUEUE                1222:43.758     1222:44.283
  40       0000000001       IA       LC        1222:43.633     1222:51.641     0000:08.008       0000:00.650
  40       0000000001       IA       LL        1223:00.766     1223:25.441     0000:24.675
  40       0000000001       IA       LP        1223:20.841     1223:29.358     0000:08.517
THIS APPLICATION CAUSED A QUEUE                1223:21.100     1223:21.633
  40       0000000001       IA       LN        1223:10.766     1223:30.058     0000:19.259       0000:10.867
THIS APPLICATION CAUSED A QUEUE                1223:23.808     1223:34.158
  40       0000000001       IA       LC        1223:23.700     1223:31.700     0000:08.000       0000:00.425
  40       0000000001       IA       LL        1223:40.766     1224:05.508     0000:24.742
  40       0000000001       IA       LP        1224:00.841     1224:07.808     0000:06.967
THIS APPLICATION CAUSED A QUEUE                1224:01.100     1224:01.941
  40       0000000001       IA       LN        1223:50.775     1224:09.383     0000:18.608       0000:11.166
THIS APPLICATION CAUSED A QUEUE                1224:03.891     1224:04.450
  40       0000000001       IA       LC        1224:03.766     1224:11.058     0000:07.292       0000:00.684
  40       0000000001       IA       LC        1224:45.766     1224:52.008     0000:06.242
```

```
                        CCMPUTER PERFCRMANCE EVALUATICN JCRNALIZATICN REPCRT
                                          HQ MAC/ADCI

     * * * PRCCESSING =N-C-R-M-A-L

TYPE=>>  TYPE-1C=> MIOH'S FCR INTERACTIVE DEVICES
       TX-NUM          PRCGRAM-ID          DEVICE-ID             TIME-1             TIME-2

     *9999999999        FLIGHT(IA)            LL             1235:42.575        1235:43.C34
      CCCCCCCCCC1       FLIGHT(IA)            LL             1235:58.7CC        1236:02.675
      CCCCCCCCCC1       *                     LL             1236:18.575        1236:19.C42
      CCCCCCCCCC1       CHK-IN(ID)            LL             1236:34.575        1236:35.C42
      CCCCCCCCCC1       CHK-IN(ID)            LL             1236:5C.7CC        1236:53.65C
      CCCCCCCCCC1       FLIGHT(IA)            LL             1237:C9.575        1237:1C.C92
      CCCCCCCCCC1       FLIGHT(IA)            LL             1237:25.7CC        1237:29.75C
      CCCCCCCCCC1       CHK-IN(ID)            LL             1237:45.575        1237:46.C92
      CCCCCCCCCC1       CHK-IN(ID)            LL             1238:C1.7CC        1238:04.45C
      CCCCCCCCCC1       FLIGHT(IA)            LL             1238:19.575        1238:2C.100
      CCCCCCCCCC1       FLIGHT(IA)            LL             1238:35.7CC        1238:44.25C
      CCCCCCCCCC1       FLIGHT(IA)            LL             1238:59.634        1239:C1.984
      CCCCCCCCCC1       FLIGHT(IA)            LL             1239:17.7CC        1239:2C.342
      CCCCCCCCCC1       FLIGHT(IA)            LL             1230:35.7CC        1239:44.259
      CCCCCCCCCC1       FLIGHT(IA)            LL             124C:CC.C34        124C:C2.742
      CCCCCCCCCC1       FLIGHT(IA)            LL             124C:18.542        124C:21.425
      CCCCCCCCCC1       FLIGHT(IA)            LL             124C:37.C34        124C:4C.842
      CCCCCCCCCC1       FLIGHT(IA)            LL             1240:57.567        124C:59.984
      CCCCCCCCCC1       FLIGHT(IA)            LL             1241:16.567        1241:19.342
      CCCCCCCCCC1       FLIGHT(IA)            LL             1241:34.634        1241:37.934
      CCCCCCCCCC1       FLIGHT(IA)            LL             1241:53.7CC        1241:56.309
      CCCCCCCCCC1       FLIGHT(IA)            LL             1242:11.7CC        1242:14.659
      CCCCCCCCCC1       MN-RES(IC)            LL             1242:3C.575        1242:31.C84
      CCCCCCCCCC1       MN-RES(IC)            LL             1242:46.7CC        1242:49.809
      CCCCCCCCCC1       CHK-IN(ID)            LL             1242:46.7CC        1243:06.15C
      CCCCCCCCCC1       CHK-IN(ID)            LL             1243:21.7CC        1243:24.359
      CCCCCCCCCC1       CHK-IN(ID)            LL             1243:39.7CC        1243:42.15C
      CCCCCCCCCC1       FLIGHT(IA)            LL             1243:57.575        1243:58.1CC
      CCCCCCCCCC1       FLIGHT(IA)            LL             1244:13.7CC        1244:17.767
      CCCCCCCCCC1       CHK-IN(ID)            LL             1244:33.575        1244:34.C67
      CCCCCCCCCC1       CHK-IN(ID)            LL             1244:49.7CC        1244:53.625
      CCCCCCCCCC1       CHK-IN(ID)            LL             1245:1C.5CC        1245:13.15C
      CCCCCCCCCC1       CHK-IN(IC)            LL             1245:28.575        1245:29.C67

             ***** >>>TCTALS:       NBR CF TRANSACTIONS        HIGH              LCW
                                          CCC33             CCCC:19.45C      CCCC:0C.459
                                                              (CCC25)           (CCCC1)
                                    REC-TYPE AVERAGE
                                     (CCOC:C3.098)
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                     COMPUTER PERFORMANCE EVALUATION JORNALIZATION REPORT
                                        HQ MAC/ADCI

   * * * PROCESSING =N-O-R-M-A-L

TYPE=>>  TYPE-13=> MFILMT PROGRAM
   TX-NUM          PROGRAM-ID         DEVICE-ID          TIME-1          TIME-2

  0000000001       FLIGHT(IA)            --            1235:59.425     1235:59.534
  0000000001       FLIGHT(IA)            --            1235:59.559     1235:59.634
  0000000001       FLIGHT(IA)            --            1235:59.650     1235:59.734
  0000000001       FLIGHT(IA)            --            1235:59.750     1235:59.834
  0000000001       FLIGHT(IA)            --            1235:59.850     1235:59.942
  0000000001       FLIGHT(IA)            --            1235:59.959     1236:00.034
  0000000001       FLIGHT(IA)            --            1236:00.050     1236:00.134
  0000000001       FLIGHT(IA)            --            1236:00.150     1236:00.234
  0000000001       FLIGHT(IA)            --            1236:00.250     1236:00.334
  0000000001       FLIGHT(IA)            --            1236:00.350     1236:00.434
  0000000001       FLIGHT(IA)            --            1236:00.450     1236:00.534
  0000000001       FLIGHT(IA)            --            1236:00.559     1236:00.650
  0000000001       CHK-IN(ID)            --            1236:50.884     1236:51.000
  0000000001       CHK-IN(ID)            --            1236:51.150     1236:51.292
  0000000001       CHK-IN(ID)            --            1236:51.317     1236:51.392
  0000000001       CHK-IN(ID)            --            1236:51.442     1236:51.567
  0000000001       CHK-IN(ID)            --            1236:51.742     1236:51.742
  0000000001       FLIGHT(IA)            --            1237:26.400     1237:26.525
  0000000001       FLIGHT(IA)            --            1237:26.542     1237:26.642
  0000000001       FLIGHT(IA)            --            1237:26.659     1237:26.750
  0000000001       FLIGHT(IA)            --            1237:26.767     1237:26.850
  0000000001       FLIGHT(IA)            --            1237:26.867     1237:26.950
  0000000001       FLIGHT(IA)            --            1237:26.967     1237:27.050
  0000000001       FLIGHT(IA)            --            1237:27.067     1237:27.142
  0000000001       FLIGHT(IA)            --            1237:27.167     1237:27.250
  0000000001       FLIGHT(IA)            --            1237:27.267     1237:27.342
  0000000001       FLIGHT(IA)            --            1237:27.367     1237:27.442
  0000000001       FLIGHT(IA)            --            1237:27.467     1237:27.542
  0000000001       FLIGHT(IA)            --            1237:27.559     1237:27.642
  0000000001       FLIGHT(IA)            --            1237:27.659     1237:27.734
  0000000001       CHK-IN(ID)            --            1238:01.875     1238:01.992
  0000000001       CHK-IN(ID)            --            1238:02.092     1238:02.259
  0000000001       CHK-IN(ID)            --            1238:02.275     1238:02.359
  0000000001       CHK-IN(ID)            --            1238:02.334     1238:02.542
  0000000001       FLIGHT(IA)            --            1238:36.417     1238:36.525
  0000000001       FLIGHT(IA)            --            1238:36.550     1238:36.625
  0000000001       FLIGHT(IA)            --            1238:36.642     1238:36.725
  0000000001       FLIGHT(IA)            --            1238:36.742     1238:36.825
  0000000001       FLIGHT(IA)            --            1238:36.842     1238:36.934
  0000000001       FLIGHT(IA)            --            1238:36.950     1238:37.025
  0000000001       FLIGHT(IA)            --            1238:37.042     1238:37.125
  0000000001       FLIGHT(IA)            --            1238:37.142     1238:37.225
  0000000001       FLIGHT(IA)            --            1238:37.242     1238:37.325
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                         COMPUTER PERFORMANCE EVALUATION JOURNALIZATION REPORT
                                             HQ MAC/ADCI

   * * * PROCESSING =N-O-R-M-A-L

TYPE=>>  TYPE-14=> APPLICATIONS PROGRAM
      TX-NUM            PROGRAM-ID         DEVICE-ID             TIME-1            TIME-2

    0000000001          FLIGHT(IA)            LL             1235:58.842       1236:00.725
    0000000001          CHK-IN(ID)            LL             1236:50.759       1236:51.700
    0000000001          FLIGHT(IA)            LL             1237:25.825       1237:27.800
    0000000001          CHK-IN(ID)            LL             1238:01.750       1238:02.492
    0000000001          FLIGHT(IA)            LL             1238:35.834       1238:42.300
    0000000001          FLIGHT(IA)            LL             1238:59.742       1239:00.042
    0000000001          FLIGHT(IA)            LL             1239:17.925       1239:18.384
    0000000001          FLIGHT(IA)            LL             1239:35.809       1239:42.300
    0000000001          FLIGHT(IA)            LL             1240:00.150       1240:00.792
    0000000001          FLIGHT(IA)            LL             1240:18.950       1240:19.475
    0000000001          FLIGHT(IA)            LL             1240:37.150       1240:38.900
    0000000001          FLIGHT(IA)            LL             1240:57.692       1240:58.034
    0000000001          FLIGHT(IA)            LL             1241:16.717       1241:17.309
    0000000001          REPORT(IB)            --             1241:17.234       1241:21.225
    0000000001          FLIGHT(IA)            LL             1241:34.759       1241:35.050
    0000000001          FLIGHT(IA)            LL             1241:53.809       1241:54.359
    0000000001          REPORT(IB)            --             1241:57.975       1242:00.692
    0000000001          FLIGHT(IA)            LL             1242:11.825       1242:12.667
    0000000001          REPORT(IB)            --             1242:12.134       1242:23.875
    0000000001          MN-RES(IC)            LL             1242:46.800       1242:47.817
    0000000001          CHK-IN(ID)            LL             1243:21.759       1243:22.409
    0000000001          CHK-IN(ID)            LL             1243:39.725       1243:40.200
    0000000001          FLIGHT(IA)            LL             1244:13.842       1244:15.825
    0000000001          CHK-IN(ID)            LL             1244:49.759       1244:51.659
    0000000001          CHK-IN(ID)            LL             1245:10.559       1245:11.200

          ***** >>>TOTALS:      NBR OF TRANSACTIONS          HIGH              LOW
                                       00025              0000:06.491     0000:00.291
                                                           (00009)          (00015)
                                 REC-TYPE AVERAGE
                                  (0000:01.760)
```

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VITA

Captain Craig J. Riesberg was born 9 November 1949 in Carroll, Iowa. He graduated from Kuemper High School in 1967. He enlisted in the United States Air Force 17 August, 1971. He attended the University of Texas in San Antonio and graduated in 1981, receiving the degree of Bachelor of Science in Mathematics and Computer Science. He was commissioned a Second Lieutenant in May 1981.

Captain Riesberg was assigned to the 1500 Computer Services Squadron, as a Software Validation and Computer Performance Evaluation Officer prior to his assignment at the School of Engineering, Air Force Institute of Technology in May of 1986.

Permanent address: 435 Ridgewood Drive
Carroll, Iowa, 51401

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MODIFICATION, IMPLEMENTATION, AND EVALUATION OF A REMOTE TERMINAL EMULATOR AS A SOFTWARE VALIDATION AND STRESS TESTING TOOL

12. PERSONAL AUTHOR(S)
Craig J. Riesberg, B.S., Captain, US Air Force

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19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

This project involved the modification, implementation and evaluation of a remote terminal emulator (RTE) as a software validation and stress testing tool. The work, sponsored by the Directorate of Integration and Standardization, Military Airlift Command, utilized a Honeywell DPS-6 Model 95 minicomputer as the host for the RTE application package.

Considerable background information is provided about the sponsor's release environment to show the sponsor's need for a reliable testing tool. Information is also presented about acceptance and validation testing.

The emphasis of this research centered on a RTE made available by the Joint Data System Support Center. This software package, capable of emulating multiple users, needed major modifications before implementation on the sponsor's equipment. After successful implementation, the study examined two areas of use for the sponsor.

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19. The modified package was found to be a very good tool for software validation. Comparisons are made between the RTE and the sponsor's internal test driver in the areas of scenario collection and management. The two tools are also compared during the emulation phase of software validation.

The RTE package was also examined as a stress testing tool. Several problems in the RTE application software which inhibit its use as a stress testing tool are discussed.