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COMPUTER AIDED TRAINING: DEVELOPMENT AND APPLICATION OF A ROCKET MOTOR ALTITUDE TEST CELL SIMULATOR

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Andrew Lewis Pickens, Jr.

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The work reported herein was accomplished at the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), Arnold Air Force Station, Tennessee. Further reproduction is authorized to satisfy the needs of the U. S. Government.

And finally, a special thanks to my wife, Marcia, and daughters, Beth and Leigh, without whose patience, understanding, and personal sacrifice this work would not have been possible.

ABSTRACT

The current training methods used by United States Air Force military engineers assigned as Rocket Propulsion Test Engineers in the Arnold Engineering Development Center's Engine Test Facility, were studied and most were determined to be inefficient. To enhance efficiency, the basic principles associated with testing a rocket motor in an altitude test cell were modelled and simulated on a computer.

Computer aided training, computer aided instruction, modelling, and simulation were researched for methods to enhance this application. Of the various methods researched, those that were selected fit the criteria of user friendliness, portability, and realism. Portability was especially important because it allows a more general application of the program.

Developing the program required extensive data analysis to model the testing principles. The results of this analysis allowed assumptions to be made which significantly simplified the model.

The result of the research, data analysis, and program development was a rocket motor test cell simulator that allows a user to conduct a simulated test through interactive graphics. Because this training method is fast, economical, and repetitive, the user can learn these principles in an extremely efficient manner.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Background

The altitude stages of rockets and missiles, and satellite space motors are routinely tested in four simulated altitude propulsion development test cells at the Arnold Engineering Development Center's (AEDC) Engine Test Facility (ETF). These test cells simulate altitude conditions of typically 100,000 ft. for sustained periods of approximately four hours. The altitude parameters simulated are pressure and temperature. The test cell ambient pressure corresponding to the desired geopotential altitude is obtained with a steam ejector-diffuser system operating in conjunction with rotating exhauster machinery. The test facility schematic in Figure 1 shows the major system components and the locations of the parameter instrumentation. Table 1 defines these parameters. A temperature conditioning system maintains the desired test cell ambient temperature. The test facilities are described in greater detail in reference [1][1].

The facilities at AEDC are owned by the Air Force, but the technical operation of the center is contracted to civilian operating contractors (OC). Air Force military engineers assigned to AEDC are responsible for monitoring the OC and evaluating OC performance.

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[1]Numbers in brackets refer to similarly numbered references in the Bibliography.

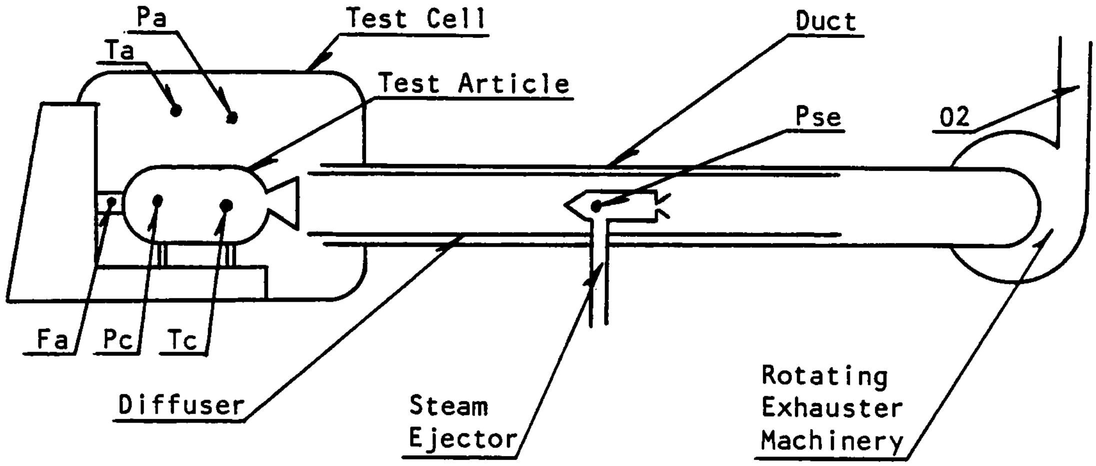

Figure 1. Test Facility Schematic

Table 1

Parameter Definitions

Facility Parameters	Test Article Parameters
Pa-Test cell ambient pressure	Fa-Motor thrust
Pse-Steam ejector pressure	Pc-Chamber pressure
O_2-Oxygen volume (percent)	Tc-Motor case temperature
Ta-Test cell ambient temperature	

Primarily because Air Force military engineers are only assigned to AEDC for four years and are initially inexperienced, it is especially important that the engineer becomes productive on the job as rapidly as possible. However, current training methods for these engineers were inadequate for maximum efficiency.

The scope of this work was to research computer aided training methods and apply those appropriate, to the specific case of training Air Force Rocket Propulsion Test Engineers at AEDC. Hereafter, the terms Air Force engineer and trainee are assumed synonymous since the Air Force engineer was the primary target of the computer aided training. The Rocket Motor Test Cell Simulator is a software program developed in the course of this research as a training tool. It is general enough to have applications outside the Air Force and will benefit anyone who requires training in AEDC rocket propulsion testing principles.

Statement of the Problem

The efficiency of the training methods for Air Force Rocket Propulsion Test Engineers at AEDC needed to be improved. Of particular concern was the time it took a trainee to become minimally proficient on the job. Minimum job proficiency was defined as that point in time when the trainee could function self-sufficiently on the job with minimal assistance from others. Many factors such as job complexity, the trainee's experience (most are assigned to AEDC fresh from undergraduate school), and time consuming training methods inhibit rapid job proficiency. Job complexity includes both the complex nature of the AEDC facilities, and the general nature of the duties expected of the trainee. These duties particularly hindered efficiency because, for example, an electrical engineer could also have to become intimately familiar with mechanical systems to adequately monitor assigned projects.

Training methods included reading, formal education, on the job training (OJT), trial and error, and short courses. The short courses could be one hour to two weeks in duration, formal or informal, and were generally limited in scope to one small aspect of the job. With the occasional exception of the short courses, these training methods didn't utilize modern training concepts.

The Solution

One method to improve training efficiency is through computer aided training. The computer can be applied to many aspects of the job. One specific application, the modelling and simulation of the rocket motor testing operations, was selected as a first (and most significant) step toward training efficiency. This application encompasses the point in time immediately before the rotating exhauster machinery (plant) is activated, ignition and firing of the rocket motor (test article), plant deactivation, and post test conditions when the pressure is returned to normal atmospheric. This period of time nominally takes four hours, but through several appropriate assumptions this whole process was simulated on a computer and condensed to approximately a twenty minute training session.

The primary goal of an interactive session on the simulator is to successfully ignite and test a rocket motor, while minimizing consummable resources. To successfully ignite the motor the countdown time must be correct and the oxygen level must be below 4% (by volume). To successfully test a motor it must be ignited successfully, photographic and digital data must be acquired during the entire motor burn time, and the motor must be successfully quenched after it burns out. Digital data must be acquired at the maximum sampling rate during the firing. The consummable resources are gaseous nitrogen (GN_2), film, and data storage space. Efficient use of these resources will minimize their consumption. Adverse consequences of improper actions range from loss of various data to destruction of the rocket motor or test facility.

A help file is provided to assist the trainee when required. The tree diagram in Figure 2 shows that the help file was designed hierarchically with three levels of increasing detail. Level one, the least detailed, provides parameter and control definitions. Level two presents a basic discussion on the purpose and use of the parameters and controls. The most detail was presented in level three. This level gives the assumptions made for the simulation so the principles in the simulator can be applied to the actual testing process.

In the following chapters, the research effort is discussed in detail. In Chapter II, the hardware and programming language are discussed. A typical test cell description is also presented. A review of rocket motor simulated altitude test cell principles is included in Chapter III. Computer aided training methods that were researched are discussed in Chapter IV. Chapter V contains a

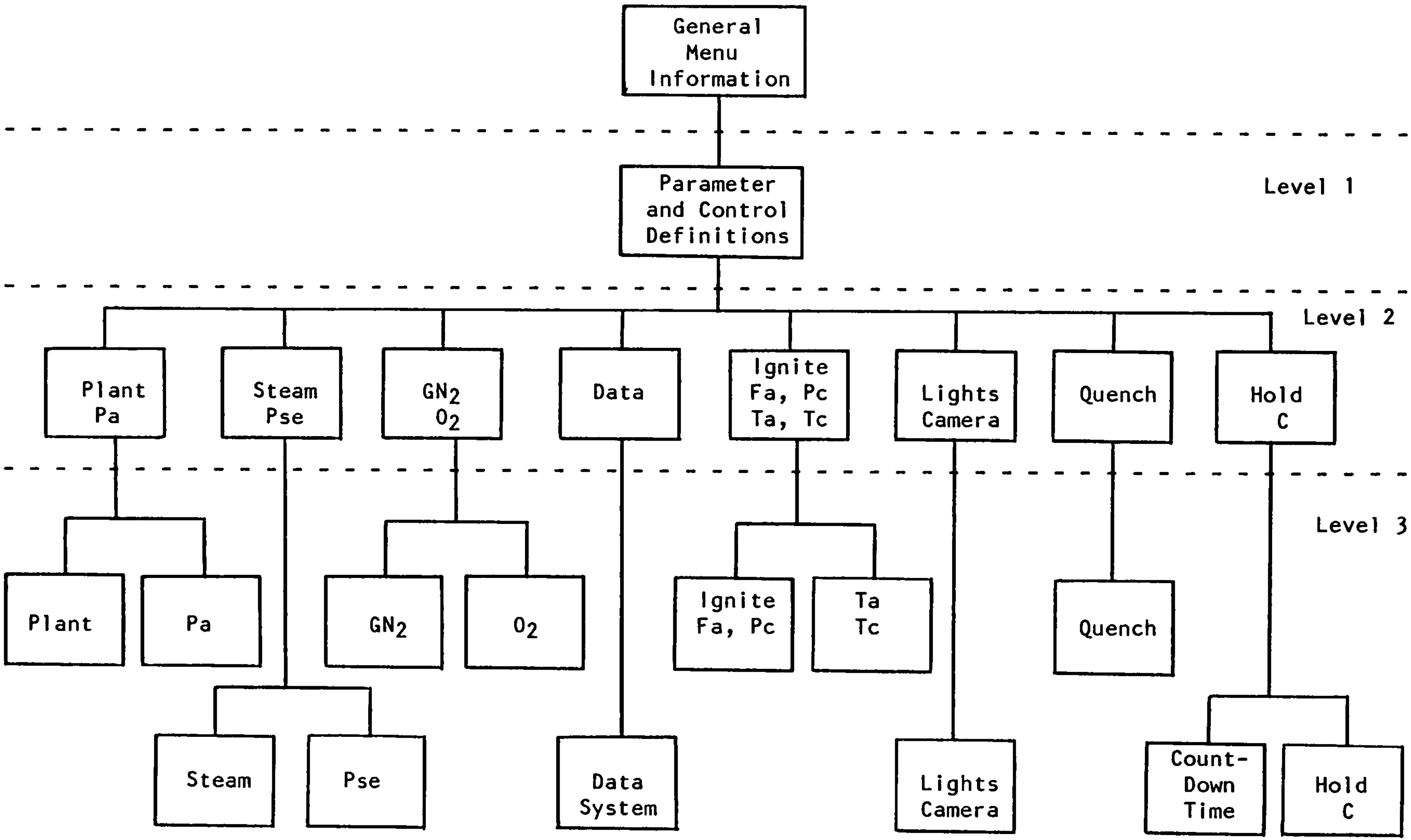

Figure 2. Help File Tree Diagram

detailed description of the simulator program. And finally, in Chapter VI, the effort is summarized and conclusions are presented.

CHAPTER II

APPARATUS

Computer

The software was developed on an IBM 9002 desktop computer. This system is based on the M68000 microprocessor and is configured with 640K of RAM. It has two 5¼ in. diskette drives and a monochrome, 480 (height) by 768 (width) pixel, CRT display. The host language is IBM BASIC, version 1.2, supported by the computer system operating sytem (CSOS), release 1.13. The computer has ten programmable "softkeys" located immediately below the CRT display, and ten programmable function keys on the keyboard. The system is described thoroughly in reference [2]. The IBM 9002 computer is shown in Figure 3.

A personal computer was selected for four major reasons. The first reason is user friendliness. The programmable keys provide an easily understandable method of user interaction. The second reason is realism. The programmable keys simulate the way a test conductor actually controls test parameters; pushing buttons on a control panel. The third reason is the portability of this user interaction method on computers which have programmable keys. And the fourth reason is the ease of using the simulator. A dedicated system can prevent interruptions from timesharing operating systems, downtime from system maintenance and backup procedures, and confusion from complicated job control language and operating systems.

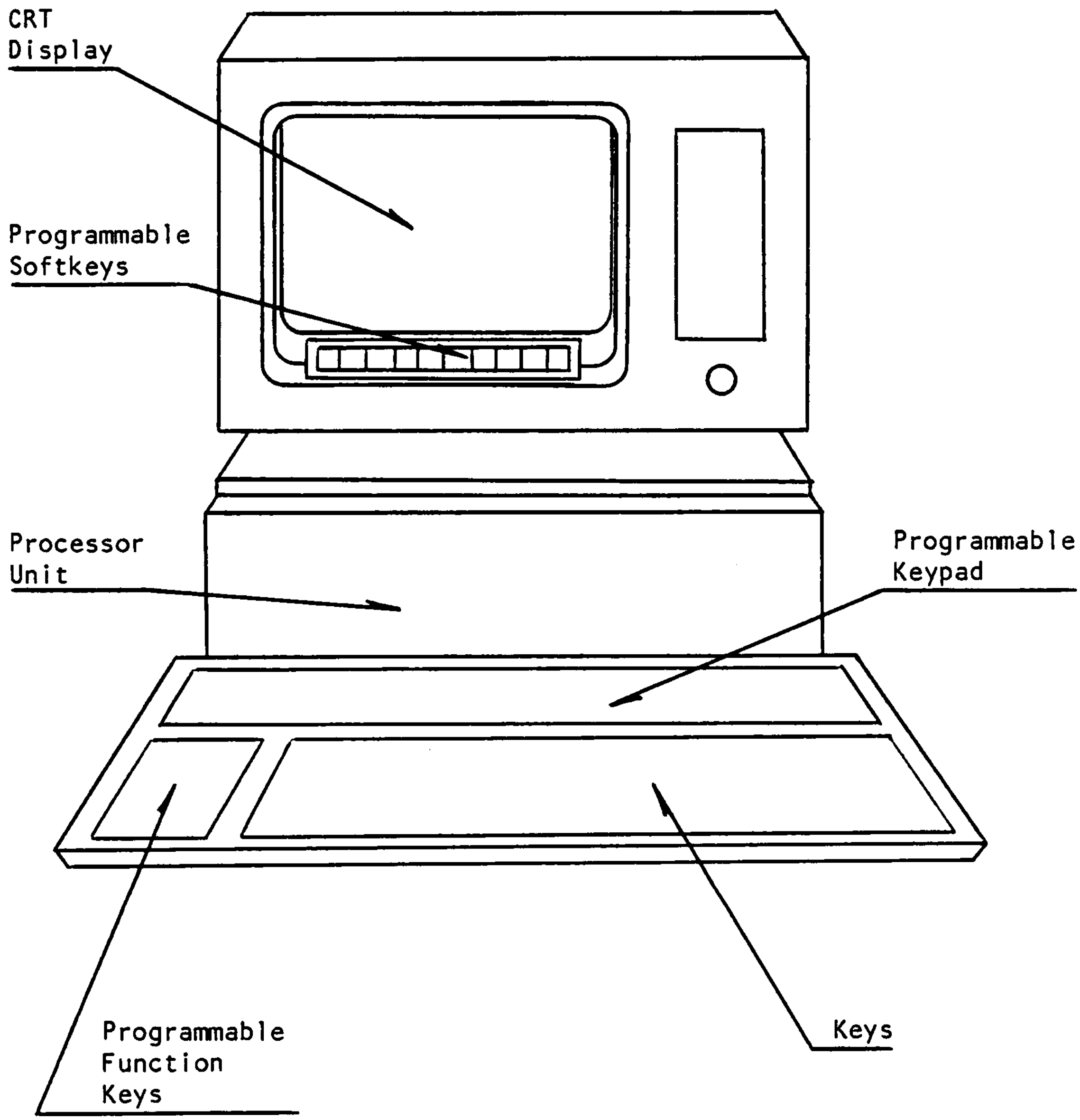

Figure 3. The IBM 9002 Desktop Computer

Software

There were several reasons for selecting BASIC to develop the simulator code. The primary reason for using BASIC was because it is the host language on many personal computers and is adaptable to many different types of machines, with minor modifications in some cases. This provides portability. Also, BASIC has evolved into a powerful language. For instance, the version of IBM BASIC used in this work has built in functions and a limited graphics capability. It allows a variety of data types and variable names of 130 characters in length. Another reason for using BASIC was its simplicity. Besides being easy to use and understand as a language, there was no requirement to use a more complex language because no complex calculations are used. Since the display is only updated once every second, speed is of minimal concern.

To assist with coding, documentation, modification, and portability, the simulator was developed in a modular style. This modularity is evident in the data flow diagram in Figure 4. Modularity aids portability because those modules which interact with the system, such as graphics, will potentially require the most modification when transferring the software to another computer.

The basic flow of the program is presented in Figure 4. From the menu module, the user selects the help file, automatic mode, or manual mode. In the automatic or manual mode, the graphics display module constructs a simulated test conductor's console on the CRT. A flashing message prompts the user to select any keyboard key to start, and the flow proceeds to the update display module where the

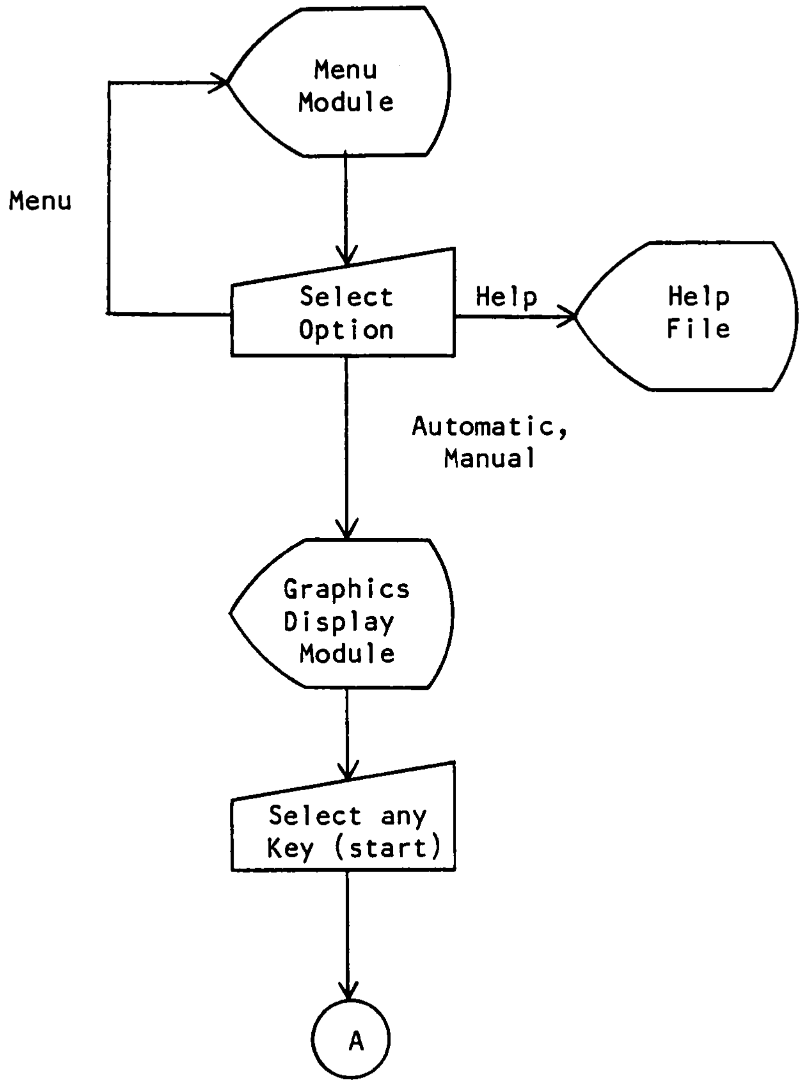

Figure 4. Simulator Data Flow Diagram

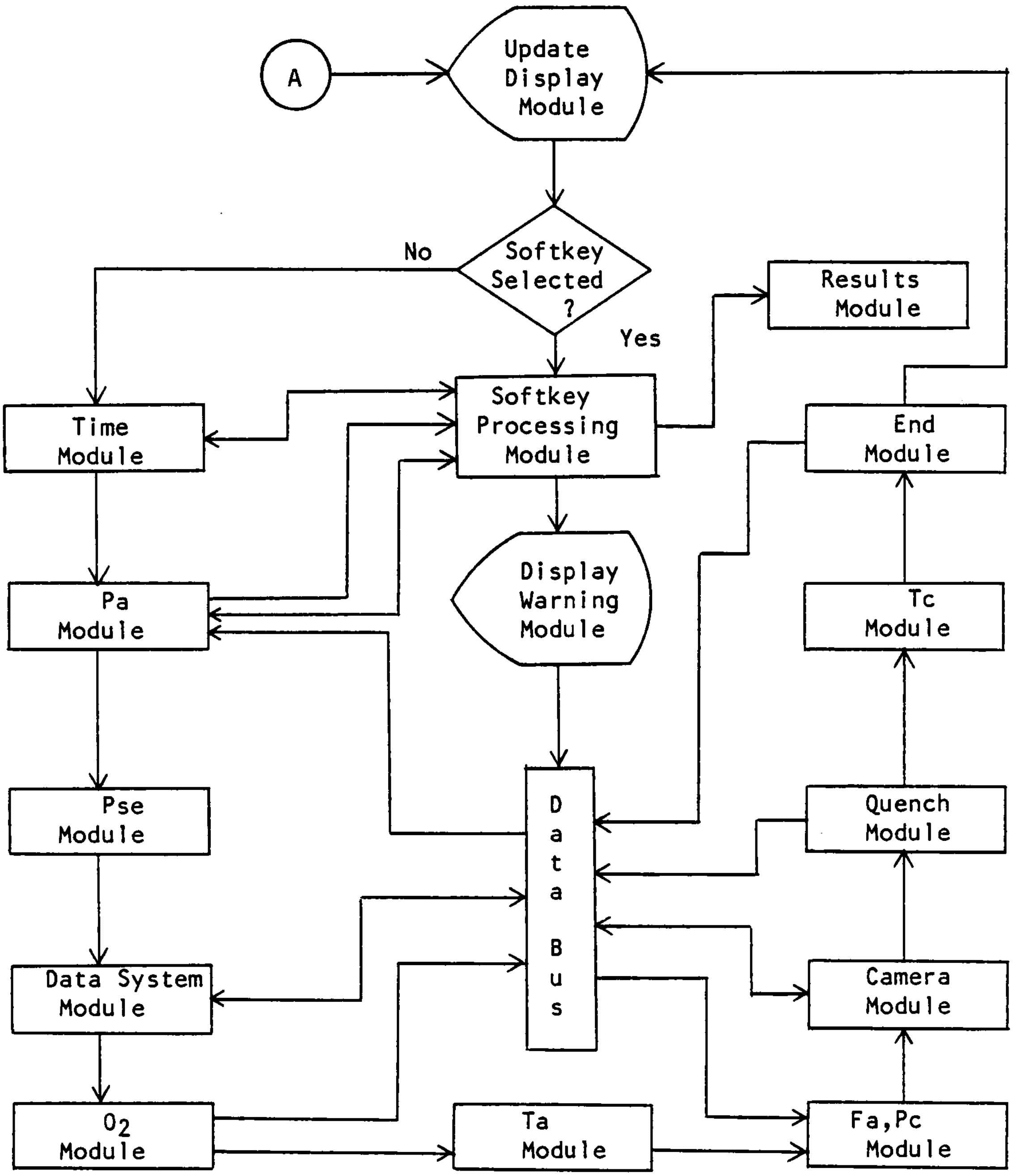

Figure 4 (continued)

parameters are updated and displayed. The normal data flow is then through the parameter modules, unless a softkey is selected, and back to the update display module. Selecting a softkey routes the flow through the softkey processing module which processes the user input and transfers the flow to the appropriate parameter module, or to the display warning module if the user selected an improper softkey. At the end of the session, the results module provides feedback to the user.

Test Cell

No particular AEDC test cell was modeled. The test cell in the simulator program is a typical test cell possessing the basic characteristics common to all four AEDC cells. The reason for this was to generalize the simulator so the basic principles could be applied to any similar test cell. Therefore, in actual test operations, although parameter values may vary between specific test cells the operating principles and control functions remain consistent.

CHAPTER III

REVIEW OF ROCKET ALTITUDE TEST CELL PRINCIPLES

To understand the simulation of the test operation process, one must first examine that process. Prior to activating the plant machinery, a test article is mounted on a thrust measuring system inside the test cell. The test article, fitted with appropriate sensors, is then connected to control systems and data recording channels. After all connections and calibrations are completed, the test cell is sealed and ready to begin the actual testing process.

When the plant machinery is activated, the test cell ambient pressure lowers to a value near the desired pressure. This value dictates the particular configuration of the various compressors which comprise the plant machinery. The plant continues to pump throughout the entire four hour test period.

All the following activities are sequenced with a countdown timer at some predetermined time before ignition of the test article. The first significant event to occur is activation of the steam ejector. The steam ejector is a device which further lowers test cell pressure to the final desired level. It functions as a jet pump using high pressure steam as the driving fluid. The steam is released into a special section of ducting called a diffuser. The steam ejector only runs from just immediately prior to ignition to shortly after the ignited test article is extinguished. The reason for this short run is due to limited steam supply and because the motor pumps itself.

Also prior to ignition the digital data recording system is activated at a slow sampling rate called the periodic mode. During the period of time that the test article is firing, the data sampling rate is increased, and this is called the continuous mode. Visual data is also acquired by activating movie and video cameras during test article firing.

Another system activated prior to ignition is a gaseous nitrogen (GN_2) system, or cell purge. This is a safety system required because rocket motor exhaust gases are fuel rich. If exposed to oxygen in the ducting between the test cell and the plant, an explosive mixture could result which can be catastrophic when exposed to an ignition source. Therefore, GN_2 is injected into the cell prior to ignition to displace the oxygen, since nitrogen will not promote combustion. The purge is activated again immediately after firing to flush out remaining exhaust gases.

Immediately after the firing, the test article may be quenched by flooding the case with water. This will preserve unburned propellant and the insulator for post fire analysis. If not quenched, heat transferred (usually from the hot nozzle) to the motor case may destroy remaining propellant and the liner.

These are the basic activities performed during a rocket motor test. This discussion was purposely intended to be general since specifics change from test to test. Also, this description is greatly simplified since the details of the testing process are beyond the scope of this work.

CHAPTER IV

COMPUTER AIDED TRAINING METHODS

Reason for the Research

The research reported in this chapter was conducted to examine methods for using a computer to more efficiently instruct a trainee in the principles of AEDC rocket motor testing. The term, "computer aided training", is defined in this work as a synonym for these methods. The computer was an especially appropriate tool for this application because computers are available to an increasing number of engineers.

Only those methods which were applied to the development of the simulator are presented. The primary reason for this was because most of these methods must (of necessity) employ methods of user friendliness such as light pens, remote cursor control devices (mouse), and input through the selection of graphic symbols (icons) [3]. Those methods that use such devices which are hardware or operating system dependent, defeat the requirement for portability, and are therefore beyond the scope of this work.

Methods

One method for learning about a system is to model the system and simulate it on a computer. Through this simulation a trainee can study and experiment with a system or a component of that system, which may be very complex [4]. Another valuable aspect of simulation is that control functions can be simulated and their effect on the system can be observed. Through this method, the trainee gains knowledge of the most important principles of the system, and the interactions between these principles. Simulation also allows repetition, which may be unfeasible in the physical system [5].

Another method is to use interactive graphics. Input and output performed interactively allows extreme flexibility during program execution, and output in graphic form is one of the easiest ways of interpreting data [6]. A specific form of interactive graphics is the use of windows, which make it possible to observe many events simultaneously [7].

Time compression is another method of learning about a system. Real world processes generally take more time to progress than is required to gain a basic understanding of these processes. The "fixed step" method is a time advancing technique where the fixed interval of time can be varied [8]. Another time compression method is to simplify the model of the system so that physical system delays are eliminated.

Still another method is using a menu to aid user interaction. Through this method, program segmentation is possible. Large programs requiring extensive internal storage, can be broken into smaller programs which become options that are selected from a master menu [5].

The use of simulation languages and programs such as ISIS, CSMP, CSSL, DYNAMO, etc. were considered, but excluded because each has one or more shortcomings for this specific application. These shortcomings included lack of appropriate graphical output, incompatibility with smaller computers, complexity, etc.

CHAPTER V

SIMULATOR DESCRIPTION

Menu

When the IBM 9002 computer is initialized, a submit file is loaded from diskette storage. This file contains system commands which are executed in sequence [2]. The first command loads the BASIC interpreter and then a menu program is loaded and executed. The only external information the trainee must learn is how to initialize the computer, load the diskette into the default drive, and distinguish the function keys and softkeys. When the menu is displayed on the CRT, the trainee selects one of three options using the appropriately defined function key. The first option is a help file, the second option is the automatic mode, and the third option is the manual mode.

Help File

The help file information is displayed in a page format on the CRT, and is arranged to progress from general to increasingly specific information (see Figure 2, page 6). From the help file, the trainee can escape to the menu, automatic mode, or manual mode. The function keys remain permanently assigned. The help file was provided to give the trainee assistance when using the simulator. Information in the help file is arranged in a three level hierarchy. The first level of information (the most general) describes the help file operation and defines parameters and controls. At the second level, a more detailed discussion of the individual functions of the parameters and controls is provided. The third level discusses assumptions made to relate the simulator to actual testing operations. The trainee should use the help file when information is required to progress on the simulator. The trainee should begin at the first level and only search the other levels as more detail is required.

Automatic Mode

The automatic mode of simulator operation is similar to the manual mode, except the control is triggered by countdown time. The computer is therefore controlling the session, and follows a procedure that is very similar to actual test operations. This procedure is not the only correct one, but it does simulate actual testing and it gives the trainee an opportunity to witness a procedure before attempting the manual mode. The manual mode will now be discussed, but the reader should note that this discussion is similar for the automatic mode, except for the method of control used.

Manual Mode

General Information

The training session begins with the computer displaying a simulated test conductor's console on the CRT, as shown in Figure 5. The console consists of simulated digital panel meters displaying test facility parameters, test article parameters, and countdown time. There are also two simulated display areas and simulated pushbutton controls (softkeys). One display area shows the data system mode which is either periodic or continuous. The other display area is a

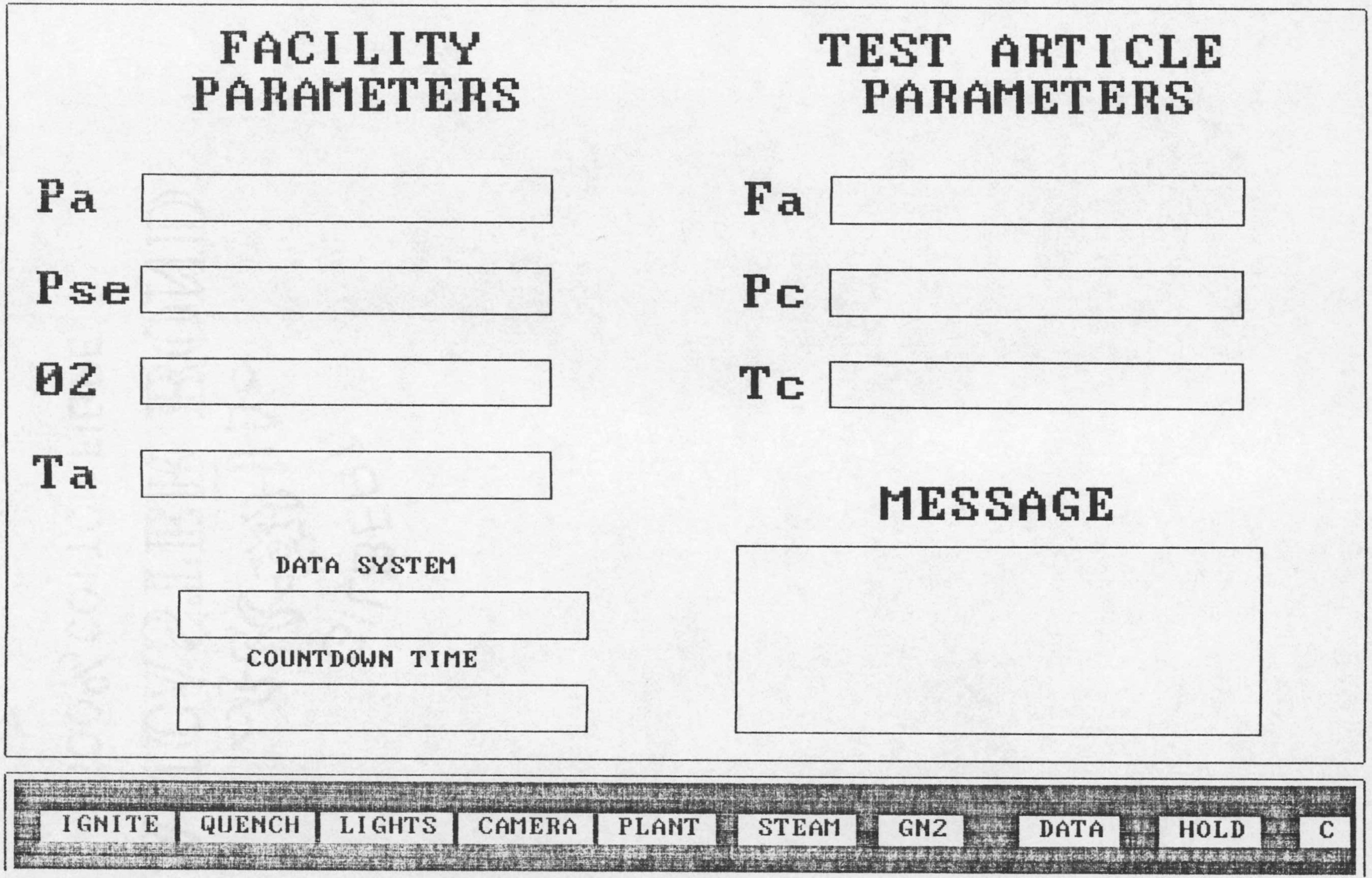

Figure 5. Simulated Test Conductor's Console, CRT Display

message box which gives the trainee feedback from selected controls, status information, and warnings. The parameters are defined in Table 1, on page 2.

Once a key is selected, the message area clears, all parameters are initialized to their normal state and displayed, and the countdown timer begins to count backwards from T - 10:00 (T minus ten minutes). The countdown time and all parameters are updated every second. Test article ignition must occur within two seconds of the time when the countdown timer reaches zero (T = 0:00 ± 0:02), or a message will be displayed indicating that timing has been compromised. This means the final data cannot be correlated to the countdown time when trying to reconstruct the sequence of events. When the timer reaches zero, it then continues to count time forward where, for example, ten minutes after ignition would be T + 10:00. The timer is initialized to ten minutes prior to ignition, because the training session can be much shorter than real time due to time compression.

The assumptions made for time compression are listed in the help file and are specifically discussed here. The complexity of the test facility and strict adherence to procedures is the primary reason for lengthy processes in actual test operations. For training purposes and because the simulator is significantly simplified (by removing intricate detail), these lengthy processes can be artificially reduced. In fact, the majority of a test conductor's time consists of waiting for operators to run their individual procedures and report on the status of their particular parameter(s). With the simulator, this time is eliminated by deleting the procedures (since they serve no training purpose), and assuming the initial response to a trainee's command, through softkey input, is virtually instantaneous. Checkout, calibration, and trivial operations are also eliminated to reduce time. But for some processes, such as activating the plant machinery, where it typically takes approximately twenty minutes for the test cell pressure to stabilize, it is recognized that this lengthy response is a physical characteristic which cannot be ignored, and not a delay between the command and the beginning of the response. In this case the help file describes the process and the assumption is made that the process will only take two minutes on the simulator.

Plant Control and Pa Parameter

The first control a trainee should select is the "plant" softkey. Other controls are shown in Figure 5. This control activates the plant machinery which begins lowering test cell ambient pressure. The complex plant is simplified and reduced to a "black box" which pumps at a steady rate and will lower the test cell pressure parameter (Pa) from its initial condition, 14.7 psia, to a stable 1.1 psia. This final Pa value is actually variable, depending on many factors (machinery configuration, mass flow rate, temperature, ambient atmospheric pressure, etc.) but is assumed to be 1.1 psia since this is a typical value.

Steam Control and Pse Parameter

After Pa stablilizes at 1.1 psia, the trainee should select the "steam" softkey. This activates the steam ejector by first prompting the trainee to enter a desired altitude. If the altitude selected by the trainee is lower or higher than the assumed typical limits of the test facility, a message so informs the trainee. The trainee is then prompted to re-enter the altitude. When a valid altitude is entered, it is processed by the lagrangian interpolation method, and the corresponding pressure in psia is displayed in the message box [8]. The steam ejector pressure parameter (Pse) begins to increase and the Pa parameter decreases to the value associated with the desired altitude. The minimum valid altitude is 65,000 ft. and the maximum valid altitude is 110,000 ft. Again, these values were selected as typical. Calculating the value for Pa as a function of Pse is extremely complex [9] and is impractical to model since other factors, which have been omitted for simplicity, also affect Pa and a precise model will confuse the basic process. The process to be modelled is that as steam ejector pressure increases, the pumpimg action causes the test cell ambient pressure to decrease. Data analysis shows that given a steam ejector pressure of 95 psia, any Pa value in the altitude limits of the test cell can be maintained. Since 95 psia is a typical steam ejector pressure, this was the value selected for the simulator.

Therefore, when an altitude is selected, Pse will increase from zero to 95 psia and remain stable until approximately thirty seconds after ignition of the test article. At this point, Pse will increase to 130 psia. The reason for this increase is because when the test article is firing into the diffuser, it pumps Pa lower than the plant and steam ejector combination can. When the test article suddenly terminates firing, the pumping action breaks down and the higher downstream pressure rushes to equalize the test cell pressure in a phenomenon called blowback. By increasing Pse to 130 psia prior to firing termination, blowback is minimized (but not eliminated) to an acceptable degree. If the steam ejector is activated before Pa is stabilized, a warning message will result and the "steam" softkey will not function until stability is achieved.

GN_2 Control and O_2 Parameter

When the steam ejector is operating and Pa is again stabilized, the trainee must then select the "GN_2" softkey. This is to begin purging the system with gaseous nitrogen (GN_2) to displace oxygen to prevent explosive mixtures of fuel rich test article exhaust products and oxygen. Because the rate at which GN_2 displaces O_2 varies between test cells depending on the size of the cell, the amount of ducting between the cell and the plant, and the amount of air leaking into the system, a typical time of 80 seconds was selected. This is the period of time it takes for the O_2 level to drop from its initial value of 20% (by volume) to below 4%, assuming air leaks are negligible. It has been determined experimentally that O_2 levels below 4% place the gaseous mixtures in the noncombustible range. Since in actual test operations the GN_2 supply is limited, the trainee is given a limited supply of GN_2 (150 seconds). This is enough to purge the test cell before ignition, after the firing terminates, and still have a small margin (46 seconds) for error or experimentation.

The "GN_2" softkey toggles between purge on and off, and echoes the state selected to the message box. When the purge is on, the O_2 parameter begins decreasing. If the purge is off, the O_2 parameter begins to increase, a status message indicates the purge is off, and the status of the GN_2 supply is given. When the O_2 level reaches its minimum value (3.1%), it stabilizes but continues to consume GN_2. During the firing, the test article exhaust gases displace the O_2, and this parameter then decreases to 2.4%. Therefore, the purging should be terminated to conserve GN_2. At the termination of the firing, the O_2 level increases until it attains the minimum level that the purge can maintain (if the purge is on), or until it exceeds 4% (if the purge is off). If the O_2 level exceeds 4% prior to 24 seconds after the test article firing terminates, it is assumed that an explosive mixture is produced, an ignition source exists, and the test facility is destroyed. This condition can only occur if the trainee depletes the GN_2 supply too soon or neglects to activate the purge after the firing. At 24 seconds after firing termination, the exhaust gases are assumed to be dispersed outside the test facility and the O_2 level can return to 20%. If the test article is ignited when the O_2 level is greater than 4%, the facility will be destroyed per the scenario described above.

Data Control and Data System Status

The "data" softkey toggles the digital data recording system between the periodic and continuous modes. The data system is assumed to be a single data tape with 150 seconds of storage available. In the periodic mode, the sampling rate is 0.1 sample per second. In the continuous mode, the rate is 1.0 sample per second. The trainee must therefore select the mode so that the storage space does not deplete prior to firing termination. But, the mode must be continuous during the firing or a message will tell the trainee that the data is compromised due to a too slow sampling rate. The modes should therefore be periodic prior to ignition, continuous just before ignition until firing termination, and then back to periodic or remain continuous until space is depleted. Enough data storage space is available to allow some margin for error or experimenting with the system.

Ignite Control and Fa, Pc, and Ta Parameters

The "ignite" softkey can be selected at any time, however, the response depends on the status of the other parameters. If the O_2 level is greater than 4% when ignite is selected, the facility will be destroyed. If ignite is selected outside the range of T = 0:00 ± 0:02 seconds, the timing will be compromised. If ignite is selected within the correct timing range, the axial thrust (Fa) and chamber pressure (Pc) parameters will display typical data to simulate a test article firing. This data will last for 66 seconds, when the message box will indicate that the test article has terminated (motor burnout). During the firing, the test cell ambient temperature (Ta) will follow a typical temperature profile as shown in Figure 6. The test article temperature (Tc) will follow one of the profiles in Figure 7 depending upon whether or not the "quench" softkey was selected prior to nine seconds after burnout.

Lights and Camera Controls

The "lights" softkey toggles the photography lights inside the test cell to on or off. The lights must be on during the firing while

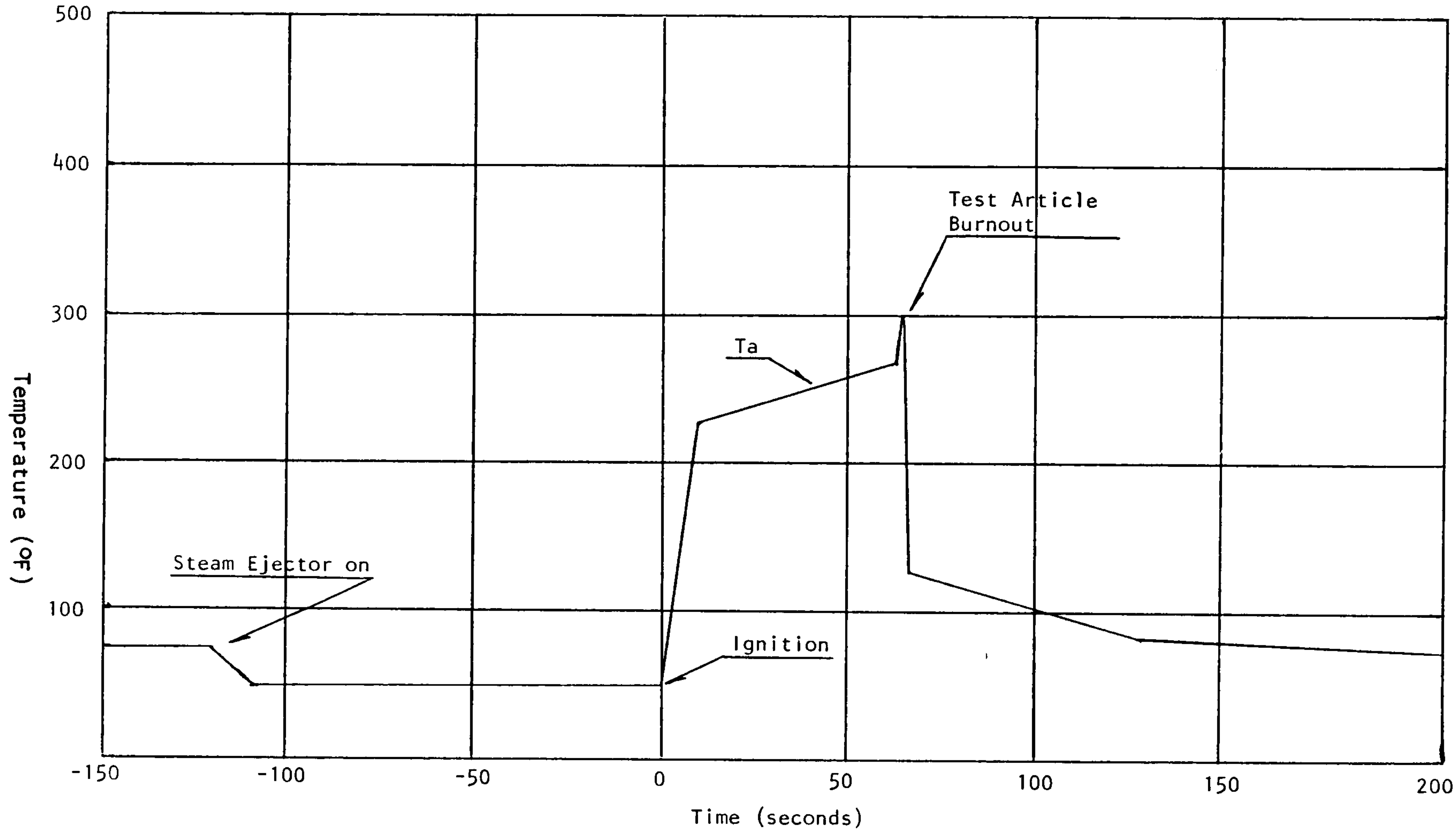

Figure 6. Test Cell Ambient Temperature Profile

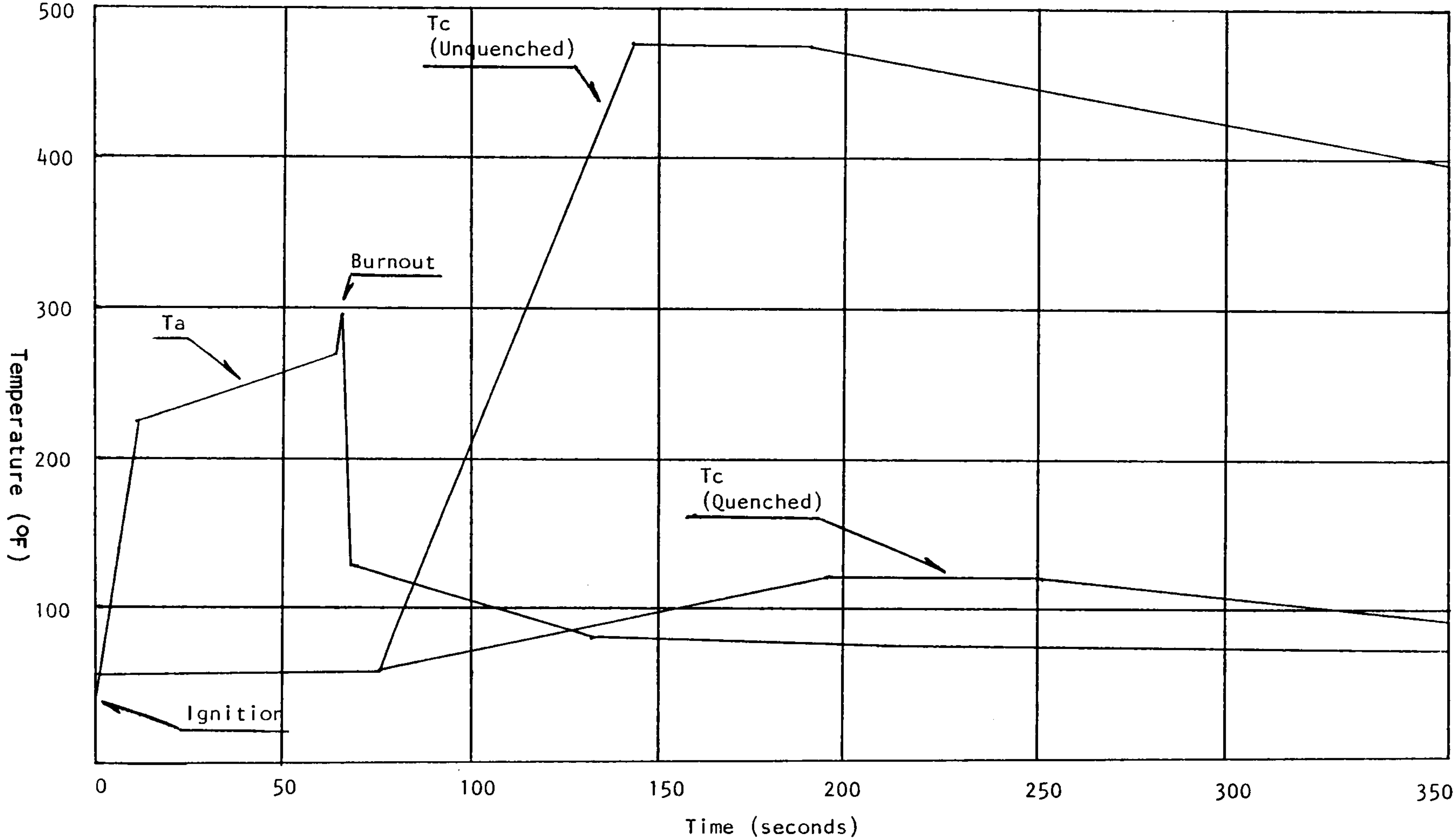

Figure 7. Ta and Tc (Quenched and Unquenched) Parameters

the camera is running or a message will be displayed which says the lights are off. Visual coverage will be lost until the lights are turned on while the camera is running.

The "camera" softkey toggles the camera, which runs until the 150 second supply of film is depleted, or until it is turned off. The on or off status is echoed to the message box as is the status of the film supply. Enough film exists to cover the firing with a small margin for error. The photography lights must also be selected as previously discussed.

Quench Control

The "quench" softkey activates the quench probe which floods the test article with water. This is done to preserve the test article from heat damage for post test inspection. If quench is selected prior to ignition, the propellant will be wetted and the test article is therefore ruined. If selected during firing, the quench probe will be destroyed and won't function after burnout. If selected later than nine seconds after burnout, quenching occurs too late and post test inspection data will be destroyed by heat transferring from the hot nozzle to the motor case. If selected at the appropriate time, the test article will be preserved for post test inspection. Post test inspection data includes unburned propellant (slivers) and the condition of the internal insulator material.

Hold and Continue Controls

The countdown timer can be stopped at any time by selecting the "hold" softkey. Two messages will alternate in the message box and countdown time will stop. The messages state, "test conductor hold" and "press softkey C to continue". Only the timer is deactivated, other controls will function normally. This provides extreme flexibility for the trainee if time is needed to consider options or synchronize timing. The timer should be running prior to and during the firing to prevent a timing compromise.

End of Session

At 120 seconds after firing, a message tells the trainee to select softkey "C" to display results. The trainee will then be shown the status of all parameters at the time the simulator was exited, the status of consummables (film, GN_2, data space), and a summary of the test as the trainee conducted it. The trainee may wait as long as desired before exiting the simulator. A reason for doing this is to observe the status of the Tc parameter to see how long it takes the test article temperature to return to normal.

A sample of the results displayed for a successful session on the simulator is shown in Figure 8. By examining the quantity of consummables remaining, the trainee obtains feedback on how efficiently the session was conducted. If any quantity of consummables remain, efficiency is considered excellent because of the small margin for error on the initial quantities. The "results of firing" displays the performance of the major parameters and serious errors (such as destroying the test facility). Analysis of these results will show the trainee whether or not the major goals, motor ignition and testing, were achieved. For example, the digital data coverage during the firing can be compared to the motor burn time to

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STATUS OF FACILITY PARAMETERS:              STATUS OF CONSUMABLE RESOURCES:

       Pa =  1.1                            DATA SPACE REMAINING = 32.6 SEC
      Pse =  0                                     GN2 REMAINING = 50 SEC
       O2 =  8.3                                  FILM REMAINING = 1 SEC
       Ta =  70
   DATA SYSTEM     = PERIODIC MODE
   COUNTDOWN TIME  = + 2 : 1  8

 RESULTS OF FIRING:

PLANT EXHAUST DUCT PRESSURE, Pe= 1.1 PSI
STEAM EJECTOR, Pse, AT 95 PSI; RAMPED TO 130 PSI AT T+30 SECONDS
AVERAGE ALTITUDE= 100000 FT.
GEOPOTENTIAL PRESSURE ALTITUDE= .162 PSI
MOTOR IGNITED AT T- 0 : 0  0
MOTOR QUENCHED SUCCESSFULLY
MOTOR BURN TIME= 66 SECONDS
MAXIMUM THRUST, Fa=  72500 LBF
MAXIMUM CHAMBER PRESSURE, Pc=  546 PSI
PHOTOGRAPHIC COVERAGE DURING FIRING= 66 SECONDS
DIGITAL DATA COVERAGE DURING FIRING= 66 SECONDS


OTHER MESSAGES:

PLANT RUNNING AT T- 2 : 5  0
STEAM EJECTOR ON AT T- 2 : 1  0
PURGE ON AT T- 1 : 2  5
PHOTO LIGHTS ON AT T- 0 : 5  0
DATA SYSTEM CONTINUOUS AT T- 0 : 1  5
CAMERA ON AT T- 0 : 1  0
MOTOR IGNITED AT T- 0 : 0  0
PURGE OFF AT T+ 0 : 0  5
QUENCHED AT T+ 1 : 0  8
CAMERA OFF AT T+ 1 : 1  0
PURGE ON AT T+ 1 : 1  5
DATA PERIODIC AT T+ 1 : 2  0
PURGE OFF AT T+ 1 : 2  5
PHOTO LIGHTS OFF AT T+ 1 : 3  0
STEAM EJECTOR OFF AT T+ 1 : 5  0
```

Figure 8. Sample Results

determine whether the coverage was adequate or not. And finally, "other messages" are displayed which show the sequencing of the motor control functions, relative to countdown time. With this information, the trainee can evaluate the timing sequence and modify it as required to achieve goals and minimize consummables.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Air Force Rocket Test Engineers at AEDC are faced with time consuming training methods that hinder rapid job proficiency. A faster method, using a computer to simulate AEDC rocket testing principles was developed through research of computer aided training methods.

Following the research, a target class of computer was selected. Because friendly user interaction, realism, portability, and a dedicated system was required, a personal computer was selected. Since BASIC is the host language on the majority of these computers, it was selected as the programming language. The programming was developed in a modular style with portability in mind. Only modules with system peculiar graphics need significant modification. The graphics are simplified so that resolution and complex programming are not required. The programming is segmented to allow an interaction method using a master menu from which options (help file, automatic mode, and manual mode) are selected. This allows the programs to run on computers with limited memory.

The AEDC rocket testing principles were modelled using appropriate assumptions to simplify complex processes. This allowed the technique of time compression to be implemented by deleting non-essential delays attributed to complexity. Simplification also permitted the model to be based on a generalized test cell to demonstrate general basic principles of operation.

Interactive graphics was the method selected to implement the simulation of testing principles based on the above model. Specifically, the use of windows allows many different parameters (named after actual parameters) to be displayed and updated simultaneously. Interactive control allows near real time simulation, and this method of control (pushing buttons) is realistic.

The basic rocket motor testing principles at AEDC are learned through formal education, on the job training, trial and error, and short courses. All of these principles are learned very efficiently on the simulator. The sessions are faster than the typical four hour test periods of the physical system, and can be repeated. To repeat an actual rocket motor test immediately is not practical, and is also expensive. The trainee gains on the job training experience by becoming the test conductor and also learns through trial and error on the simulator. Detailed background information, similar to formal education and short course material, is available to the trainee in the help file.

Several ideas were considered as future improvements to the simulator. The first idea was to allow the user to define the parameters and controls and the relationships between them. This would allow the simulator to be applied to other types of testing, thus establishing a more general application. Another idea was to adapt the automatic mode to use data from an actual rocket motor test and thus "replay" the test. And finally, the manual mode could supply random problems during a session to which the trainee must react. This would add more realism to the simulator.

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APPENDIX

APPENDIX

PROGRAM LISTING

```
40 REM ************************************************************************
41 REM **********                       MENU MODULE                     *********
42 REM ************************************************************************
45 CLS
50 TEXT (20,400,"ROCKET MOTOR TEST SIMULATOR PROGRAM",3)
55 TEXT (300,300,"MENU",4)
60 TEXT (50,250,"FUCTION KEY",2)
65 TEXT (500,250,"OPTION",2)
70 TEXT (120,200,"F1",2)
75 TEXT (450,200,"AUTOMATIC MODE",2)
80 TEXT (120,150,"F2",2)
85 TEXT (450,150,"MANUAL MODE",2)
87 TEXT (120,100,"F3",2)
89 TEXT (450,100,"HELP FILE",2)
92 TEXT (120,50,"F4",2)
95 TEXT (450,50,"MENU",2)
97 LINE (50,250,250,250)
98 LINE (500,250,615,250)
99 REM ************************************************************************
100 REM *********                  ASSIGN FUNCTION KEYS            ***************
101 REM ***********************************************************************
105 DIM F%(30),G%(30)
110 OPEN "#KPD" AS FILE #1
115 DATA "RUN AUTOMATE","RUN GRAPHICS","RUN HELP","RUN MENU","INVALID"
120 DATA "INVALID","INVALID","INVALID","INVALID","INVALID"
125 READ KEYNAME$(I) FOR I=1 TO 10
126 G%(1)=23
127 G%(3)=2
128 G%(4)=0
130 F%(1)=12                        ! KEYPAD DRIVER, FUNCTION 12
135 F%(3)= 2                        ! FUNCTION KEY TABLE
140 F%(4)=2                         ! USE KEYBOARD BUFFER
145 FOR I=1 TO 10
150 F%(2)=58+I                      ! SCAN CODE OF FUNCTION KEY
155 F%(5)=LEN(KEYNAME$(I))          ! STRING LENGTH
160 FOR J=1 TO F%(5)
165 F%(J+5)=ASCII(MID(KEYNAME$(I),J,1))      ! CONVERT TO ASCII
170 NEXT J
175 F%(J+5)=13                      ! CARRIAGE RETURN
180 F%(J+6)=0                       ! END OF FUNCTION PACKET
181 G%(2)=F%(2)
182 CALL SYSFUNC(1,G%(1))
185 CALL SYSFUNC(1,F%(1))           ! SEND FUNCTION PACKET TO DRIVER
190 NEXT I
205 CLOSE #1
210 LOCATE 20,5
215 END
```

```
10 REM ************************************************************************
20 REM **********                    PROGRAM:  HELP                 **********
30 REM **********        PROGRAMMER:  CAPT ANDY PICKENS, JR          **********
40 REM ************************************************************************
50 REM **********          DATE OF LAST REVISION: 13 MAY 85          **********
60 REM ************************************************************************
70 REM ************************************************************************
100 CLS
110 TEXT(250,450,"HELP FILE",2)
120 PRINT
125 PRINT"GENERAL INFORMATION:"
130 PRINT
135 PRINT"THE FUNCTION KEYS ARE PERMANENTLY ASSIGNED AS FOLLOWS:"
140 PRINT
145 PRINT"          F1= AUTOMATIC MODE          F3= HELP FILE"
150 PRINT"          F2= MANUAL MODE             F4= MASTER MENU"
155 PRINT
160 PRINT"THEY CAN BE USED AT ANY TIME, EXCEPT WHEN A PROGRAM IS RUNNING."
165 PRINT
170 PRINT"IN RESPONSE TO THE HELP FILE PROMPT:"
175 PRINT"     F= FORWARD PAGING; B= BACKWARD PAGING; E= EXIT TO FIRST PAGE"
180 PRINT
185 PRINT"TO TERMINATE HELP FILE:  EXIT TO FIRST PAGE, THEN"
190 PRINT"   TYPE ""STOP"" FOR A LIST OF OPTIONS."
191 PRINT
192 PRINT"THE FILE HAS 3 LEVELS.  EACH LEVEL HAS SUCCESSIVELY MORE DETAIL.  AS"
193 PRINT"   A CHALLENGE, STUDY ONLY LEVEL 1 AND THEN TRY THE SIMULATOR."
194 PRINT"   RETURN TO THIS FILE, AND THROUGH THE OTHER LEVELS ONLY AS FAR"
195 PRINT"   AS NEEDED TO PROGRESS ON THE SIMULATOR."
196 PRINT
197 PRINT"REVIEW AUTOMATIC MODE FOR ONE POSSIBLE SOLUTION TO THE SIMULATOR."
198 PRINT
199 PRINT
200 INPUT"INPUT <F>; OR TYPE ""STOP"" TO END HELP FILE SESSION:";PAGE$
205 IF PAGE$="F" THEN 265
210 IF PAGE$="STOP" THEN 230
212 IF PAGE$="E" THEN 226
215 CLS
218 TEXT(100,200,"INVALID INPUT- REENTER!",3)
220 WAIT(50)
225 GO TO 100
226 CLS
227 TEXT(10,200,"YOU ARE CURRENTLY ON THE FIRST PAGE!",2)
228 GO TO 220
230 CLS
235 TEXT(50,400,"TYPE ""BYE/Y"" TO TERMINATE SESSION OR,",2)
240 TEXT(100,300,"SELECT FUNCTION KEY:",3)
245 TEXT(75,200,"F1= AUTOMATIC MODE   F3= HELP FILE",2)
250 TEXT(75,100,"F2= MANUAL MODE      F4= MASTER MENU",2)
260 END
265 CLS
266 TEXT(250,450,"LEVEL 1",2)
268 PRINT
270 PRINT"PARAMETER DEFINITIONS:"
275 PRINT
280 PRINT"      Pa - TEST CELL AMBIENT PRESSURE, PSIA."
285 PRINT"      Pse - STEAM EJECTOR STEAM PRESSURE, PSIA."
290 PRINT"      O2 - OXYGEN VOLUME, PERCENT."
295 PRINT"      Ta - TEST CELL AMBIENT TEMPERATURE."
300 PRINT"      Tc - MOTOR CASE TEMPERATURE, DEG. F."
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```
305 PRINT"      Fa - MOTOR AXIAL THRUST, LBF."
310 PRINT"      Pc - MOTOR CHAMBER PRESSURE, PSIA."
315 PRINT
320 PRINT"CONTROLS DEFINITIONS:"
325 PRINT
330 PRINT"      IGNITE - MOTOR IGNITION."
335 PRINT"      QUENCH - QUENCH MOTOR WITH WATER."
340 PRINT"      LIGHTS - TURN ON/OFF CELL PHOTO LIGHTS."
345 PRINT"      CAMERA - TURN ON/OFF CAMERA."
350 PRINT"      PLANT  - TURN ON/OFF EXHAUSTER MACHINERY (PLANT)."
355 PRINT"      STEAM  - TURN ON/OFF STEAM EJECTOR."
360 PRINT"      GN2    - TURN ON/OFF CELL PURGE."
365 PRINT"      DATA   - SELECT DATA SYSTEM MODE (CONTINUOUS/PERIODIC)."
370 PRINT"      HOLD   - STOP COUNTDOWN TIME."
375 PRINT"      C      - CONTINUE COUNTDOWN TIME."
380 PRINT
385 INPUT"INPUT <F/B/E>";PAGE$
390 IF PAGE$="F" THEN 420
395 IF PAGE$="B" THEN 100
400 IF PAGE$="E" THEN 100
405 CLS
408 TEXT(100,200,"INVALID INPUT- REENTER!",3)
410 WAIT(50)
415 GO TO 265
420 CLS
425 TEXT(250,450,"LEVEL 2",2)
430 PRINT
435 PRINT"                  PLANT CONTROL AND Pa PARAMETER"
440 PRINT
445 PRINT"THE ""PLANT"" SOFTKEY IS A CONTROL THAT TURNS THE EXHAUSTER MACHINERY"
450 PRINT"(PLANT) ON OR OFF.  THE PLANT IS A PUMP WHICH LOWERS THE TEST CELL"
455 PRINT"AMBIENT PRESSURE TO 1.1 PSIA.  THE TEST CELL AMBIENT PRESSURE"
460 PRINT"PARAMETER IS DESIGNATED, Pa.  WHEN THE ""PLANT"" CONTROL IS FIRST"
465 PRINT"SELECTED IT TAKES 28 SECONDS FOR Pa TO REACH 1.1 PSIA.  WHEN SELECTED"
470 PRINT"AGAIN, THE PLANT IS TURNED OFF AND Pa RETURNS TO 14.7 PSIA."
475 PRINT
480 PRINT"                  STEAM CONTROL AND Pse PARAMETER"
485 PRINT
490 PRINT"WITH THE PLANT HOLDING Pa STEADY AT 1.1 PSIA, THE ""STEAM"" CONTROL"
495 PRINT"SOFTKEY WILL STOP THE COUNTDOWN TIMER AND PROMPT THE USER FOR A"
500 PRINT"DESIRED ALTITUDE.  THE USER SHOULD ENTER A NUMERIC VALUE WITHOUT"
505 PRINT"IMBEDDED COMMAS OR UNITS (FEET), WITHIN THE LIMITS OF THE TEST CELL."
510 PRINT"THE CELL LIMITS ARE 65,000 TO 110,000 FEET, GEOPOTENTIAL ALTITUDE.  A"
515 PRINT"""RETURN"" WILL ENTER THE SELECTED VALUE.  THE CORRESPONDING PRESSURE"
520 PRINT"WILL THEN BE DISPLAYED IN THE MESSAGE BOX, THE TIMER WILL CONTINUE"
525 PRINT"COUNTING, THE STEAM EJECTOR WILL BE TURNED ON AND THE STEAM EJECTOR"
530 PRINT"PRESSURE PARAMETER (Pse) WILL INCREASE TO 95 PSIA, AND Pa WILL LOWER"
535 PRINT"TO THE PRESSURE CORRESPONDING TO THE SELECTED ALTITUDE.  SELECTING"
540 PRINT"""STEAM"" AGAIN WILL TURN OFF THE STEAM EJECTOR."
545 PRINT
550 INPUT"INPUT <F/B/E>";PAGE$
560 IF PAGE$="F" THEN 595
565 IF PAGE$="B" THEN 265
570 IF PAGE$="E" THEN 100
575 CLS
580 TEXT(100,200,"INVALID INPUT- REENTER!",3)
585 WAIT(50)
590 GO TO 420
595 CLS
600 PRINT"                  GN2 CONTROL AND O2 PARAMETER"
```

```
605 PRINT
610 PRINT"THE ""GN2"" CONTROL ACTIVATES THE CELL PURGE WHICH FLOODS THE CELL"
615 PRINT"WITH GASEOUS NITROGEN.  IT THEN TAKES 81 SECONDS FOR THE GN2 TO"
620 PRINT"DISPLACE THE OXYGEN VOLUME (PERCENT) IN THE SYSTEM TO A STABLE VALUE"
625 PRINT"OF 3%.  THE MOTOR SHOULD NOT BE IGNITED WHILE THE O2% IN THE"
630 PRINT"SYSTEM IS ABOVE 4%, BECAUSE FUEL AND O2 IN THE SYSTEM WILL BE IN"
635 PRINT"THE EXPLOSIVE RANGE.  AN IGNITION SOURCE IS ASSUMED TO EXIST AND THE"
640 PRINT"FACILITY WILL BE DESTROYED.  THE ""GN2"" CONTROL MAY BE SELECTED"
645 PRINT"AGAIN TO TURN OFF THE PURGE.  THIS WILL CAUSE THE O2% TO INCREASE AND"
650 PRINT"THE REMAINING GN2 SUPPLY WILL BE SHOWN IN THE MESSAGE BOX.  THERE"
655 PRINT"IS A 150 SECOND INITIAL SUPPLY OF GN2.  THE PURGE MAY BE TURNED OFF"
660 PRINT"DURING MOTOR FIRING BECAUSE THE EXHAUST GASES DISPLACE THE O2.  AT"
665 PRINT"MOTOR BURNOUT THE O2 LEVEL MUST REMAIN BELOW 4% UNTIL T+ 1:30, SINCE"
670 PRINT"TRACES OF FUEL REMAIN UNTIL THEN."
675 PRINT
680 PRINT"                 DATA CONTROL"
685 PRINT
690 PRINT"THE DATA RECORDING SYSTEM HAS 150 SECONDS OF DATA STORAGE.  THE"
695 PRINT"""DATA"" CONTROL WILL TOGGLE THE DATA SYSTEM BETWEEN THE PERIODIC"
700 PRINT"MODE (0.1 SAMPLE/SECOND) AND THE CONTINUOUS MODE (1.0 SAMPLE/SECOND)."
705 PRINT"THE DATA SYSTEM MUST BE CONTINUOUS DURING THE MOTOR FIRING."
710 PRINT
715 PRINT
720 INPUT"INPUT <F/B/E>";PAGE$
725 IF PAGE$="F" THEN 760
730 IF PAGE$="B" THEN 420
735 IF PAGE$="E" THEN 100
740 CLS
745 TEXT(100,200,"INVALID INPUT- REENTER!",3)
750 WAIT(50)
755 GO TO 595
760 CLS
765 PRINT"                 IGNITE CONTROL AND Fa, Pc PARAMETERS"
770 PRINT
775 PRINT"THE ""IGNITE"" CONTROL IGNITES THE MOTOR AND SHOULD BE SELECTED AT"
780 PRINT"T= 0:00 (PLUS OR MINUS 0:02).  SELECTING OUTSIDE THIS RANGE WILL"
785 PRINT"CORRUPT THE TIMING USED TO CORRELATE THE DATA.  THE ROCKET MOTOR"
790 PRINT"AXIAL THRUST PARAMETER (Fa) AND CHAMBER PRESSURE PARAMETER (Pc) WILL"
795 PRINT"DISPLAY A ""TYPICAL"" ROCKET MOTOR FIRING PROFILE.  WHEN Fa AND Pc"
800 PRINT"DROP TO ZERO, THE MESSAGE BOX WILL INDICATE ""MOTOR BURNOUT!""."
805 PRINT
810 PRINT"                 Ta, Tc PARAMETERS"
815 PRINT
820 PRINT"THE TEST CELL AMBIENT TEMPERATURE PARAMETER (Ta) IS NOT CONTROLLABLE"
825 PRINT"AND ONLY DISPLAYS THE TEMPERATURE PROFILE (IN DEGREES FAHRENHEIT) AS"
830 PRINT"AFFECTED BY OTHER CONTROLS.  THE ROCKET MOTOR CASE TEMPERATURE"
835 PRINT"PARAMETER (Tc), HOWEVER, CAN FOLLOW ONE OF TWO PROFILES DEPENDING ON"
840 PRINT"WHETHER OR NOT THE ""QUENCH"" CONTROL WAS SELECTED APPROPRIATELY."
845 PRINT
850 PRINT"                 QUENCH CONTROL"
855 PRINT
860 PRINT"IF THE ""QUENCH"" CONTROL IS SELECTED FOLLOWING MOTOR BURNOUT AND"
865 PRINT"PRIOR TO 9 SECONDS AFTER BURNOUT, THE INTERNAL INTEGRITY OF THE MOTOR"
870 PRINT"WILL BE PRESERVED.  IF SELECTED TOO LATE, THE MOTOR WILL OVERHEAT."
875 PRINT"IF TOO EARLY, THE MOTOR OR QUENCH PROBE WILL BE DESTROYED."
880 PRINT
885 INPUT"INPUT <F/B/E>";PAGE$
890 IF PAGE$="F" THEN 925
895 IF PAGE$="B" THEN 595
900 IF PAGE$="E" THEN 100
```

```
905 CLS
910 TEXT(100,200,"INVALID INPUT- REENTER!",3)
915 WAIT(50)
920 GO TO 760
925 CLS
930 PRINT"                    LIGHTS AND CAMERA CONTROLS"
935 PRINT
940 PRINT"THE ""LIGHTS"" CONTROL TOGGLES THE IN-CELL PHOTOGRAPHY LIGHTS BETWEEN"
945 PRINT"THE ON AND OFF MODES.  THE LIGHTS CAN BE SELECTED AT ANY TIME, BUT"
950 PRINT"SHOULD BE ON DURING MOTOR FIRING WHILE THE CAMERA IS RUNNING, OR LOSS"
955 PRINT"OF VISUAL COVERAGE WILL RESULT.  THE ""CAMERA"" CONTROL TOGGLES"
960 PRINT"BETWEEN CAMERA ON AND OFF.  THE CAMERA HAS AN 80 SECOND SUPPLY"
965 PRINT"OF FILM, AND SHOULD COVER THE ENTIRE 66 SECOND MOTOR BURN TIME."
970 PRINT
975 PRINT"                    HOLD AND C CONTROLS"
980 PRINT
985 PRINT"THE ""HOLD"" CONTROL STOPS THE COUNTDOWN TIMER, BUT OTHER CONTROLS"
990 PRINT"CONTINUE TO FUNCTION.  TWO MESSAGES ALTERNATE IN THE MESSAGE BOX."
995 PRINT"THE FIRST MESSAGE SAYS, ""TEST CONDUCTOR HOLD"", AND THE SECOND"
1000 PRINT"MESSAGE SAYS, ""PRESS SOFTKEY C TO CONTINUE"".  WHEN THE ""C"""
1005 PRINT"CONTROL IS SELECTED THE TIMER CONTINUES COUNTING.  AT T+ 2:00, A"
1008 PRINT"MESSAGE WILL INFORM THE USER THAT IF THE ""C"" CONTROL IS AGAIN"
1010 PRINT"SELECTED, THE ""RESULTS"" MODE WILL BE ENTERED AND THE USER WILL"
1015 PRINT"BE PROVIDED A SUMMARY OF PERFORMANCE.  IF NOT SELECTED, THE USER"
1020 PRINT"MAY CONTINUE VIEWING THE SIMULATOR UNTIL ""C"" IS SELECTED."
1025 PRINT
1030 PRINT\PRINT\PRINT
1050 INPUT"INPUT <F/B/E>";PAGE$
1055 IF PAGE$="F" THEN 1090
1060 IF PAGE$="B" THEN 760
1065 IF PAGE$="E" THEN 100
1070 CLS
1075 TEXT(100,200,"INVALID INPUT- REENTER!",3)
1080 WAIT(50)
1085 GO TO 925
1090 CLS
1095 TEXT(250,450,"LEVEL 3",2)
1100 PRINT
1105 PRINT"                    THE PLANT"
1110 PRINT
1115 PRINT"THE PLANT IS COMPOSED OF MANY ROTATING EXHAUSTER MACHINES WHICH ARE"
1120 PRINT"CONNECTED TO THE TEST CELL THROUGH A NETWORK OF DUCTING.  THROUGH"
1125 PRINT"THIS NETWORK, THE CELLS CAN BE CONNECTED TO THE EXHAUSTERS IN"
1130 PRINT"VARIOUS COMBINATIONS TO ACHIEVE SPECIFIC ALTITUDE AND MASS FLOW"
1135 PRINT"REQUIREMENTS.  THE EXHAUSTERS ACHIEVE THE SYSTEM'S FIRST STAGE OF"
1140 PRINT"COMPRESSION BY PUMPING THE PRESSURE IN THE DUCTING TO A VALUE AS"
1145 PRINT"LOW AS POSSIBLE.  FACTORS THAT LIMIT THE FINAL VALUE THAT THE PLANT"
1150 PRINT"CAN PUMP TO ARE THE LIMITS OF THE EXHAUSTERS THEMSELVES, AIR LEAKS"
1155 PRINT"IN THE MAZE OF DUCTING, AND THE CONFIGURATION OF THE EXHAUSTERS"
1160 PRINT"SELECTED.  SURGE VALVES ALLOW AIR IN THE SYSTEM WHEN THE ROCKET"
1165 PRINT"MOTOR IS NOT FIRING TO PROVIDE A MASS FLOW TO PREVENT THE EXHAUSTERS"
1170 PRINT"FROM CAVITATING.  IN THE SIMULATOR, THE PLANT IS ASSUMED TO BE A"
1175 PRINT"""BLACK BOX"" CONTAINING A SINGLE PUMP WHICH CAN HANDLE ANY MASS"
1180 PRINT"FLOW AND THUS PROVIDE A CONSTANT DUCT PRESSURE OF 1.1 PSIA AGAINST"
1185 PRINT"AN AMBIENT ATMOSPHERIC PRESSURE OF 14.7 PSIA.  THE PHYSICAL PROCESS"
1190 PRINT"OF PUMPING THE MASSIVE DUCTING NETWORK TO A STABLE PRESSURE TAKES"
1195 PRINT"APPROXIMATELY 20 MINUTES IN REAL TIME.  IN THE SIMULATOR, THIS"
1200 PRINT"PROCESS IS ASSUMED TO ONLY TAKE 28 SECONDS."
1205 PRINT
1215 PRINT
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```
1220 PRINT
1225 INPUT"INPUT <F/B/E>";PAGE$
1230 IF PAGE$="F" THEN 1265
1235 IF PAGE$="B" THEN 925
1240 IF PAGE$="E" THEN 100
1245 CLS
1250 TEXT(100,200,"INVALID INPUT- REENTER!",3)
1255 WAIT(50)
1260 GO TO 1090
1265 CLS
1270 PRINT"                    Pa"
1275 PRINT
1280 PRINT"A PRESSURE TRANSDUCER IS TAPPED INTO THE TEST CELL AND LABELLED Pa."
1285 PRINT"THIS TRANSDUCER MEASURES AND DISPLAYS THE AMBIENT TEST CELL PRESSURE"
1290 PRINT"AS A FACILITY PARAMETER ON THE TEST CONDUCTOR'S CONSOLE.  Pa IS"
1295 PRINT"MEASURED IN PSIA UNITS.  A SPECIFIC PROFILE WILL BE FOLLOWED BY Pa"
1300 PRINT"DEPENDING ON WHEN CONTROLS ARE SELECTED AND THE ALTITUDE REQUIRED."
1305 PRINT"THE INITIAL CONDITION, 14.7 PSIA WILL STABILIZE AT 1.1 PSIA WHEN"
1310 PRINT"THE PLANT IS ACTIVATED.  ACTIVATING THE STEAM EJECTOR WILL LOWER Pa"
1315 PRINT"TO THE USER SELECTED FINAL PRESSURE.  WHEN THE ROCKET MOTOR IS"
1320 PRINT"IGNITED, Pa WILL LOWER SLIGHTLY BECAUSE THE MOTOR PUMPS VERY"
1325 PRINT"EFFICIENTLY FOR A SHORT PERIOD OF TIME.  WHEN THE MOTOR BURNS OUT,"
1330 PRINT"Pa WILL SPIKE UPWARD MOMENTARILY WHILE HIGHER DUCT PRESSURES RUSH TO"
1335 PRINT"EQUALIZE TEST CELL PRESSURE.  TURNING OFF THE STEAM EJECTOR AND"
1340 PRINT"PLANT WILL, IN TURN, RETURN Pa TO 14.7 PSIA."
1345 PRINT
1350 PRINT"                    THE STEAM EJECTOR"
1355 PRINT
1360 PRINT"THE STEAM EJECTOR IS A JET PUMP USING HIGH PRESSURE STEAM AS THE"
1365 PRINT"DRIVING FLUID.  THE ESCAPING STEAM EXPANDS AND ATTACHES TO THE WALLS"
1370 PRINT"OF A SPECIAL SECTION OF DUCTING CALLED A DIFFUSER.  TWO GENERAL"
1375 PRINT"TYPES OF STEAM EJECTORS, CENTER-BODY AND ANNULAR, ARE USED AT AEDC."
1380 PRINT"THE SIMULATOR IS ASSUMED TO BE USING AN ANNULAR STEAM EJECTOR."
1385 PRINT
1390 INPUT"INPUT <F/B/E>";PAGE$
1395 IF PAGE$="F" THEN 1430
1400 IF PAGE$="B" THEN 1090
1405 IF PAGE$="E" THEN 100
1410 CLS
1415 TEXT(100,200,"INVALID INPUT- REENTER!",3)
1420 WAIT(50)
1425 GO TO 1265
1430 CLS
1435 PRINT"ASSUMING THE PLANT HOLDS A CONSTANT DUCT PRESSURE OF 1.1 PSIA, THEN"
1440 PRINT"THE CELL PRESSURE, Pa, WILL DECREASE AS STEAM SUPPLY PRESSURE"
1445 PRINT"INCREASES.  THE STEAM EJECTOR CAN THUS BE ASSUMED TO PROVIDE ANY"
1450 PRINT"DESIRED FINAL Pa VALUE WITHIN THE SYSTEM LIMITS (65,000 - 110,000"
1455 PRINT"FT.).  THOUGH PHYSICALLY A STEAM SUPPLY IS LIMITED, IT IS FURTHER"
1460 PRINT"ASSUMED IN THE SIMULATOR THAT THE STEAM SUPPLY IS UNLIMITED."
1465 PRINT
1470 PRINT"                    Pse"
1475 PRINT
1480 PRINT"A PRESSURE TRANSDUCER IS TAPPED INTO THE STEAM SUPPLY TO THE STEAM"
1485 PRINT"EJECTOR AND LABLELLED Pse.  THIS TRANSDUCER MEASURES AND DISPLAYS"
1490 PRINT"THE STEAM EJECTOR SUPPLY PRESSURE AS A FACILITY PARAMETER ON THE"
1495 PRINT"TEST CONDUCTOR'S CONSOLE.  Pse IS MEASURED IN PSIA UNITS.  BECAUSE"
1500 PRINT"OF PREVIOUS ASSUMPTIONS CONCERNING DUCT PRESSURES, A Pse VALUE OF 95"
1505 PRINT"PSIA PROVIDES ADEQUATE CAPACITY FOR THE STEAM EJECTOR TO ATTAIN ANY"
1510 PRINT"Pa VALUE WITHIN THE SYSTEM LIMITS.  IT IS ALSO ASSUMED THAT Pse IS"
1515 PRINT"AUTOMATICALLY INCREASED TO 130 PSIA AT A POINT 30 SECONDS AFTER"
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1520 PRINT"IGNITION.  THIS ALLOWS THE STEAM EJECTOR TO HELP PREVENT THE Pa"
1525 PRINT"SPIKE, PREVIOUSLY DISCUSSED, WHICH OCCURS WHEN THE MOTOR BURNS OUT"
1530 PRINT"AND DUCT PRESSURES RUSH TO EQUALIZE Pa."
1535 PRINT
1540 PRINT
1545 PRINT
1550 PRINT
1555 INPUT"INPUT <F/B/E>";PAGE$
1560 IF PAGE$="F" THEN 1595
1565 IF PAGE$="B" THEN 1265
1570 IF PAGE$="E" THEN 100
1575 CLS
1580 TEXT(100,200,"INVALID INPUT- REENTER!",3)
1585 WAIT(50)
1590 GO TO 1430
1595 CLS
1600 PRINT"                GN2"
1605 PRINT
1610 PRINT"THE GN2 (GASEOUS NITROGEN) SYSTEM IS ALSO CALLED THE PURGE SYSTEM"
1615 PRINT"BECAUSE IT'S PURPOSE IS TO PURGE THE TEST FACILITY OF OXYGEN.  IT"
1620 PRINT"DOES THIS BY INTRODUCING ENOUGH GN2 INTO THE FACILITY TO DISPLACE"
1625 PRINT"THE OXYGEN FROM AN INITIAL VALUE OF 20% (BY VOLUME) TO BELOW 4%."
1630 PRINT"THIS IS REQUIRED BECAUSE A ROCKET MOTOR PRODUCES FUEL RICH EXHAUST"
1635 PRINT"GASES WHEN FIRING.  WHEN MIXED WITH O2 AN EXPLOSIVE MIXTURE RESULTS."
1640 PRINT"IT IS ASSUMED THAT IF THE O2 LEVEL IS GREATER THAN 4% IN THE"
1645 PRINT"PRESENCE OF ROCKET EXHAUST, AN EXPLOSIVE MIXTURE WILL RESULT, AN"
1650 PRINT"IGNITION SOURCE EXISTS, AND THE FACILITY WILL BE DESTROYED.  IT IS"
1655 PRINT"ALSO ASSUMED THAT THE GN2 SYSTEM PROVIDES A FIXED (AND APPROPRIATE)"
1660 PRINT"FLOW RATE BUT CAN ONLY SUPPLY GN2 FOR 150 SECONDS.  DURING ROCKET"
1665 PRINT"MOTOR FIRING, THE EXHAUST GASES DISPLACE O2 AND THE PURGE SYSTEM"
1670 PRINT"MAY BE TURNED OFF TO CONSERVE GN2.  THIS PRODUCES A MIXTURE THAT IS"
1675 PRINT"""TOO RICH"" TO EXPLODE.  IT IS ALSO ASSUMED THAT WHEN THE MOTOR"
1680 PRINT"BURNS OUT, TRACES OF EXHAUST GASES WILL REMAIN IN THE FACILITY FOR"
1685 PRINT"24 SECONDS.  ENOUGH PURGE CAPABILITY MUST THEREFORE REMAIN AT BURN"
1690 PRINT"OUT TO PREVENT O2 FROM EXCEEDING 4% FOR 24 SECONDS."
1695 PRINT\PRINT\PRINT\PRINT\PRINT
1700 INPUT"INPUT <F/B/E>";PAGE$
1705 IF PAGE$="F" THEN 1743
1710 IF PAGE$="B" THEN 1430
1715 IF PAGE$="E" THEN 100
1720 CLS
1725 TEXT(100,200,"INVALID INPUT- REENTER!",3)
1730 WAIT(50)
1740 GO TO 1595
1743 CLS
1745 PRINT"                O2"
1750 PRINT
1755 PRINT"AN O2 ANALYZER IS TAPPED INTO THE EXHAUSTER STACKS (OPEN TO ATMOS-"
1760 PRINT"PHERE) AND LABELLED O2.  THIS INSTRUMENT DISCRETELY SAMPLES AND DIS-"
1765 PRINT"PLAYS OXYGEN PERCENTAGE (BY VOLUME) AS A FACILITY PARAMETER ON THE"
1770 PRINT"TEST CONDUCTOR'S CONSOLE.  THE O2 LEVEL REACHES A MINIMUM OF 3.1%,"
1775 PRINT"BUT CONTINUES TO CONSUME GN2 UNTIL THE PURGE IS TURNED OFF.  THE"
1780 PRINT"ROCKET MOTOR EXHAUST GASES WILL LOWER O2 TO A MINIMUM OF 2.4%.  A"
1785 PRINT"TYPICAL TIME REQUIRED FOR THE PURGE TO DISPLACE O2 BELOW 4% IS 80"
1790 PRINT"SECONDS.  THIS TIME IS THEREFORE ASSUMED FOR THE SIMULATOR."
1795 PRINT
1800 PRINT"                DATA SYSTEM"
1805 PRINT
1810 PRINT"THE DATA SYSTEM IS COMPOSED OF FREQUENCY MODULATION (FM), OSCILLO-"
1815 PRINT"GRAPH, DIGITAL, AND ANALOG SUBSYSTEMS.  IT IS ASSUMED IN THE SIMU-"
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1820 PRINT"LATOR, THAT THE DATA SYSTEM CONSISTS OF A DIGITAL RECORDING SYSTEM"
1825 PRINT"WITH A 150 SECOND LIMITED SUPPLY OF DATA STORAGE.  THE SYSTEM IS"
1830 PRINT"FURTHER ASSUMED TO RUN CONTINUOUSLY AT 0.1 SAMPLE/SECOND IN THE"
1835 PRINT"""PERIODIC"" MODE.  PHYSICALLY, MANY SAMPLING RATES ARE POSSIBLE."
1840 PRINT"BUT, IT IS ASSUMED THAT IN THE ""CONTINUOUS"" MODE THE MAXIMUM RATE"
1845 PRINT"IS 1.0 SAMPLE/SECOND.  THE MAXIMUM SAMPLING RATE MUST BE SELECTED"
1850 PRINT"IMMEDIATELY PRIOR TO IGNITION AND MUST CONTINUE THROUGH MOTOR BURN"
1855 PRINT"OUT.  THIS ALLOWS THE BEST POSSIBLE PRECISION ONLY DURING THE PART"
1860 PRINT"OF THE TESTING PROCESS CONSIDERED THE MOST CRITICAL."
1865 INPUT"INPUT <F/B/E>";PAGE$
1870 IF PAGE$="F" THEN 1905
1875 IF PAGE$="B" THEN 1595
1880 IF PAGE$="E" THEN 100
1885 CLS
1890 TEXT(100,200,"INVALID INPUT- REENTER!",3)
1895 WAIT(50)
1900 GO TO 1743
1905 CLS
1910 PRINT"                  IGNITE, Fa, Pc"
1915 PRINT
1920 PRINT"THE ROCKET MOTOR IS ASSUMED ARMED, AND MUST BE IGNITED AT T= 0:00"
1925 PRINT"PLUS OR MINUS 0:02 SECONDS.  IT IS ASSUMED THAT IF IGNITION OCCURS"
1930 PRINT"OUTSIDE THIS RANGE, TIMING IS COMPROMISED AND THE DATA CAN'T BE"
1935 PRINT"ACCURATELY RELATED TO REAL TIME.  IN REALITY, IGNITION IS PERFORMED"
1940 PRINT"BY COMPUTER AT PRECISELY T= 0:00.  TWO SECONDS ARE ALLOWED IN THE"
1945 PRINT"SIMULATOR FOR HUMAN RESPONSE AND A PECULIARITY DUE TO PROGRAMMING"
1950 PRINT"THE SIMULATION.  A SPECIALLY CALIBRATED STRAIN GAGE MEASURES MOTOR"
1955 PRINT"AXIAL THRUST IN LBF UNITS.  THE STRAIN GAGE (LOAD CELL) IS LABELLED"
1960 PRINT"Fa AND IS DISPLAYED AS A TEST ARTICLE PARAMETER ON THE TEST CONDUCT-"
1965 PRINT"OR'S CONSOLE.  A PRESSURE TRANSDUCER IS TAPPED INTO THE ROCKET MOTOR"
1970 PRINT"CASE AND LABELLED Pc.  THIS TRANSDUCER MEASURES AND DISPLAYS MOTOR"
1975 PRINT"CHAMBER PRESSURE AS A TEST ARTICLE PARAMETER ON THE TEST CONDUCTOR'S"
1980 PRINT"CONSOLE.  Pc IS MEASURED IN PSIA UNITS.  BOTH Fa AND Pc DISPLAY"
1985 PRINT"""TYPICAL"" DATA AS COMPILED FROM MANY DIFFERENT ACTUAL MOTOR"
1990 PRINT"FIRINGS."
1995 PRINT
2000 PRINT"                  Ta, Tc"
2005 PRINT
2010 PRINT"A THERMOCOUPLE IS INSTALLED IN THE TEST CELL AND LABELLED Ta.  THIS"
2015 PRINT"THERMOCOUPLE MEASURES AND DISPLAYS TEST CELL AMBIENT TEMPERATURE AS"
2020 PRINT"A FACILITY PARAMETER ON THE TEST CONDUCTOR'S CONSOLE.  Ta IS MEA-"
2025 PRINT
2030 INPUT"INPUT <F/B/E>";PAGE$
2035 IF PAGE$="F" THEN 2070
2040 IF PAGE$="B" THEN 1743
2045 IF PAGE$="E" THEN 100
2050 CLS
2055 TEXT(100,200,"INVALID INPUT- REENTER!",3)
2060 WAIT(50)
2065 GO TO 1905
2070 CLS
2075 PRINT"SURED IN DEGREES FAHRENHEIT UNITS.  Ta IS ASSUMED TO BE INITIALLY"
2080 PRINT"AT AN AMBIENT 70 DEG. F.  Ta FOLLOWS A TYPICAL PROFILE DURING WHICH"
2085 PRINT"IT DOESN'T VARY SIGNIFICANTLY UNTIL THE STEAM EJECTOR IS TURNED ON."
2090 PRINT"AT THIS TIME, WATER VAPOR IN THE TEST CELL ""FLASHES"" INTO GAS AND"
2095 PRINT"THUS GIVES UP HEAT (RESULTING IN MINOR Ta DECREASE).  AT IGNITION,"
2100 PRINT"Ta WILL INCREASE SIGNIFICANTLY DUE TO HEAT FROM COMBUSTION.  Ta WILL"
2105 PRINT"""SPIKE"" UPWARD WHEN THE MOTOR BURNS OUT DUE TO THE PREVIOUSLY"
2110 PRINT"DISCUSSED ""BLOWBACK"" INTO THE TEST CELL.  AT THIS POINT, Ta BEGINS"
2115 PRINT"TO RAPIDLY ASSUME AMBIENT VALUES DUE TO LACK OF HEAT TRANSFER IN THE"
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2120 PRINT"TEST CELL ATMOSPHERE.  A SIMILAR THERMOCOUPLE LABELLED Tc IS INSTAL-"
2125 PRINT"LED ON THE ROCKET MOTOR CASE TO MEASURE MOTOR CASE TEMPERATURE (IN"
2130 PRINT"DEG. F.) AS A TEST ARTICLE PARAMETER AND DISPLAY Tc ON THE TEST CON-"
2135 PRINT"DUCTOR'S CONSOLE.  BECAUSE Tc IS MOUNTED TO A SIGNIFICANT MASS, A"
2140 PRINT"SIGNIFICANT DELAY IS INTRODUCED BECAUSE THE ENTIRE MASS IS ASSUMED"
2145 PRINT"TO CHANGE TEMPERATURE UNIFORMLY BEFORE Tc RECORDS A DIFFERENCE.  AS"
2150 PRINT"A RESULT, Tc WILL NOT CHANGE DURING THE FIRING.  AFTER THE MOTOR"
2155 PRINT"BURNS OUT, HOWEVER, IT IS ASSUMED THAT THE HOT NOZZLE WILL TRANSFER"
2160 PRINT"HEAT TO THE CASE.  IF QUENCHED, Tc WILL ASSUME A MAXIMUM TEMPERATURE"
2165 PRINT"OF 125 DEG. F., AND IF NOT QUENCHED, Tc WILL ASSUME A MAXIMUM TEMP-"
2170 PRINT"ERATURE OF 480 DEG. F.  THIS IS ASSUMED HOT ENOUGH TO BURN PROPEL-"
2175 PRINT"LANT SLIVERS, CHAR INTERNAL INSULATION, AND WARP THE TITANIUM MOTOR"
2180 PRINT"CASE.  IT IS ALSO ASSUMED THAT A REQUIREMENT EXISTS TO PRESERVE"
2185 PRINT"POST TEST EVIDENCE (SLIVERS AND INSULATION) AND THE CASE."
2190 PRINT
2195 INPUT"INPUT <F/B/E>";PAGE$
2200 IF PAGE$="F" THEN 2235
2205 IF PAGE$="B" THEN 1905
2210 IF PAGE$="E" THEN 100
2215 CLS
2220 TEXT(100,200,"INVALID INPUT- REENTER!",3)
2225 WAIT(50)
2230 GO TO 2070
2235 CLS
2240 PRINT"                    LIGHTS, CAMERA"
2245 PRINT
2250 PRINT"PHOTOGRAPHY LIGHTS ARE MOUNTED IN THE TEST CELL AND MUST BE ON PRIOR"
2255 PRINT"TO AND IMMEDIATELY AFTER THE CAMERA IS RECORDING.  IT IS ASSUMED"
2260 PRINT"THAT THE ROCKET MOTOR PLUME WITHOUT PHOTO LIGHTS RUINS CAMERA COVER-"
2265 PRINT"AGE BECAUSE IT IS TWO BRIGHT IN THE CENTER AND DOESN'T UNIFORMLY "
2270 PRINT"ILLUMINATE CRITICAL FEATURES ON THE MOTOR AND TEST CELL.  IT IS"
2275 PRINT"FURTHER ASSUMED THAT THE LIGHTS DON'T BURN OUT AND HEAT FROM THEM"
2280 PRINT"IS NEGLIGIBLE TO Ta AND Tc PARAMETERS.  MANY CAMERAS ARE MOUNTED"
2285 PRINT"OUTSIDE THE TEST CELL, FILMING THROUGH VIEWPORTS.  IT IS ASSUMED IN"
2290 PRINT"THE SIMULATOR THAT ONLY ONE CAMERA EXISTS, AND IT HAS AN 80 SECOND"
2295 PRINT"LIMITED SUPPLY OF FILM.  IT IS FURTHER ASSUMED THAT THE CAMERA MUST"
2300 PRINT"BE RECORDING JUST PRIOR TO IGNITION AND CONTINUE THROUGH MOTOR BURN"
2305 PRINT"OUT TO COVER THE MOST CRITICAL PERIOD IN THE TESTING PROCESS.  THIS"
2310 PRINT"THEREFORE REQUIRES THAT THE PHOTO LIGHTS MUST BE ON DURING THIS"
2315 PRINT"PROCESS."
2320 PRINT
2325 PRINT"                    QUENCH"
2330 PRINT
2335 PRINT"A TELESCOPING QUENCH PROBE IS LOCATED BELOW THE EXIT PLANE OF THE"
2340 PRINT"ROCKET MOTOR NOZZLE.  WHEN ACTUATED, THE PROBE EXTENDS AND FILLS "
2345 PRINT"THE MOTOR WITH WATER TO PREVENT FURTHER HEAT DAMAGE.  IT IS ASSUMED"
2350 PRINT"THAT PRESERVING THE MOTOR FOR POST TEST ANALYSIS AND RE-USING THE"
2355 PRINT
2360 INPUT"INPUT <F/B/E>";PAGE$
2365 IF PAGE$="F" THEN 2400
2370 IF PAGE$="B" THEN 2070
2375 IF PAGE$="E" THEN 100
2380 CLS
2385 TEXT(100,200,"INVALID INPUT- REENTER!",3)
2390 WAIT(50)
2395 GO TO 2235
2400 CLS
2405 PRINT"CASE IS A REQUIREMENT.  IT IS ALSO ASSUMED THAT THE QUENCH PROBE"
2410 PRINT"MUST BE ACTIVATED WITHIN 9 SECONDS AFTER MOTOR BURN OUT TO BE EF-"
2415 PRINT"FECTIVE.  IF THE PROBE IS EXTENDED BEFORE THE MOTOR IS IGNITED, THE"
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2420 PRINT"MOTOR IS DESTROYED BECAUSE THE PROPELLANT IS WETTED, ALTERING ITS"
2425 PRINT"CHEMICAL COMPOSITION.  IF EXTENDED DURING THE MOTOR FIRING, THE"
2430 PRINT"PLUME WILL BURN OFF THE PROBE TIP AND THE WATER WILL SPILL INTO THE"
2435 PRINT"CELL.  THIS WILL NOT DAMAGE THE MOTOR IMMEDIATELY, BUT WILL WHEN"
2440 PRINT"THE MOTOR BURNS OUT AND THE HEAT FROM THE NOZZLE TRANSFERS TO THE"
2445 PRINT"CASE."
2450 PRINT
2455 PRINT"                COUNTDOWN TIME"
2460 PRINT
2465 PRINT"THE COUNTDOWN TIME IS USED BY A TEST CONTROLLING COMPUTER (SEQUEN-"
2470 PRINT"CER), WHICH USES IT TO SEQUENCE THE FACILITY CONTROLS AND TO IGNITE"
2475 PRINT"THE ROCKET MOTOR AT PRECISELY T= 0:00 FOR DATA CORRELATION.  ONLY"
2480 PRINT"THE TIMER IS STOPPED.  PROCESSES IN EFFECT CONTINUE, AND OTHER CON-"
2485 PRINT"TROLS MAY BE ACTIVATED."
2490 PRINT\PRINT\PRINT\PRINT\PRINT\PRINT\PRINT
2495 INPUT"INPUT <F/B/E>";PAGE$
2500 IF PAGE$="F" THEN 2535
2505 IF PAGE$="B" THEN 2235
2510 IF PAGE$="E" THEN 100
2515 CLS
2520 TEXT(100,200,"INVALID INPUT- REENTER!",3)
2525 WAIT(50)
2530 GO TO 2400
2535 CLS
2540 PRINT"                HOLD, C"
2545 PRINT
2550 PRINT"COUNTDOWN TIME CAN BE STOPPED FOR MANUAL OPERATIONS, TO ALLOW"
2555 PRINT"LENGTHY PROCESSES TO COMPLETE, OR FOR EMERGENCIES.  LIKEWISE, THE"
2560 PRINT"TIMER IN THE SIMULATOR CAN BE HELD, AND CONTINUED (C) WHEN DESIRED."
2565 PRINT"IT IS ASSUMED TO BE AN ACCEPTABLE PRACTICE TO STOP THE TIMER TO"
2570 PRINT"ALLOW A PROCESS TO COMPLETE, OR SELECT A CONTROL WHEN IT IS OBVIOUS"
2575 PRINT"THAT THERE WOULD OTHERWISE BE NO TIME TO COMPLETE THEM BEFORE "
2580 PRINT"T= 0:00.  THE ONLY LIMITATION IS THAT THE MOTOR CANNOT BE FIRED"
2585 PRINT"WHEN THE TIMER IS ON HOLD, BECAUSE THIS IS NOT POSSIBLE NOR PRACTI-"
2590 PRINT"CAL IN THE PHYSICAL SYSTEM."
2595 PRINT\PRINT\PRINT\PRINT\PRINT\PRINT\PRINT
2600 PRINT\PRINT\PRINT\PRINT\PRINT\PRINT
2605 INPUT"INPUT <B/E>";PAGE$
2610 IF PAGE$="B" THEN 2400
2615 IF PAGE$="E" THEN 100
2620 CLS
2625 TEXT(100,200,"INVALID INPUT- REENTER!",3)
2630 WAIT(50)
2635 GO TO 2535
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10 REM ***********************************************************************
20 REM **********                 PROGRAM: AUTOMATE                  **********
30 REM ***********************************************************************
40 REM **********          ROCKET MOTOR TEST CELL SIMULATOR          **********
50 REM **********                                                    **********
60 REM **********       CAPT ANDREW L. PICKENS, JR.   PROGRAMMER     **********
70 REM **********         IBM SYSTEM 9002 BASIC 1.2 FOR CSOS         **********
80 REM **********         CSOS (OPERATING SYSTEM) RELEASE 1.1        **********
90 REM **********                                                    **********
100 REM *********          DATE OF LAST REVISION: 08 MAR 1985        **********
110 REM **********************************************************************
120 REM **********************************************************************
130 REM *********          SET UP ALPHA WINDOW AND CONSOLE BOX       **********
140 REM **********************************************************************
150 REM **********************************************************************
160 CLS
170 DIM FPK%(50),G%(30),X(10),FX(10),L(10)
180 OPEN "#SCRN0" AS FILE #1                 ! OPEN ALPHA WINDOW
190 OPEN "#CNSL0" AS FILE #2                 ! OPEN CONSOLE BOX
200 FPK%(1)=23
210 FPK%(2)=0
220 CALL SYSFUNC(1,FPK%(1))                  ! FRAME ALPHA WINDOW
230 CALL SYSFUNC(2,FPK%(1))                  ! FRAME CONSOLE BOX
240 FPK%(3)=36
250 FPK%(4)=$FFFF
260 FPK%(5)=0
270 FPK%(6)=3
280 FPK%(7)=$0001
290 FPK%(8)=0
300 CALL SYSFUNC(2,FPK%(3))                  ! DEFINE FILL WORD
310 CALL SYSFUNC(2,FPK%(6))                  ! FILL CONSOLE BOX
320 REM ***********************************************************************
330 REM ***********                 ASSIGN SOFTKEYS                **************
340 REM ***********************************************************************
350 OPEN "#KPD" AS FILE #3
360 DATA " IGNITE "," QUENCH "," LIGHTS "," CAMERA "," PLANT "
370 DATA " STEAM "," GN2 "," DATA "," HOLD "," C "
380 READ NAME$(I) FOR I=1 TO 10
390 G%(1)=23
400 G%(3)=3
410 G%(4)=0
420 FPK%(1)=12                               ! ADD TO SOFTKEY TABLE
430 FPK%(3)=3
440 FPK%(4)=2
450 FOR I=1 TO 10
460 FPK%(2)=189+I
470 FPK%(5)=LEN(NAME$(I))
480 FOR J=1 TO FPK%(5)
490 FPK%(J+5)=ASCII(MID(NAME$(I),J,1))
500 NEXT J
510 FPK%(J+5)=13
520 FPK%(J+6)=0
530 G%(2)=FPK%(2)
540 CALL SYSFUNC(3,G%(1))
550 CALL SYSFUNC(3,FPK%(1))
560 TEXT((I-1)*75+27,15,NAME$(I))            ! DISPLAY NAME$(I) ON CRT
570 NEXT I
580 REM ***********************************************************************
590 REM ***************              DRAW PARAMETER WINDOWS       ***************
600 REM ***********************************************************************
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610 LINE(80,350,300,350)\LINE(300,350,300,375)
620 LINE(300,375,80,375)\LINE(80,375,80,350)       ! Pa WINDOW
630 LINE(80,300,300,300)\LINE(300,300,300,325)
640 LINE(300,325,80,325)\LINE(80,325,80,300)       ! Pse WINDOW
650 LINE(80,250,300,250)\LINE(300,250,300,275)
660 LINE(300,275,80,275)\LINE(80,275,80,250)       ! O2 WINDOW
670 LINE(80,200,300,200)\LINE(300,200,300,225)
680 LINE(300,225,80,225)\LINE(80,225,80,200)       ! Ta WINDOW
690 LINE(100,125,320,125)\LINE(320,125,320,150)
700 LINE(320,150,100,150)\LINE(100,150,100,125)    ! DATA SYSTEM WINDOW
710 LINE(100,75,320,75)\LINE(320,75,320,100)
720 LINE(320,100,100,100)\LINE(100,100,100,75)     ! COUNTDOWN TIME WINDOW
730 LINE(450,350,670,350)\LINE(670,350,670,375)
740 LINE(670,375,450,375)\LINE(450,375,450,350)    ! Fa WINDOW
750 LINE(450,300,670,300)\LINE(670,300,670,325)
760 LINE(670,325,450,325)\LINE(450,325,450,300)    ! Pc WINDOW
770 LINE(450,250,670,250)\LINE(670,250,670,275)
780 LINE(670,275,450,275)\LINE(450,275,450,250)    ! Tc WINDOW
790 LINE(400,75,680,75)\LINE(680,75,680,175)
800 LINE(680,175,400,175)\LINE(400,175,400,75)     ! MESSAGE WINDOW
810 REM ****************************************************************
820 REM ***************      HEADINGS AND LABELS        ********************
830 REM ****************************************************************
840 TEXT(100,425," FACILITY          TEST ARTICLE",2)
850 TEXT(85,400," PARAMETERS          PARAMETERS",2)
860 TEXT(20,345,"Pa",2)\TEXT(400,345,"Fa",2)
870 TEXT(20,295,"Pse",2)\TEXT(400,295,"Pc",2)
880 TEXT(20,245,"O2",2)\TEXT(400,245,"Tc",2)
890 TEXT(20,195,"Ta",2)\TEXT(475,180,"MESSAGE",2)
900 TEXT(150,155,"DATA SYSTEM")\TEXT(135,105,"COUNTDOWN TIME")
910 REM ****************************************************************
920 REM ***************           INITIALIZE           ***************
930 REM ****************************************************************
940 CLOSE #1\CLOSE #2\CLOSE #3
950 INIT=0\FACTOR=0.1\PA=14.7\FILM=80\DATA$="PERIODIC MODE"\TIMER=181
960 GN2=150\O2=20\TA=70\TC=70\MAXFA=72500\MAXPC=546
970 DALT=100000\COVER=0
980 REM *******   TARGET FOR RETURN FROM MODULES   ********
990 CALL GETKEY(A,B,C,D,E)
1000 IF E=12 THEN 1060
1010 LOCATE 20,45\PRINT"                              "\LOCATE 20,45
1020 INPUT SOFTKEY$
1030 IF B=199 THEN 3780
1040 LOCATE 20,45
1050 PRINT"CONTROL DISCONNECTED      "
1060 REM ****************************************************************
1070 REM ***************           TIME MODULE          ***************
1080 REM ****************************************************************
1090 IF INIT>0 THEN 1140
1100 SIGN$="-"\MIN%=3\COLON$=":"\SEC1%=0\SEC%=0
1110 WAIT(10)
1120 TIMER=TIMER-1
1130 GO TO 1390
1140 IF SIGN$="+" THEN 1290
1150 SEC%=SEC%-1
1160 IF SEC%<0 THEN 1180
1170 GO TO 1110
1180 SEC%=9
1190 SEC1%=SEC1%-1
1200 IF SEC1%<0 THEN 1220
```

```
1210 GO TO 1110
1220 SEC1%=5
1230 SEC%=9
1240 MIN%=MIN%-1
1250 IF MIN%<0 THEN 1270
1260 GO TO 1110
1270 SIGN$="+"\SEC%=1\SEC1%=0\MIN%=0
1280 GO TO 1110
1290 SEC%=SEC%+1
1300 IF SEC%>9 THEN 1320
1310 GO TO 1110
1320 SEC%=0
1330 SEC1%=SEC1%+1
1340 IF SEC1%>5 THEN 1360
1350 GO TO 1110
1360 SEC%=0\SEC1%=0
1370 MIN%=MIN%+1
1380 GO TO 1110
1390 REM *******************************************************************
1400 REM ***************                  Pa MODULE             ***************
1410 REM *******************************************************************
1420 IF TIMER=170 THEN 3820
1430 IF BLOWBACK=1 THEN 1640
1440 IF PUMPDOWN=1 THEN 1610
1450 IF STEAM=1 THEN 1580
1460 IF PLANT=1 THEN 1510
1470 IF PA<14.7 THEN 1490
1480 GO TO 1680
1490 PA=PA+FACTOR
1500 GO TO 1480
1510 IF PA<=1.2 THEN 1540
1520 PA=PA-0.5
1530 GO TO 1480
1540 IF PA<1.0 THEN 1570
1550 PA=1.1
1560 GO TO 1480
1570 GO TO 1490
1580 IF PA<=PALT THEN 1600
1590 PA=PA-FACTOR
1600 GO TO 1480
1610 IF PA<=PALT-0.1 THEN 1630
1620 PA=PA-0.01
1630 GO TO 1480
1640 PA=0.7
1650 BLOWBACK=0
1660 PUMPDOWN=0
1670 GO TO 1480
1680 REM*******************************************************************
1690 REM ***************                  Pse MODULE          *****************
1700 REM *******************************************************************
1710 IF TIMER=130 THEN 3900
1720 IF TIMER=-110 THEN 3900
1730 IF STEAM=1 THEN 1750
1740 GO TO 1860
1750 IF BURNTIME>30 THEN 1810
1760 IF PSE>=90 THEN 1790
1770 PSE=PSE+9
1780 GO TO 1850
1790 PSE=95
1800 GO TO 1850
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1810 IF PSE>=130 THEN 1840
1820 PSE=PSE+7
1830 GO TO 1850
1840 PSE=130
1850 GO TO 1930
1860 IF STEAM=2 THEN 1880
1870 GO TO 1850
1880 PSE=PSE-10
1890 IF PSE<0 THEN 1910
1900 GO TO 1850
1910 PSE=0
1920 GO TO 1850
1930 REM ***********************************************************************
1940 REM *************              DATA SYSTEM MODULE              ****************
1950 REM ***********************************************************************
1960 IF TIMER=15 THEN 4020
1970 IF TIMER=-80 THEN 4020
1980 IF DATASYS>=150 THEN 2110
1990 IF DATA$="PERIODIC MODE" THEN 2020
2000 DATASYS=DATASYS+1
2010 GO TO 2030
2020 DATASYS=DATASYS+0.1
2030 IF IGNITE=0 THEN 2070
2040 IF BURNOUT=1 THEN 2070
2050 IF DATA$="PERIODIC MODE" THEN 2080
2060 COVER=COVER+1
2070 GO TO 2140
2080 SLOWDATA=1
2090 COVER=COVER+0.1
2100 GO TO 2070
2110 DATASYS=150
2120 IF DATOUT=1 THEN 2070
2130 GO TO 4780
2140 REM ***********************************************************************
2150 REM ***************              02 MODULE              *****************
2160 REM ***********************************************************************
2170 IF TIMER=85 THEN 4110
2180 IF TIMER=-5 THEN 4110
2190 IF TIMER=-75 THEN 4110
2200 IF TIMER=-85 THEN 4110
2210 IF IGNITE=1 THEN 2260
2220 IF PURGE=1 THEN 2340
2230 IF O2<20 THEN 2390
2240 INIT=1
2250 GO TO 2410
2260 IF BURNOUT=1 THEN 2310
2270 IF O2<2.4 THEN 2290
2280 O2=O2-FACTOR
2290 IF PURGE=1 THEN 2370
2300 GO TO 2240
2310 IF BURNTIME>90 THEN 2220
2320 IF O2`4 THEN 4660
2330 GO TO 2220
2340 IF GN <1 THEN 4660
2350 IF O2 3.1 THEN 2370
2360 O2=O2 (2*FACTOR)
2370 GN2=GN2-1
2380 GO TO 2240
2390 O2=O2+FACTOR
2400 GO TO 2240
```

```
2410 REM ********************************************************************
2420 REM **************              Ta MODULE              *****************
2430 REM ********************************************************************
2440 IF IGNITE=1 THEN 2500
2450 IF STEAM=1 THEN 2470
2460 GO TO 2710
2470 IF TA<52 THEN 2460
2480 TA=TA-2
2490 GO TO 2460
2500 IF BURNTIME>9 THEN 2540
2510 TA=TA+17.5
2520 BURNTIME=BURNTIME+1
2530 GO TO 2460
2540 IF BURNOUT=1 THEN 2570
2550 TA=TA+0.8
2560 GO TO 2520
2570 IF SPIKE=0 THEN 2680
2580 IF SPIKE=1 THEN 2600
2590 GO TO 2630
2600 IF CYCLE=5 THEN 2670
2610 TA=TA-35
2620 CYCLE=CYCLE+1
2630 IF BURNTIME>125 THEN 2660
2640 TA=TA-0.8
2650 GO TO 2520
2660 TA=70\GO TO 2520
2670 SPIKE=2\GO TO 2630
2680 TA=300
2690 SPIKE=1
2700 GO TO 2630
2710 REM ********************************************************************
2720 REM ***************            Fa,Pc MODULE            *****************
2730 REM ********************************************************************
2740 IF TIMER=0 THEN 4300
2750 IF BURNOUT=1 THEN 2780
2760 IF IGNITE=1 THEN 2790
2770 FA=0\PC=0
2780 GO TO 2820
2790 IF BURNTIME>65 THEN 4680
2800 READ FA,PC
2810 GO TO 2780
2820 REM ********************************************************************
2830 REM ***************         Fa,Pc DATA MODULE         *****************
2840 REM ********************************************************************
2850 DATA 55000,450,50000,415,53000,420,55000,430,58000,450,62000,475
2860 DATA 63000,480,64000,490,65000,500,66000,505,67000,510,68000,515
2870 DATA 68500,520,68750,525,69000,530,69750,535,70000,538,70500,541
2880 DATA 71000,543,71500,544,72000,545,72200,546,72500,546,72500,546
2890 DATA 72500,545,72000,544,71000,542,70500,540,70000,537,69500,534
2900 DATA 69000,530,68500,525,68000,520,67500,515,67000,510,66500,505
2910 DATA 66000,500,65500,495,65000,490,64500,485,64000,480,63750,478
2920 DATA 63500,475,63250,472,63000,470,62750,468,62500,466,62250,463
2930 DATA 62000,460,61000,455,60000,450,58500,440,57500,435,55000,425
2940 DATA 53000,400,52000,390,51000,380,49000,370,48000,365,47750,360
2950 DATA 47500,355,47500,350,47750,355,25000,180,1000,10,0,0
2960 GO TO 2970
2970 REM ********************************************************************
2980 REM *************            CAMERA MODULE            ***************
2990 REM ********************************************************************
3000 IF TIMER=50 THEN 4360
```

```
3010 IF TIMER=10 THEN 4460
3020 IF TIMER=-70 THEN 4460
3030 IF TIMER=-90 THEN 4360
3040 IF CAMERA=0 THEN 3100
3050 IF FILM=1 THEN 4730
3060 FILM=FILM-1
3070 IF IGNITE=0 THEN 3100
3080 IF BURNOUT=1 THEN 3100
3090 COVRAGE=COVRAGE+1
3100 GO TO 3130
3130 REM ********************************************************************
3140 REM ************                QUENCH MODULE                ******************
3150 REM ********************************************************************
3160 IF TIMER=-68 THEN 4580
3170 QUENCH=3
3180 GO TO 3190
3190 REM ********************************************************************
3200 REM ***************                 Tc MODULE                ******************
3210 REM ********************************************************************
3220 IF QUENCH=3 THEN 3320
3230 IF BURNTIME>75 THEN 3250
3240 GO TO 3440
3250 IF BURNTIME>140 THEN 3280
3260 TC=TC+6.2
3270 GO TO 3240
3280 IF BURNTIME>195 THEN 3300
3290 GO TO 3240
3300 TC=TC-0.5
3310 GO TO 3240
3320 IF BURNTIME>75 THEN 3340
3330 GO TO 3240
3340 IF BURNTIME>195 THEN 3370
3350 TC=TC+0.4
3360 GO TO 3240
3370 IF BURNTIME>250 THEN 3390
3380 GO TO 3240
3390 TC=TC-0.2
3400 IF TC<70 THEN 3420
3410 GO TO 3240
3420 TC=70
3430 GO TO 3240
3440 REM *******************************************************************
3450 REM ***********                 END MODULE                ****************
3460 REM *******************************************************************
3470 IF SIGN$="+" THEN 3490
3480 GO TO 3520
3490 IF FINIS=1 THEN 3510
3500 IF MIN%=2 THEN 4810
3510 GO TO 3480
3520 REM *******************************************************************
3530 REM **************           DISPLAY UPDATE MODULE          *****************
3540 REM *******************************************************************
3550 LOCATE 23,12
3560 PRINT SIGN$;MIN%;COLON$;SEC1%;SEC%
3570 LOCATE 6,10
3580 PRINT PA;"PSI";"    "
3590 LOCATE 9,10
3600 PRINT PSE;"PSI";" "
3610 LOCATE 20,12
3620 PRINT DATA$;"      "
```

```
3630 LOCATE 12,10
3640 PRINT O2;"%";"        "
3650 LOCATE 15,10
3660 PRINT TA;"DEG. F";"        "
3670 LOCATE 6,50
3680 PRINT FA;"LBF";"        "
3690 LOCATE 9,50
3700 PRINT PC;"PSI";"     "
3710 LOCATE 12,50
3720 PRINT TC;"DEG. F";"        "
3730 LOCATE 19,45
3740 GO TO 980
3750 REM ********************************************************************
3760 REM ***************        SOFTKEY PROCESSING MODULE        *****************
3770 REM ********************************************************************
3780 IF FINIS=1 THEN 4850
3790 LOCATE 21,45
3800 PRINT"CONTINUE                   "
3810 GO TO 1060
3820 LOCATE 21,45
3830 IF PLANT=1 THEN 3880
3840 PAMIN%=MIN%\PASEC1%=SEC1%\PASEC%=SEC%
3850 PLANT=1\PRINT"PLANT RUNNING                  "
3860 PE=1.1
3870 GO TO 1430
3880 PLANT=0\PRINT"PLANT STOPPED                  "
3890 GO TO 3870
3900 IF STEAM=1 THEN 3980
3910 LOCATE 21,45
3920 PRINT"DESIRED ALTITUDE = ";DALT
3930 S1MIN%=MIN%\S1SEC1%=SEC1%\S1SEC%=SEC%
3940 PALT=0.162
3950 LOCATE 22,45\PRINT"PRESSURE ALTITUDE=";PALT;"  "
3960 STEAM=1
3970 GO TO 1730
3980 STEAM=2
3990 LOCATE 21,45\PRINT"STEAM EJECTOR OFF          "
4000 S2MIN%=MIN%\S2SEC1%=SEC1%\S2SEC%=SEC%
4010 GO TO 3970
4020 LOCATE 21,45
4030 IF DATA$="PERIODIC MODE" THEN 4070
4040 D2MIN%=MIN%\D2SEC1%=SEC1%\D2SEC%=SEC%
4050 DATA$="PERIODIC MODE"
4060 GO TO 4090
4070 DATA$="CONTINUOUS MODE"
4080 D1MIN%=MIN%\D1SEC1%=SEC1%\D1SEC%=SEC%
4090 PRINT DATA$;"          "
4100 GO TO 1980
4110 IF PURGE=1 THEN 4220
4120 IF JUMP=1 THEN 4190
4130 O21MIN%=MIN%\O21SEC1%=SEC1%\O21SEC%=SEC%
4140 JUMP=1
4150 PURGE=1
4160 LOCATE 21,45\PRINT"PURGING TEST CELL          "
4170 LOCATE 22,45\PRINT"GN2 SUPPLY= ";GN2;"          "
4180 GO TO 2210
4190 O23MIN%=MIN%\O23SEC1%=SEC1%\O23SEC%=SEC%
4200 JUMP=2
4210 GO TO 4150
4220 IF JUMP=2 THEN 4280
```

```
4230 O22MIN%=MIN%\O22SEC1%=SEC1%\O22SEC%=SEC%
4240 LOCATE 22,45\PRINT"GN2 SUPPLY= ";GN2;"              "
4250 LOCATE 21,45\PRINT"PURGE OFF                        "
4260 PURGE=0
4270 GO TO 4180
4280 O24MIN%=MIN%\O24SEC1%=SEC1%\O24SEC%=SEC%
4290 GO TO 4240
4300 LOCATE 21,45
4310 IGNSIGN$=SIGN$\IGNMIN%=MIN%\IGNSEC1%=SEC1%\IGNSEC%=SEC%
4320 IGNITE=1\PUMPDOWN=1
4330 PRINT"                              "\LOCATE 21,45
4340 PRINT"MOTOR FIRING!"
4350 GO TO 2750
4360 LOCATE 22,45
4370 IF LIGHTS=1 THEN 4420
4380 P1MIN%=MIN%\P1SEC1%=SEC1%\P1SEC%=SEC%
4390 PRINT"PHOTO LIGHTS ON               "
4400 LIGHTS=1
4410 GO TO 3040
4420 PRINT"PHOTO LIGHTS OFF              "
4430 P2MIN%=MIN%\P2SEC1%=SEC1%\P2SEC%=SEC%
4440 LIGHTS=0
4450 GO TO 4410
4460 LOCATE 22,45
4470 IF CAMERA=1 THEN 4520
4480 C1MIN%=MIN%\C1SEC1%=SEC1%\C1SEC%=SEC%
4490 PRINT"CAMERA ON                     "
4500 CAMERA=1
4510 GO TO 4550
4520 PRINT"CAMERA OFF                    "
4530 C2MIN%=MIN%\C2SEC1%=SEC1%\C2SEC%=SEC%
4540 CAMERA=0
4550 LOCATE 23,45
4560 PRINT"FILM SUPPLY= ";FILM;"  "
4570 GO TO 980
4580 LOCATE 21,45
4590 PRINT"QUENCHING MOTOR               "
4600 Q1MIN%=MIN%\Q1SEC1%=SEC1%\Q1SEC%=SEC%
4610 QUENCH=1
4620 GO TO 980
4630 REM ********************************************************************
4640 REM ************            WARNING MODULE                ****************
4650 REM ********************************************************************
4660 LOCATE 21,45\PRINT"O2 MODULE PROBLEMS"
4670 END
4680 LOCATE 20,45
4690 PRINT"MOTOR BURNOUT!                "
4700 BURNOUT=1\BLOWBACK=1
4710 DURATION=BURNTIME
4720 GO TO 2820
4730 LOCATE 23,45
4740 PRINT"OUT OF FILM                   "
4760 CAMSIGN$=SIGN$\CAMMIN%=MIN%\CAMSEC1%=SEC1%\CAMSEC%=SEC%
4770 GO TO 3060
4780 LOCATE 22,45
4790 PRINT"OUT OF DATA STORAGE           "
4800 DATOUT=1
4810 LOCATE 23,45
4820 PRINT"PRESS SOFTKEY C TO END        "
4830 FINIS=1
```

```
4840 GO TO 3510
4850 REM ***********************************************************************
4860 REM *************              RESULTS MODULE              ************
4870 REM ***********************************************************************
4880 CLS
4890 DATASPACE=150-DATASYS
4900 PRINT"STATUS OF FACILITY PARAMETERS:","STATUS OF CONSUMABLE RESOURCES:"
4910 PRINT
4920 PRINT"          Pa = ";PA,,"DATA SPACE REMAINING =";DATASPACE;"SEC"
4930 PRINT"         Pse = ";PSE,,"        GN2 REMAINING =";GN2;"SEC"
4940 PRINT"          O2 = ";O2,,"       FILM REMAINING =";FILM;"SEC"
4950 PRINT"          Ta = ";TA
4960 PRINT"    DATA SYSTEM      = ";DATA$
4970 PRINT"    COUNTDOWN TIME   = ";SIGN$;MIN%;COLON$;SEC1%;SEC%
4980 PRINT
4990 PRINT" RESULTS OF FIRING:"
5000 PRINT
5010 PRINT"PLANT EXHAUST DUCT PRESSURE, Pe=";PE;"PSI"
5020 PRINT"STEAM EJECTOR, Pse, AT 95 PSI; RAMPED TO 130 PSI AT T+30 SECONDS"
5030 PRINT"AVERAGE ALTITUDE=";DALT;"FT."
5040 PRINT"GEOPOTENTIAL PRESSURE ALTITUDE=";PALT;"PSI"
5050 PRINT"MOTOR IGNITED AT T";IGNSIGN$;IGNMIN%;COLON$;IGNSEC1%;IGNSEC%
5060 PRINT"MOTOR QUENCHED SUCCESSFULLY"
5070 PRINT"MOTOR BURN TIME=";DURATION;"SECONDS"
5080 PRINT"MAXIMUM THRUST, Fa= ";MAXFA;"LBF"
5090 PRINT"MAXIMUM CHAMBER PRESSURE, Pc= ";MAXPC;"PSI"
5100 PRINT"PHOTOGRAPHIC COVERAGE DURING FIRING=";COVRAGE;"SECONDS"
5110 PRINT"DIGITAL DATA COVERAGE DURING FIRING=";COVER;"SECONDS"
5120 PRINT
5130 INPUT"PRESS RETURN KEY TO CONTINUE ";CONTINUE$
5140 CLS
5150 PRINT"OTHER MESSAGES:"
5160 PRINT
5170 PRINT"PLANT RUNNING AT T-";PAMIN%;COLON$;PASEC1%;PASEC%
5180 PRINT"STEAM EJECTOR ON AT T-";S1MIN%;COLON$;S1SEC1%;S1SEC%
5190 PRINT"PURGE ON AT T-";O21MIN%;COLON$;O21SEC1%;O21SEC%
5200 PRINT"PHOTO LIGHTS ON AT T-";P1MIN%;COLON$;P1SEC1%;P1SEC%
5210 PRINT"DATA SYSTEM CONTINUOUS AT T-";D1MIN%;COLON$;D1SEC1%;D1SEC%
5220 PRINT"CAMERA ON AT T-";C1MIN%;COLON$;C1SEC1%;C1SEC%
5230 PRINT"MOTOR IGNITED AT T";IGNSIGN$;IGNMIN%;COLON$;IGNSEC1%;IGNSEC%
5240 PRINT"PURGE OFF AT T+";O22MIN%;COLON$;O22SEC1%;O22SEC%
5250 PRINT"QUENCHED AT T+";Q1MIN%;COLON$;Q1SEC1%;Q1SEC%
5260 PRINT"CAMERA OFF AT T+";C2MIN%;COLON$;C2SEC1%;C2SEC%
5270 PRINT"PURGE ON AT T+";O23MIN%;COLON$;O23SEC1%;O23SEC%
5280 PRINT"DATA PERIODIC AT T+";D2MIN%;COLON$;D2SEC1%;S2SEC%
5290 PRINT"PURGE OFF AT T+";O24MIN%;COLON$;O24SEC1%;O24SEC%
5300 PRINT"PHOTO LIGHTS OFF AT T+";P2MIN%;COLON$;P2SEC1%;P2SEC%
5310 PRINT"STEAM EJECTOR OFF AT T+";S2MIN%;COLON$;S2SEC1%;S2SEC%
5320 END
```

```
50 REM ***********************************************************************
52 REM **********         ROCKET MOTOR TEST CELL SIMULATOR          **********
54 REM **********                                                   **********
56 REM **********      CAPT ANDREW L. PICKENS, JR.   PROGRAMMER     **********
58 REM **********        IBM SYSTEM 9002 BASIC 1.2 FOR CSOS         **********
60 REM **********        CSOS (OPERATING SYSTEM) RELEASE 1.1        **********
62 REM **********                                                   **********
64 REM **********        DATE OF LAST REVISION: 08 MAR 1985         **********
66 REM ***********************************************************************
79 REM ***********************************************************************
80 REM **********        SET UP ALPHA WINDOW AND CONSOLE BOX         *********
81 REM ***********************************************************************
88 REM ***********************************************************************
90 CLS
100 DIM FPK%(50),G%(30),X(10),FX(10),L(10)
110 OPEN "#SCRNO" AS FILE #1                  ! OPEN ALPHA WINDOW
120 OPEN "#CNSLO" AS FILE #2                  ! OPEN CONSOLE BOX
130 FPK%(1)=23
140 FPK%(2)=0
150 CALL SYSFUNC(1,FPK%(1))                   ! FRAME ALPHA WINDOW
160 CALL SYSFUNC(2,FPK%(1))                   ! FRAME CONSOLE BOX
170 FPK%(3)=36
180 FPK%(4)=$FFFF
190 FPK%(5)=0
200 FPK%(6)=3
210 FPK%(7)=$0001
220 FPK%(8)=0
230 CALL SYSFUNC(2,FPK%(3))                   ! DEFINE FILL WORD
240 CALL SYSFUNC(2,FPK%(6))                   ! FILL CONSOLE BOX
249 REM ***********************************************************************
250 REM ***********             ASSIGN SOFTKEYS                **************
251 REM ***********************************************************************
260 OPEN "#KPD" AS FILE #3
270 DATA " IGNITE "," QUENCH "," LIGHTS "," CAMERA "," PLANT "
280 DATA " STEAM "," GN2 "," DATA "," HOLD "," C "
290 READ NAME$(I) FOR I=1 TO 10
295 G%(1)=23
296 G%(3)=3
297 G%(4)=0
300 FPK%(1)=12                                ! ADD TO SOFTKEY TABLE
310 FPK%(3)=3
320 FPK%(4)=2
330 FOR I=1 TO 10
340 FPK%(2)=189+I
350 FPK%(5)=LEN(NAME$(I))
360 FOR J=1 TO FPK%(5)
370 FPK%(J+5)=ASCII(MID(NAME$(I),J,1))
380 NEXT J
390 FPK%(J+5)=13
400 FPK%(J+6)=0
405 G%(2)=FPK%(2)
410 CALL SYSFUNC(3,G%(1))
412 CALL SYSFUNC(3,FPK%(1))
415 TEXT((I-1)*75+27,15,NAME$(I))            ! DISPLAY NAME$(I) ON CRT
420 NEXT I
430 REM ***********************************************************************
431 REM ***************          DRAW PARAMETER WINDOWS         ***************
432 REM ***********************************************************************
434 LINE(80,350,300,350)\LINE(300,350,300,375)
436 LINE(300,375,80,375)\LINE(80,375,80,350)          ! Pa WINDOW
```

```
438 LINE(80,300,300,300)\LINE(300,300,300,325)
440 LINE(300,325,80,325)\LINE(80,325,80,300)        ! Pse WINDOW
442 LINE(80,250,300,250)\LINE(300,250,300,275)
444 LINE(300,275,80,275)\LINE(80,275,80,250)        ! O2 WINDOW
450 LINE(80,200,300,200)\LINE(300,200,300,225)
452 LINE(300,225,80,225)\LINE(80,225,80,200)        ! Ta WINDOW
454 LINE(100,125,320,125)\LINE(320,125,320,150)
456 LINE(320,150,100,150)\LINE(100,150,100,125)     ! DATA SYSTEM WINDOW
458 LINE(100,75,320,75)\LINE(320,75,320,100)
460 LINE(320,100,100,100)\LINE(100,100,100,75)      ! COUNTDOWN TIME WINDOW
462 LINE(450,350,670,350)\LINE(670,350,670,375)
464 LINE(670,375,450,375)\LINE(450,375,450,350)     ! Fa WINDOW
466 LINE(450,300,670,300)\LINE(670,300,670,325)
468 LINE(670,325,450,325)\LINE(450,325,450,300)     ! Pc WINDOW
470 LINE(450,250,670,250)\LINE(670,250,670,275)
472 LINE(670,275,450,275)\LINE(450,275,450,250)     ! Tc WINDOW
474 LINE(400,75,680,75)\LINE(680,75,680,175)
476 LINE(680,175,400,175)\LINE(400,175,400,75)      ! MESSAGE WINDOW
478 REM **********************************************************************
479 REM ***************        HEADINGS AND LABELS          ********************
480 REM **********************************************************************
482 TEXT(100,425," FACILITY             TEST ARTICLE",2)
484 TEXT(85,400," PARAMETERS            PARAMETERS",2)
486 TEXT(20,345,"Pa",2)\TEXT(400,345,"Fa",2)
488 TEXT(20,295,"Pse",2)\TEXT(400,295,"Pc",2)
490 TEXT(20,245,"02",2)\TEXT(400,245,"Tc",2)
492 TEXT(20,195,"Ta",2)\TEXT(475,180,"MESSAGE",2)
494 TEXT(150,155,"DATA SYSTEM")\TEXT(135,105,"COUNTDOWN TIME")
496 REM **********************************************************************
497 REM ***************             START MESSAGE                ****************
498 REM **********************************************************************
500 OPEN "#CON" AS FILE #4
505 CALL GETKEY(A,B,C,D,E)
510 LOCATE 21,45
515 PRINT"HIT ANY KEY TO START"
520 IF E=0 THEN 550
525 WAIT(6)
530 LOCATE 21,45
535 PRINT"                    "
540 WAIT(6)
545 GO TO 505
550 INIT=0\FACTOR=0.1\PA=14.7\FILM=80\DATA$="PERIODIC MODE"
553 GN2=150\O2=20\TA=70\TC=70\MAXFA=72500\MAXPC=546\COVER=-1
555 LOCATE 21,45\PRINT"                    "
560 REM **********************************************************************
561 REM ************        CHECK SOFTKEYS FOR INPUT               ***************
562 REM **********************************************************************
565 CALL GETKEY(A,B,C,D,E)
567 IF E=12 THEN 600
569 LOCATE 20,45\PRINT"                              "\LOCATE 20,45
571 INPUT SOFTKEY$
573 IF B=190 THEN 20270
574 IF B=191 THEN 20450
575 IF B=192 THEN 20350
576 IF B=193 THEN 20395
577 IF B=194 THEN 20050
578 IF B=195 THEN 20070
579 IF B=196 THEN 20225
580 IF B=197 THEN 20190
581 IF B=198 THEN 20005
```

```
582 IF B=199 THEN 20031
583 LOCATE 22,45\PRINT"ERROR- INVALID KEY"
585 END
600 REM ************************************************************************
601 REM ***************                  TIME MODULE                 *****************
602 REM ************************************************************************
605 IF HOLD=1 THEN 20005
610 IF INIT>0 THEN 630
615 SIGN$="-"\MIN%=3\COLON$=":"\SEC1%=0\SEC%=0
620 WAIT(10)
625 GO TO 800
630 IF SIGN$="+" THEN 705
635 SEC%=SEC%-1
640 IF SEC%<0 THEN 650
645 GO TO 620
650 SEC%=9
655 SEC1%=SEC1%-1
660 IF SEC1%<0 THEN 670
665 GO TO 620
670 SEC1%=5
675 SEC%=9
680 MIN%=MIN%-1
685 IF MIN%<0 THEN 695
690 GO TO 620
695 SIGN$="+"\SEC%=1\SEC1%=0\MIN%=0
700 GO TO 620
705 SEC%=SEC%+1
710 IF SEC%>9 THEN 720
715 GO TO 620
720 SEC%=0
725 SEC1%=SEC1%+1
730 IF SEC1%>5 THEN 740
735 GO TO 620
740 SEC%=0\SEC1%=0
745 MIN%=MIN%+1
750 GO TO 620
800 REM ************************************************************************
801 REM ***************                   Pa MODULE                 ******************
802 REM ************************************************************************
805 IF BLOWBACK=1 THEN 894
810 IF PUMPDOWN=1 THEN 888
815 IF STEAM=1 THEN 875
820 IF PLANT=1 THEN 845
825 IF PA<14.7 THEN 835
830 GO TO 900
835 PA=PA+FACTOR
840 GO TO 830
845 IF PA<=1.2 THEN 860
850 PA=PA-0.5
855 GO TO 830
860 IF PA<1.0 THEN 870
863 PA=1.1
865 GO TO 830
870 GO TO 835
875 IF PA<=PALT THEN 885
880 PA=PA-FACTOR
885 GO TO 830
888 IF PA<=PALT-0.1 THEN 892
890 PA=PA-0.01
892 GO TO 830
```

```
894 PA=0.7
896 BLOWBACK=0
898 PUMPDOWN=0
899 GO TO 830
900 REM*******************************************************************
901 REM ***************              Pse MODULE             ******************
902 REM *******************************************************************
905 IF STEAM=1 THEN 915
910 GO TO 970
915 IF BURNTIME>30 THEN 945
920 IF PSE>=90 THEN 935
925 PSE=PSE+9
930 GO TO 965
935 PSE=95
940 GO TO 965
945 IF PSE>=130 THEN 960
950 PSE=PSE+7
955 GO TO 965
960 PSE=130
965 GO TO 1000
970 IF STEAM=2 THEN 980
975 GO TO 965
980 PSE=PSE-10
985 IF PSE<0 THEN 995
990 GO TO 965
995 PSE=0
998 GO TO 965
1000 REM *****************************************************************
1001 REM *************          DATA SYSTEM MODULE         ****************
1002 REM *****************************************************************
1005 IF DATASYS>=150 THEN 1060
1010 IF DATA$="PERIODIC MODE" THEN 1025
1015 DATASYS=DATASYS+1
1020 GO TO 1030
1025 DATASYS=DATASYS+0.1
1030 IF IGNITE=0 THEN 1045
1033 IF BURNOUJ=1 THEN 1045
1035 IF DATA$="PERIODIC MODE" THEN 1050
1040 COVER=COVER+1
1045 GO TO 1100
1050 SLOWDATA=1
1053 COVER=COVER+0.1
1055 GO TO 1045
1060 DATASYS=150
1063 IF DATOUT=1 THEN 1045
1065 GO TO 25290
1100 REM *****************************************************************
1101 REM ***************             02 MODULE             ****************
1102 REM *****************************************************************
1105 IF IGNITE=1 THEN 1125
1110 IF PURGE=1 THEN 1165
1115 IF 02<20 THEN 1190
1120 INIT=1
1122 GO TO 1200
1125 IF BURNOUT=1 THEN 1150
1130 IF 02<2.4 THEN 1140
1135 02=02-FACTOR
1140 IF PURGE=1 THEN 1180
1145 GO TO 1120
1150 IF BURNTIME>90 THEN 1110
```

```
1155 IF O2>4 THEN 25072
1160 GO TO 1110
1165 IF GN2<1 THEN 25035
1170 IF O2<3.1 THEN 1180
1175 O2=O2-(2*FACTOR)
1180 GN2=GN2-1
1185 GO TO 1120
1190 O2=O2+FACTOR
1195 GO TO 1120
1200 REM *****************************************************************
1201 REM **************              Ta MODULE               *****************
1202 REM *****************************************************************
1205 IF IGNITE=1 THEN 1235
1210 IF STEAM=1 THEN 1220
1215 GO TO 1300
1220 IF TA<52 THEN 1215
1225 TA=TA-2
1230 GO TO 1215
1235 IF BURNTIME>9 THEN 1255
1240 TA=TA+17.5
1245 BURNTIME=BURNTIME+1
1250 GO TO 1215
1255 IF BURNOUT=1 THEN 1270
1260 TA=TA+0.8
1265 GO TO 1245
1270 IF SPIKE=0 THEN 1296
1275 IF SPIKE=1 THEN 1280
1278 GO TO 1286
1280 IF CYCLE=5 THEN 1294
1282 TA=TA-35
1284 CYCLE=CYCLE+1
1286 IF BURNTIME>125 THEN 1292
1288 TA=TA-0.8
1290 GO TO 1245
1292 TA=70\GO TO 1245
1294 SPIKE=2\GO TO 1286
1296 TA=300
1298 SPIKE=1
1299 GO TO 1286
1300 REM *****************************************************************
1301 REM ***************          Fa,Pc MODULE          *********************
1302 REM *****************************************************************
1303 IF BURNOUT=1 THEN 1315
1305 IF IGNITE=1 THEN 1320
1310 FA=0\PC=0
1315 GO TO 1400
1320 IF BURNTIME>66 THEN 25135
1325 READ FA,PC
1330 GO TO 1315
1400 REM *****************************************************************
1405 REM ***************          Fa,Pc DATA MODULE          ****************
1410 REM *****************************************************************
1415 DATA 55000,450,50000,415,53000,420,55000,430,58000,450,62000,475
1420 DATA 63000,480,64000,490,65000,500,66000,505,67000,510,68000,515
1425 DATA 68500,520,68750,525,69000,530,69750,535,70000,538,70500,541
1430 DATA 71000,543,71500,544,72000,545,72200,546,72500,546,72500,546
1435 DATA 72500,545,72000,544,71000,542,70500,540,70000,537,69500,534
1440 DATA 69000,530,68500,525,68000,520,67500,515,67000,510,66500,505
1445 DATA 66000,500,65500,495,65000,490,64500,485,64000,480,63750,478
1450 DATA 63500,475,63250,472,63000,470,62750,468,62500,466,62250,463
```

```
1455 DATA 62000,460,61000,455,60000,450,58500,440,57500,435,55000,425
1460 DATA 53000,400,52000,390,51000,380,49000,370,48000,365,47750,360
1465 DATA 47500,355,47500,350,47750,355,25000,180,1000,10,0,0
1470 GO TO 1600
1600 REM ***********************************************************************
1601 REM *************            CAMERA MODULE                  **************
1602 REM ***********************************************************************
1605 IF CAMERA=0 THEN 1635
1610 IF FILM=1 THEN 25245
1612 IF FILM=0 THEN 1635
1615 FILM=FILM-1
1620 IF IGNITE=0 THEN 1635
1625 IF LIGHTS=0 THEN 25270
1628 IF BURNOUT=1 THEN 1635
1630 COVRAGE=COVRAGE+1
1635 GO TO 1700
1700 REM ***********************************************************************
1701 REM ************             QUENCH MODULE               *****************
1702 REM ***********************************************************************
1705 IF QUENCH>2 THEN 1730
1710 IF BURNTIME>75 THEN 25360
1715 IF QUENCH=0 THEN 1730
1720 IF QUENCH=2 THEN 1730
1725 QUENCH=3
1730 GO TO 1800
1800 REM ***********************************************************************
1801 REM ***************             Tc MODULE              ******************
1802 REM ***********************************************************************
1805 IF QUENCH=3 THEN 1855
1810 IF BURNTIME>75 THEN 1820
1815 GO TO 1900
1820 IF BURNTIME>140 THEN 1835
1825 TC=TC+6.2
1830 GO TO 1815
1835 IF BURNTIME>195 THEN 1845
1840 GO TO 1815
1845 TC=TC-0.5
1850 GO TO 1815
1855 IF BURNTIME>75 THEN 1865
1860 GO TO 1815
1865 IF BURNTIME>195 THEN 1880
1870 TC=TC+0.4
1875 GO TO 1815
1880 IF BURNTIME>250 THEN 1890
1885 GO TO 1815
1890 TC=TC-0.2
1892 IF TC<70 THEN 1896
1894 GO TO 1815
1896 TC=70
1898 GO TO 1815
1900 REM **********************************************************************
1901 REM ***********             END MODULE                 ***************
1902 REM **********************************************************************
1905 IF SIGN$="+" THEN 1915
1910 GO TO 10000
1915 IF FINIS=1 THEN 1925
1920 IF MIN%=2 THEN 25400
1925 GO TO 1910
10000 REM *********************************************************************
10001 REM *************          DISPLAY UPDATE MODULE         *****************
```

```
10002 REM ****************************************************************************
10005 LOCATE 23,12
10010 PRINT SIGN$;MIN%;COLON$;SEC1%;SEC%
10015 LOCATE 6,10
10020 PRINT PA;"PSI";"    "
10025 LOCATE 9,10
10030 PRINT PSE;"PSI";" "
10035 LOCATE 20,12
10040 PRINT DATA$;"      "
10045 LOCATE 12,10
10050 PRINT O2;"%";"       "
10055 LOCATE 15,10
10060 PRINT TA;"DEG. F";"       "
10065 LOCATE 6,50
10070 PRINT FA;"LBF";"        "
10075 LOCATE 9,50
10080 PRINT PC;"PSI";"     "
10085 LOCATE 12,50
10090 PRINT TC;"DEG. F";"       "
10095 LOCATE 19,45
10100 GO TO 560
20000 REM ****************************************************************************
20001 REM ***************        SOFTKEY PROCESSING MODULE       ******************
20002 REM ****************************************************************************
20005 IF FLIP=1 THEN 20015
20007 LOCATE 21,45\PRINT"TEST CONDUCTOR HOLD        "
20009 FLIP=FLIP+0.5
20011 FLOP=0
20013 GO TO 20021
20015 IF FLOP=1 THEN 20040
20017 FLOP=FLOP+0.5
20019 LOCATE 21,45\PRINT"HIT SOFTKEY C TO CONTINUE "
20021 CALL GETKEY(A,B,C,D,E)
20023 IF B=199 THEN 20029
20025 HOLD=1
20027 GO TO 620
20029 LOCATE 20,45\INPUT SOFTKEY$
20031 LOCATE 21,45\PRINT"CONTINUE                   "
20032 IF FINIS=1 THEN 26000
20033 HOLD=0
20035 GO TO 20027
20040 FLIP=0
20045 GO TO 20019
20050 LOCATE 21,45
20053 IF PLANT=1 THEN 20059
20055 PLANT=1\PRINT"PLANT RUNNING           "
20056 PE=1.1
20058 GO TO 560
20059 IF STEAM=1 THEN 25225
20060 PLANT=0\PRINT"PLANT STOPPED           "
20065 GO TO 20058
20070 LOCATE 21,45\PRINT"                          "
20071 IF PLANT=0 THEN 25155
20072 IF PA>1.1 THEN 25380
20073 IF STEAM=1 THEN 20183
20074 LOCATE 21,45
20075 INPUT"DESIRED ALTITUDE = ";DALT
20080 X(0)=0.818\X(1)=0.644\X(2)=0.507\X(3)=0.401\X(4)=0.317
20085 X(5)=0.251\X(6)=0.199\X(7)=0.158\X(8)=0.126\X(9)=0.100
20090 FX(0)=65000\FX(1)=70000\FX(2)=75000\FX(3)=80000\FX(4)=85000
```

```
20095 FX(5)=90000\FX(6)=95000\FX(7)=100000\FX(8)=105000\FX(9)=110000
20100 IF DALT<65000 THEN 25195
20105 IF DALT>110000 THEN 25210
20110 IF DALT<80000 THEN 20160
20115 IF DALT>95000 THEN 20150
20120 FOR I=0 TO 9
20125 IF DALT<FX(I) THEN 20140
20130 NEXT I
20135 GO TO 25180
20140 LOOP=I
20145 GO TO 20900
20150 LOOP=7
20155 GO TO 20900
20160 LOOP=0
20165 GO TO 20900
20170 PALT=SUM
20172 SUM=0
20173 LOCATE 22,45\PRINT"PRESSURE ALTITUDE=";PALT;"  "
20175 STEAM=1
20180 GO TO 560
20183 STEAM=2
20184 LOCATE 21,45\PRINT"STEAM EJECTOR OFF          "
20185 GO TO 560
20190 LOCATE 21,45
20195 IF DATA$="PERIODIC MODE" THEN 20210
20200 DATA$="PERIODIC MODE"
20205 GO TO 20215
20210 DATA$="CONTINUOUS MODE"
20215 PRINT DATA$;"             "
20220 GO TO 560
20225 IF PURGE=1 THEN 20250
20230 LOCATE 21,45\PRINT"PURGING TEST CELL           "
20235 LOCATE 22,45\PRINT"GN2 SUPPLY= ";GN2;"           "
20240 PURGE=1
20245 GO TO 560
20250 LOCATE 22,45\PRINT"GN2 SUPPLY= ";GN2;"           "
20255 LOCATE 21,45\PRINT"PURGE OFF                   "
20260 PURGE=0
20265 GO TO 20245
20270 LOCATE 21,45
20275 IF MIN%<>0 THEN 25050
20280 IF SEC1%<>0 THEN 25050
20285 IF SEC%>2 THEN 25050
20290 IF PLANT=0 THEN 25073
20295 IF O2>4 THEN 25085
20300 IF STEAM=0 THEN 25100
20305 IGNSIGN$=SIGN$\IGNMIN%=MIN%\IGNSEC1%=SEC1%\IGNSEC%=SEC%
20310 IGNITE=1\PUMPDOWN=1
20315 PRINT"                          "\LOCATE 21,45
20320 PRINT"MOTOR FIRING!"
20325 GO TO 560
20350 LOCATE 22,45
20355 IF LIGHTS=1 THEN 20375
20360 PRINT"PHOTO LIGHTS ON          "
20365 LIGHTS=1
20370 GO TO 560
20375 PRINT"PHOTO LIGHTS OFF         "
20380 LIGHTS=0
20385 GO TO 20370
20395 LOCATE 22,45
```

```
20400 IF CAMERA=1 THEN 20425
20405 PRINT"CAMERA ON                    "
20410 CAMERA=1
20420 GO TO 20435
20425 PRINT"CAMERA OFF                   "
20430 CAMERA=0
20435 LOCATE 23,45
20440 PRINT"FILM SUPPLY= ";FILM;"  "
20445 GO TO 560
20450 LOCATE 21,45
20455 IF QUENCH>0 THEN 20490
20460 PRINT"QUENCHING MOTOR              "
20465 QUENCH=1
20470 IF SIGN$="-" THEN 25315
20480 IF BURNOUT=0 THEN 25340
20485 GO TO 560
20490 PRINT"QUENCH DEPLETED              "
20495 GO TO 20485
20900 REM ********************************************************************
20901 REM **********       LAGRANGIAN INTERPOLATION METHOD        ****************
20902 REM **********   ATTACHED TO SOFTKEY PROCESSING MODULE    ****************
20903 REM ********************************************************************
20905 FOR I=LOOP TO (LOOP+2)
20910 PART2=1\PART4=1
20915 FOR J=LOOP TO (LOOP+2)
20920 IF J=I THEN 20945
20925 PART1=DALT-FX(J)
20930 PART2=PART2*PART1
20935 PART3=FX(I)-FX(J)
20940 PART4=PART3*PART4
20945 NEXT J
20950 L(I)=PART2/PART4
20955 F(I)=L(I)*X(I)
20960 NEXT I
20965 FOR K=LOOP TO (LOOP+2)
20970 SUM=SUM+F(K)
20975 NEXT K
20980 GO TO 20170
25000 REM ********************************************************************
25001 REM ************             WARNING MODULE                ****************
25002 REM ********************************************************************
25005 LOCATE 21,45
25010 PRINT"PRESSURE TOO LOW          "\WAIT(30)
25015 GO TO 20070
25020 LOCATE 21,45
25025 PRINT"PRESSURE TOO HIGH         "\WAIT(30)
25030 GO TO 20070
25035 LOCATE 22,45
25040 PRINT"GN2 SUPPLY DEPLETED        "
25045 PURGE=0\GO TO 20255
25050 LOCATE 22,45
25055 PRINT"COMPROMISED TIMING         "
25060 FIRING=1
25065 GO TO 20290
25070 F9=1
25072 GO TO 25075
25073 F8=1
25075 LOCATE 22,45
25080 PRINT"TEST CELL DESTROYED        "
25082 WAIT(70)
```

```
25083 GO TO 26000
25085 LOCATE 22,45
25090 PRINT"PLANT DESTROYED           "
25095 F8=1
25096 WAIT(70)
25098 GO TO 26000
25100 IF FIRING=1 THEN 25125
25105 LOCATE 21,45
25110 PRINT"DATA COMPROMISED          "
25115 ALTITUDE=1
25120 GO TO 20305
25125 LOCATE 22,45
25130 GO TO 25110
25135 LOCATE 21,45
25140 PRINT"MOTOR BURNOUT!            "
25145 BURNOUT=1\BLOWBACK=1
25148 DURATION=BURNTIME
25150 GO TO 1400
25155 LOCATE 22,45
25160 PRINT"PLANT NOT RUNNING         "
25165 F1=F1+1          ! NUMBER OF TIMES FOR THIS FAULT
25170 STEAM=0          ! TRYED TO START STEAM BEFORE PLANT
25175 GO TO 560
25180 LOCATE 22,45
25185 PRINT"INVALID DATA -REENTER     "
25190 GO TO 20070
25195 LOCATE 22,45
25200 PRINT"ALTITUDE TOO LOW -REENTER "
25203 F6=F6+1
25205 GO TO 20070
25210 LOCATE 22,45
25215 PRINT"ALTITUDE TOO HIGH -REENTER"
25218 F7=F7+1
25220 GO TO 20070
25225 LOCATE 21,45
25230 PRINT"SHUTDOWN STEAM FIRST      "
25235 F2=F2+1      ! TRIED TO STOP PLANT BEFORE STEAM
25240 GO TO 20058
25245 LOCATE 23,45
25250 PRINT"OUT OF FILM               "
25260 CAMSIGN$=SIGN$\CAMMIN%=MIN%\CAMSEC1%=SEC1%\CAMSEC%=SEC%
25265 GO TO 1615
25270 LOCATE 21,45
25275 PRINT"PHOTO LIGHTS OFF          "
25280 F3=F3+1      ! TIME VISUAL COVERAGE LOST
25285 GO TO 1635
25290 LOCATE 22,45
25295 PRINT"OUT OF DATA STORAGE       "
25300 DATOUT=1
25305 DATSIGN$=SIGN$\DATMIN%=MIN%\DATSEC1%=SEC1%\DATSEC%=SEC%
25310 GO TO 1045
25315 LOCATE 22,45
25320 PRINT"MOTOR DESTROYED!          "
25325 LOCATE 23,45
25330 PRINT"PROPELLANT WETTED         "
25332 WAIT(70)
25335 F4=1\GO TO 26000
25340 LOCATE 22,45
25345 PRINT"QUENCH PROBE DESTROYED    "
25350 QUENCH=2
```

```
25355 GO TO 560
25360 LOCATE 22,45
25365 PRINT"QUENCHED TOO LATE          "
25370 QUENCH=4
25375 GO TO 1730
25380 LOCATE 22,45
25385 PRINT"WAIT TILL Pa STABILIZES    "
25390 F5=F5+1
25395 GO TO 560
25400 LOCATE 23,45
25405 PRINT"PRESS SOFTKEY C TO END     "
25410 FINIS=1
25415 GO TO 1925
26000 REM *****************************************************************
26001 REM *************                 RESULTS MODULE            ************
26002 REM *****************************************************************
26005 CLS
26008 DATASPACE=150-DATASYS
26010 PRINT"STATUS OF FACILITY PARAMETERS:","STATUS OF CONSUMABLE RESOURCES:"
26015 PRINT
26020 PRINT"          Pa = ";PA,,"DATA SPACE REMAINING =";DATASPACE;"SEC"
26025 PRINT"         Pse = ";PSE,,"        GN2 REMAINING =";GN2;"SEC"
26030 PRINT"          O2 = ";O2,,"        FILM REMAINING =";FILM;"SEC"
26035 PRINT"          Ta = ";TA
26040 PRINT"    DATA SYSTEM      = ";DATA$
26045 PRINT"    COUNTDOWN TIME   = ";SIGN$;MIN%;COLON$;SEC1%;SEC%
26050 PRINT
26055 PRINT" RESULTS OF FIRING:"
26058 PRINT
26060 IF PE=1.1 THEN 26070
26063 PRINT"PLANT NOT ACTIVATED"
26065 GO TO 26080
26070 PRINT"PLANT EXHAUST DUCT PRESSURE, Pe=";PE;"PSI"
26075 IF STEAM>0 THEN 26090
26080 PRINT"STEAM EJECTOR NOT ACTIVATED"
26085 GO TO 26110
26090 IF STEAM=2 THEN 26100
26095 PRINT"STEAM EJECTOR NOT TURNED OFF"
26100 PRINT"STEAM EJECTOR, Pse, AT 95 PSI; RAMPED TO 130 PSI AT T+30 SECONDS"
26110 PRINT"AVERAGE ALTITUDE=";DALT;"FT."
26115 PRINT"GEOPOTENTIAL PRESSURE ALTITUDE=";PALT;"PSI"
26120 IF F4=1 THEN 26265
26125 IF IGNITE=1 THEN 26140
26130 PRINT"MOTOR NOT IGNITED"
26135 GO TO 26180
26140 IF FIRING=1 THEN 26240
26145 PRINT"MOTOR IGNITED AT T";IGNSIGN$;IGNMIN%;COLON$;IGNSEC1%;IGNSEC%
26150 IF F9=1 THEN 26230
26155 IF QUENCH=0 THEN 26225
26160 IF QUENCH=2 THEN 26215
26165 IF QUENCH=4 THEN 26205
26170 PRINT"MOTOR QUENCHED SUCCESSFULLY"
26175 PRINT"MOTOR BURN TIME=";DURATION;"SECONDS"
26176 PRINT"MAXIMUM THRUST, Fa= ";MAXFA;"LBF"
26177 PRINT"MAXIMUM CHAMBER PRESSURE, Pc= ";MAXPC;"PSI"
26180 PRINT"PHOTOGRAPHIC COVERAGE DURING FIRING=";COVRAGE;"SECONDS"
26185 PRINT"DIGITAL DATA COVERAGE DURING FIRING=";COVER;"SECONDS"
26190 IF SLOWDATA=1 THEN 26200
26195 GO TO 26275
26200 PRINT"DATA SAMPLING RATE TOO SLOW- PERIODIC MODE"
```

```
26203 GO TO 26275
26205 PRINT"WAITED TOO LONG TO QUENCH"
26210 GO TO 26220
26215 PRINT"QUENCH PROBE DESTROYED, EXTENDED DURING FIRING"
26220 PRINT"POST TEST ANALYSIS IMPOSSIBLE, MOTOR NOT QUENCHED"
26225 GO TO 26175
26230 PRINT"TEST CELL DESTROYED, FAILED TO INERT AFTER BURNOUT"
26235 GO TO 26180
26240 PRINT"TIMING COMPROMISED"
26245 IF F8=1 THEN 26255
26250 GO TO 26145
26255 PRINT"FACILITY DESTROYED"
26260 GO TO 26180
26265 PRINT"MOTOR DESTROYED, PROPELLANT WET, PREMATURE QUENCH"
26270 GO TO 26180
26275 PRINT
26280 INPUT"PRESS RETURN KEY TO CONTINUE ";CONTINUE$
26285 CLS
26290 PRINT"OTHER MESSAGES:"
26295 PRINT
26300 END
```

VITA

Andrew Lewis Pickens, Jr. was born in Ripley, Tennessee on April 12, 1954. He attended many schools as a military dependant and graduated from Cooper High School in Abilene, Texas in June 1972. He then entered the United States Army as a Medical Equipment Repairman, and was honorably discharged after serving three years.

He attended the University of Tennessee at Martin in September 1975 and graduated with a Bachelor of Science degree in Electrical Engineering Technology in June 1980.

He was commissioned a Second Lieutenant in the United States Air Force, and began working as a Rocket Propulsion Test Engineer at the Arnold Engineering Development Center at Arnold Air Force Station, Tennessee in October 1980. It was here that he entered the University of Tennessee Space Institute Graduate School and received the Master of Science degree with a major in Computer Science in June 1985.

The author is currently a Captain in the Air Force and will continue working for the Air Force as an engineer after graduation.