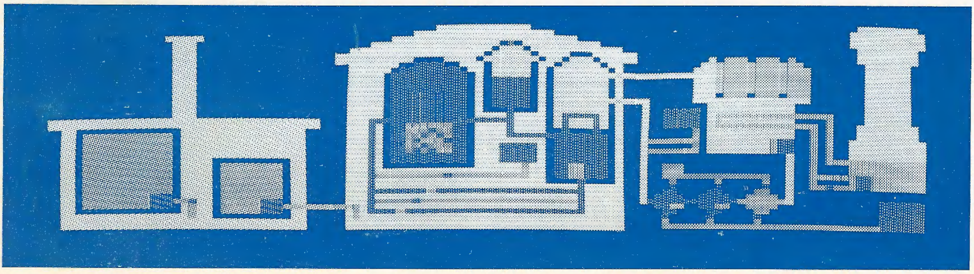
Put yourself in control of this nuclear reactor . . .



THREE MILE ISLAND

SPECIAL EDITION

MUSE SOFTWARE™

For Apple II or Apple II Plus (48K)

THREE MILE ISLAND™

* Special Edition *

Published by

MUSE SOFTWARE, Inc.
347 N. Charles Street
Baltimore, MD 21201

For Apple II or Apple II Plus
Requires 48K

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Three Mile Island™ * Special Edition * is a 6502 assembly language implementation of the original Integer Basic version.

CONTENTS

INTRODUCTION

Is the technology of a nuclear reactor too complex to handle? Now you have a chance to decide for yourself with Three Mile Island, a realistic simulation of a pressurized nuclear reactor. This documentation manual describes the details of the operating mechanisms and component interactions. Supply electric power to your customers at a profitable rate of return or lose your license to operate. Sloppy operation may leak radiation into the atmosphere and force an extensive evacuation of the population. But in any event, avoid a Melt-Down!

PROGRAM OPERATION

LOADING THE PROGRAM

Load the program from Basic by typing PR#s (where s is the slot number of your disk drive) and press RETURN. For example, if your disk is in slot 6 you would type PR#6 and press RETURN. From the Apple Monitor, type 6 followed by CTRL-P and press RETURN.

The program's title page will be displayed and the required program files will be loaded. This will require about 15 seconds.

The first message is the "WELCOME TO ..." screen. To initialize the reactor automatically, press Y. To initialize manually, or from a previously saved file, press N.

NOTE... it is not necessary to press RETURN following each command. The RETURN key will always return to the main menu screen.

If the automatic sequence is selected, sit back and watch the valves, pumps, turbines, and filters switch on. After preparations are complete, the control rods are retracted from the reactor core, firing up the reactor. The automatic initialization sequence takes approximately 1 minute to complete.

When the main menu screen appears and the ticking clock (day/hour:min) displays the passing minutes at the bottom of the screen, you are in control.

If the automatic sequence is bypassed, by pressing N, the main menu screen is immediately displayed, and the clock begins ticking at the screen bottom.

If it is desired to abort the automatic initialization after it has been started, type a SPACE, and control reverts to the keyboard.

Two special control modes are available from the Main Menu display. Press CTRL-D from the Main Menu to begin the display mode. In the display mode, each screen of the program is displayed in succession, for 10 ticks per screen, finally retuning to the Main Menu for 5 ticks before automatically repeating the sequence. While the display mode is in control, all keyboard input is ignored except for space, which will return control to the keyboard, leaving whichever screen is currently showing on the display. The fast clock mode is started by pressing CTRL-F from the main menu. All commands function as in the normal mode, but all the action is sped up. To return to the normal clock mode, press CTRL-S from the Main Menu display. The combination of CTRL-F followed by CTRL-D provides a 'fast display' mode.

While the clock is ticking, the program is ready to receive commands from the keyboard (unless the CTRL-D display mode has been invoked). Time stops while the screen is being drawn or updated.

COMMANDS

All Three Mile Island commands are one key commands. That is, do not press RETURN to complete a command.

When the program is running, pressing RESET will cause the program to exit to the Apple II Monitor, and * will appear in the lower left corner of the screen. The program may be CONTINUED at the point it was interrupted by typing:

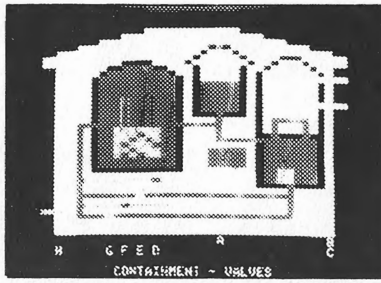
1003G RETURN

To RESTART the program from the beginning "Welcome to..." message, type:

1000G RETURN

COMMAND SUMMARY

RETURN	Always returns to main menu display.
Digit 0-7	Select view 0 to 7.
Letter	Activate/deactivate the valve, pump, turbine, or filter above that letter on the screen. If the letter is not on the screen the key will have no effect.
CTRL-V	Display valve labels and set valve control mode allowing operation of the valves on the screen.
CTRL-P	Display pump labels and set pump control mode allowing control of the pumps on the screen.
CTRL-T	Display turbine labels and allow turbine control by setting turbine control mode.
CTRL-F	Display filter labels and set filter control mode to allow bringing filters on-line and off-line.
ESC	Stop the simulation clock until pressed again. The ticking will stop, but full control is maintained.



VIEW ZERO - CONTAINMENT BUILDING

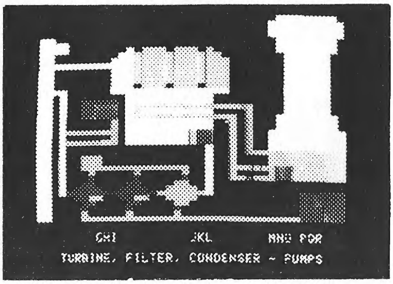
VIEW ZERO is displayed whenever the 0 key is pressed. The clock stops ticking while the view is being drawn. Using this view it is possible to monitor the state of the Core Vessel, the Pressurizer, and the Steamer, giving an indication of the pressure and temperature of the Primary Cooling System (PCS). The pumps of the Primary Cooling System (D, E, and F) and those of the Emergency Core Cooling System (A, B, and C) can be turned ON (GREEN) and OFF (RED). The valves in the Primary Cooling System loop (E, F, and G) as well as Valve D which controls the flow of the Emergency Core Cooling System (ECCS), can be OPENed (GREEN) or SHUT (RED). Valve A at the top of the Pressurizer is activated automatically and is not usually operated manually. The Steamer supplies steam to the Turbines via Valve B. The return water loop to the Steamer is through Valve C. Valve H connects the Containment Building to the Pump House.

VIEW ZERO COMMANDS:

RETURN	Return to MAIN MENU.
CTRL-P	Set Pump Control Mode, display Pump labels.
CTRL-V	Set Valve Control Mode, display Valve labels.
Letter	Activate/deactivate the Pump or Valve above.
Digit 0-7	Select VIEW 0 to 7.

When View Zero is first drawn the Pump Control Mode is set and the Pumps are labeled. Any Pump whose label appears at the bottom of the screen can be turned ON or OFF by pressing its key. Do not press RETURN until ready to return to the MAIN MENU display. To change to Valve Control Mode press CTRL-V. The labels at the screen bottom identify the Valves that can be controlled by typing their letter on the keyboard.

PUMPS: A,B,C,D,E,F
VALVES: A,B,C,D,E,F,G,H



VIEW ONE - TURBINE, FILTER and CONDENSER

VIEW ONE can be selected at any time by pressing 1. The clock is stopped while the VIEW is being drawn. When the pump labels have been printed at the bottom of the screen, the clock will begin ticking and commands will again be executed. This view is required to bring Turbines ON-LINE, to monitor the condition of the Condenser and the Tower Cooling System, and to flush the sludge build-up in the Filters.

VIEW ONE COMMANDS:

RETURN	Return to MAIN MENU.
CTRL-P	Set Pump Control Mode and display Pump labels.
CTRL-V	Set Valve Control Mode and display Valve labels.
CTRL-T	Set Turbine Control Mode and display Turbine labels.
CTRL-F	Set Filter Control Mode and display Filter labels.
Digit 0-7	Select VIEW 0 to 7.

Letter Activate/deactivate the device above.

PUMPS: G,H,I,J,K,L,M,N,O,P,Q,R
VALVES: B,C,I,J,K,L,M,N,O,P,Q,R
TURBINES: A,B,C,D
FILTERS: A,B,C

The Containment Building is visible on the left edge of VIEW ONE. A pipe connects the Steamer in the Containment Building with the Turbines at the top via Valve B. The Filters at the bottom complete the return water loop to the Steamer through Valve C.

While the pipe supplies steam to the Turbines it is AQUA colored and electric output is possible. If the pipe loses steam it becomes GREY in color, and electric output drops to 0.

Below the Turbines is the Condenser, which when cooled by the Tower Cooling System to the right, converts the steam into water. The Condenser's three pumps (J,K,L) push the water through the three Filters, completing the return water loop to the Steamer in the Containment.

At least one Filter MUST be ON-LINE to complete the return water loop. While a Filter is ON-LINE and water is flowing through it, sludge accumulates which must be cleaned out by using the Flushing Water System at the lower right with pumps P, Q, and R. The sludge accumulation rate is a function of the number of Filters which are ON-LINE. A Filter must be OFF-LINE and the valve connecting the Filter to the Flushing Water System (P, Q, or R) must be OPEN to allow the flushing action. Each additional Pump increases the pressure of the flushing water. The increased pressure is indicated by the darkening color of the water in the flushing pipe. If necessary, a blast of high pressure air can be added from the High Pressure Air System, just above the Filters. The High Pressure Air System (HP AIR) is activated by OPENing the Valve (M, N, or O) connecting the HP AIR to a Filter. The HP AIR system is drawn in GREY when OFF and YELLOW when ON.

NOTE: The control system protects against activating the HP AIR if the Filter is not OFF-LINE with the Flushing Water System ON and connected to the Filter. In addition, the water valve for a Filter can not be OPENed if the Filter is ON-LINE, and the Filter cannot be brought ON-LINE if the water valve is OPEN. Improper operator commands are signaled by 3 bells.

To the right of the Condenser is the Tower Cooling System with Pumps M, N and O. Valves K and L connect the Tower Cooling System to the Condenser. At least one of the Valves must be OPEN and at least one Pump ON to prevent the Condenser from boiling dry.

To the left of the Condenser is the Emergency Secondary Cooling System (ESCS) with pumps G, H, I. The ESCS is connected directly to the Steamer return water loop, bypassing the Filters entirely, via Valves I and J.

If this return water supply is interrupted for a long enough time (fifteen ticks = fifteen simulated minutes), the Steamer will boil completely dry, and the temperature will begin to climb. It is then necessary to add water to the system from the Emergency Secondary Cooling System.

When the sludge buildup in a Filter exceeds 10 units (each PINK square in a Filter is one unit of sludge), the Filter is automatically taken OFF-LINE.

An OFF-LINE Filter is drawn in GREY. A Filter which is ON-LINE is shown in BROWN.

When VIEW ONE is drawn, the Pump Control Mode is set and the Pumps are labeled. Any Pump whose label appears at the bottom of the screen can be turned ON or OFF by typing that key.

A Turbine can be brought ON-LINE by entering the Turbine Control Mode (type CTRL-T), and then the letter name of the Turbine (A,B,C, or D). An OFF-LINE Turbine is shown in GREY; an ON-LINE Turbine is YELLOW.

VIEW TWO - REACTOR CORE and CONTROL RODS

This View gives a cross-section of the Reactor Core, showing the position of the Control Rods. Fuel Rods are GREY and stop just below the top of the View. Control Rods are BROWN and extend to the top of the screen. When a Control Rod is retracted, the space between the Fuel Rods will glow ORANGE and then RED. This space will change color while the clock is ticking to indicate radioactivity.

If the Core becomes uncovered and the temperature goes high enough, Fuel Rod damage will result. The GREY Fuel Rods will begin to turn BLACK, from the top down, to indicate the extent of the damage. In VIEW 0, only severe damage is represented in the Core Schematic, ie. greater than 15 units.

This View also provides an accurate reading of the Core temperature:

TEMP=nnnn CNT=n

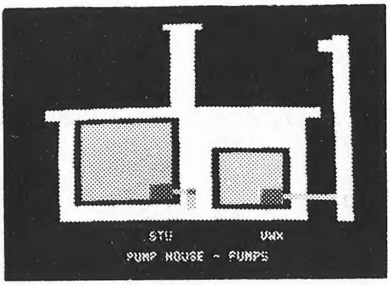
The value of CNT is the number of Pumps required to stabilize the temperature, assuming the Steamer has not boiled dry, and the Steamer is connected to the Condenser. This View provides commands to raise the Control Rods, allowing the Core to increase in temperature. The temperature of the Core controls the amount of electricity which can be generated. At least 400 degrees is required, with 500 degrees sufficient for 1,000 Megawatts of output.

VIEW TWO COMMANDS:

RETURN	Return to MAIN MENU.
Digit 0-7	Select the View 0 to 7
<--	Move the Control Rod indicator to the LEFT
-->	Move the Control Rod indicator to the RIGHT.
+	Move the indicated Control Rod UP one unit.
-	Move the indicated Control Rod DOWN one unit.

It is convenient to use the REPT key for maximum speed when raising or lower Control Rods.

The minimum temperature of the Core is determined by the setting of the Control Rods. This is the second value shown in VIEW SIX - OPERATIONAL STATUS, as CNTRL RODS. The actual Core temperature is the first value, TEMP.



VIEW THREE - PUMP HOUSE

The Pump House is to the left of the Containment Building. It contains two storage tanks. The smaller of the tanks, with pumps V, W, and X, is a siphon tank for water which accumulates on the floor of the Containment. It is connected via valve H. A Pump in the small tank is activated automatically whenever water accumulates on the Containment floor. The second tank, with Pumps S, T, and U, is used to clean-up and hold any water which is on the Pump House floor.

This View is useful for controlling a clean-up operation and to prevent radiation escaping into the atmosphere.

VIEW THREE COMMANDS:

RETURN	Return to MAIN MENU.
CTRL-P	Set Pump Control Mode and display Pump labels.
CTRL-V	Set Valve Control Mode and display Valve labels.

PUMPS: S,T,U,V,W,X
VALVES: H,S

If water accumulates on the floor of the Pump House, radiation is released into the atmosphere. Radiation is displayed as a PINK cloud at the top of the screen. VIEW SIX will give the quantity of radiation in millirems per hour, as PMPHSE RAD.

VIEW FOUR - MAINTENANCE SCHEDULE

This View shows the time at which an activated device will FAIL, or the time at which a device in REPAIR will be available for use. The initial schedule is for Pumps. The schedule for Valves or Turbines can be selected by pressing CTRL-V or CTRL-T. To begin repair of a listed device, type the letter for the device. It is not necessary to turn OFF a Pump, SHUT a Valve or take a Turbine OFF-LINE prior to service since that will be done automatically when the device enters REPAIR. (Sometimes this is the only way to deactivate a device). The schedule will then be updated to indicate the time the REPAIR operation will be completed. The system clock is displayed at the bottom of the screen while in this View. Also displayed in this View are the infallible TEMP and CNT values.

VIEW FOUR COMMANDS

RETURN	Return to MAIN MENU.
CTRL-P	Set Pump Control Mode and display Pump schedule.
CTRL-V	Set Valve Control Mode and display Valve schedule.
CTRL-T	Set Turbine Control Mode and display Turbine schedule.
Digit 0-7	Select View 0 to 7.
Letter	Put device letter into REPAIR.

Any other key will be ignored.

NOTE:

(1) A device must be activated to show the expected time for failure.

(2) A Valve that is OPEN is not aged (that is, will not fail), if the pipe is empty (GREY). Also, Valves A, B, and C are not aged since they do not have backup counter-parts.

(3) A Valve will stay in whatever position it is in at the time of failure. However, a failed Valve which is open has a 2% probability of changing to the shut position, each tick.

(4) A device which is put into repair is automatically taken OFF-LINE first.

(5) One bell indicates some device has just failed.

(6) Two bells indicate that some device has just completed repair.

VIEW FIVE - COST ANAYSIS

Select VIEW FIVE (by typing 5) to monitor the overhead cost of operation, the accumulated maintenance cost, the electric demand, the electric output, and the accumulated profit (or loss). Also included is the time at which the demand will change, and at the bottom of the screen, the system clock.

VIEW FIVE COMMANDS:

RETURN	Return to MAIN MENU.
Digit 0:7	Select VIEW 0 to 7.

The costs of operating the nuclear facility are subject to the following conditions:

The OPERATING COST is a fixed overhead cost which increases each day by a random amount, to simulate inflation, fuel costs, salaries, fringe benefits, insurance premiums, etc. The initial OPERATING COST is $137,000, representing a $1 billion plant, with a 20 year lifetime.

The MAINTENANCE COST is the accumulated repair costs for the current day. Whenever a Pump, Valve, Turbine, or the Gauges are placed in REPAIR, a random maintenance cost is assigned to the repair task.

At the start of each new day, the total of OPERATING COST + MAINTENANCE COST is subtracted from the PROJECTED PROFIT and ACTUAL PROFIT. The MAINTENANCE COST is then reset to $0.

To make a profit (ACTUAL PROFIT), it is necessary to have at least one Megawatt of ELECTRIC OUTPUT for each $1,000 of OPERATING COST plus MAINTENANCE COST. If a BROWNOUT condition exists, the profit will only click up every other tick, to simulate the need to purchase power from the grid.

The ELECTRIC DEMAND is initialized to 100 Megawatts when the program starts. The ELECTRIC DEMAND changes approximately each hour. Each change in electric demand is signaled by two sets of three bells. The ELECTRIC DEMAND increases toward 2 PM and decreases again toward midnight, having a maximum value of 1000 Megawatts and a minimum value of 100 Megawatts.

The ELECTRIC OUTPUT cannot exceed the amount of ELECTRIC DEMAND regardless of the number of turbines ON-LINE.

The PROJECTED PROFIT reflects the fact that the ELECTRIC DEMAND exceeds the total operating costs.

If the ACTUAL PROFIT becomes negative, it is surrounded by < and > symbols with a flashing LOSS flag appearing to the right. When the loss exceeds $200,000 it is possible to petition the Public Utilities Commission for a rate increase. A reminder notice to that effect will be displayed at the bottom of the screen of VIEW FIVE every 15 ticks. The petition will be entered by typing a $. The ruling on the petition will then be displayed at the bottom of the screen. If the petition is approved the ACTUAL PROFIT (that is, the LOSS) is reset to $0. There is a 5% chance that the petition will be approved when submitted. The $ can be typed whether or not the reminder notice appears on the screen.

If the loss exceeds $500,000 the simulation terminates due to fiscal irresponsibility.

The amount of ELECTRIC OUTPUT is determined by the Reactor Core temperature, the number of Turbines ON-LINE, the ELECTRIC DEMAND, and whether steam is being supplied to the Turbines from the Steamer in the Containment.

VIEW SIX - OPERATIONAL STATUS

VIEW SIX shows the readings for 10 gauges, as well as 13 annunciators. The gauges will fail over time, and then give misleading readings. This is the topic of a SAFETY DIRECTIVE which will be received when failure of one or more gauges becomes more likely. Typing Y when the SAFETY DIRECTIVE is on the screen is the only way to have defective gauges repaired. It is not mandatory to repair the gauges when requested - the repeated updating of the screen may eventually yield the desired reading. If the Directive is ignored, by typing any key except Y, then the SAFETY DIRECTIVE will be repeated periodically. When the inspection period has elapsed, a second SAFETY DIRECTIVE gives the number of gauges which were defective.

VIEW SIX COMMANDS:

RETURN	Return to MAIN MENU.

Each time the screen is updated, the readings for the gauges are printed in the following order:

CORE TEMP - the actual temperature of the Reactor Core.

CTRL RODS - the minimum temperature of the Reactor Core, as set by the Control Rods.

PCS PRES - the Primary Cooling System Pressure, as measured in the Core Vessel.

PMPS REQ'D - the number of pumps required in the Primary Cooling System to maintain a stable temperature, assuming the Steamer and Condenser are operating properly.

CNTMT PRES - the atmospheric pressure in the Containment.

CNTMT WTR - the amount of water on the floor of the Containment.

PMPHSE WTR - the amount of water on the floor of the Pump House.

PMPHSE RAD - the amount of radiation escaping from the vent in the Pump House. This is measured in millirems per hour.

FLUSH TIME - an elapsed time clock showing how long the High Pressure Air System has been ON.

PRSZER WTR - the amount of water in the Pressurizer. If the level exceeds 24,000 GAL, the Pressurizer will overflow onto the floor of the Containment.

In addition to the gauge readings, there are 13 annunciators which will light up or begin flashing to signal abnormal conditions:

SEALED The pressure in the Containment Building has exceeded the safety limit (88 psi) and the Containment Building has automatically sealed itself. An EMERGENCY NOTICE is issued when this occurs.

HITEMP The Reactor Core has exceeded 600 degrees.

FRDAMAGE The Core has become uncovered, resulting in damage to the Fuel Rods.

SCRAM All Control Rods are in the down position.

ECCS At least one Pump of the Emergency Core Cooling System is ON.

ESCS At least one Pump of the Emergency Secondary Cooling System is ON.

RADLEAK Radiation is escaping from the Pump House vent as a result of radioactive water on the floor of the Pump House.

FLTR All Filters are OFF- LINE.

AIR The High Pressure Air System is ON.

CNDSER The Condenser is beginning to boil dry. When completely dry the indicator will flash.

STMER The Steamer is beginning to boil dry. When completely dry the indicator will flash.

PCSLEAK The Primary Cooling System has a leak from excessive pressure in the Core Vessel. An EMERGENCY NOTICE is issued when this occurs.

ELECTRIC This indicates that the proper amount of electric output is being generated.

BROWNOUT This lighted indicator replaces the above indicator when the amount of ELECTRIC OUTPUT is less than the current ELECTRIC DEMAND.

BLACKOUT This flashing indicator replaces the above indicator when there is no ELECTRIC OUTPUT.

The following is a set of normal readings for the gauges:

TEMP	0 - 500	DEG
CTRLRODS	0 - 594	DEG
PCS PRES	2200	PSI
PMPS REQ'D	2	
CNTMT PRES	14.00	PSI
CNTMT WTR	0	GAL
PMPHSE WTR	0	GAL
PMPHSE RAD	0.00	MREMS/HR
FLUSH CNT	00:00	MIN
PRSZER WTR	6,000	GAL

When the Reactor is ON, no lighted or flashing indicators should be seen.

VIEW SEVEN - SAVE/RESET STATE

This VIEW does not actually control the Reactor System, but rather allows the present STATE of the system to be saved on the disk. Alternatively, a previously saved STATE can be retrieved from disk and the simulation continued from that point.

When VIEW SEVEN is selected the screen is cleared and the title SAVE/RESET STATE will appear at the top. The first prompt is a request for CATALOG (Y OR N) ?. Typing Y will display the disk catalog on the screen. Any other response will continue to the next prompt, SAVE OR RESET (S OR R) ?. If neither S nor R is typed you will be returned to the MAIN MENU. Otherwise, the next prompt is ENTER STATE NAME*. Enter a 1 to 30 character name to identify the STATE and press RETURN. This is the only time that you must press RETURN to complete a command! If only a RETURN is typed you will be returned to the MAIN MENU. Otherwise the STATE is either Saved or Reset and control returns to the MAIN MENU.

The clock will not tick while the program is in VIEW SEVEN.

Approximately 75 STATES can be stored on the program disk. Each STATE is stored as a binary file of 4 sectors. Additional disks can be used if they are inserted prior to pressing RETURN after the name given in response to the ENTER STATE NAME* prompt, as described above.

One STATE file is provided on the program disk with the STATE NAME of TEMP450. This file contains the STATE of the Reactor System for a situation different from the automatic initialization sequence.

DISK INITIALIZATION

Before a blank disk can be used for saving a reactor STATE it must be INITialized WITH THE DOS ON THIS PROGRAM DISK. Follow this procedure to initialize a disk:

1. Boot the Three Mile Island disk.

2. Press ESC to exit the HELLO program and enter Basic.

3. REMOVE the Three Mile Island program disk and insert a blank disk to be initialized.

4. Type NEW and press RETURN.

5. Type INIT HELLO,V1 and press RETURN.

The initialization will take approximately two minutes. When it is complete, the disk can be used to store Three Mile Island reactor States.

DISKS THAT ARE INITIALIZED WITH OTHER VERSIONS OF DOS WILL NOT OPERATE PROPERLY WITH THIS PROGRAM. BE SURE TO REMOVE THE THREE MILE ISLAND PROGRAM DISK BEFORE INITIALIZING!!

SYSTEM DYNAMICS

CLOCK DYNAMICS

Each tick of the simulation clock represents one minute of simulation time. At each tick, the program goes through the simulation loop, updating values and checking for conditions that have changed, and then updating the screen currently being viewed.

The MAIN MENU and VIEWS 4, 5 and 6 show the system clock at the bottom of the screen. The clock shows both the simulation day since the program started (day 1), and the current time. The format is (day number/hours:minutes). The clock is updated each tick.

Pressing ESC will suspend the simulation clock until ESC is pressed again. The clock will not tick while a command is being executed, or while a VIEW is being drawn, or while in VIEW SEVEN.

TEMPERATURE DYNAMICS

The temperature of the Reactor Core (TEMP) is used in the simulation as a measure of the stress on the system. This stress causes the devices in the system, that is, the Pumps, Valves, Turbines, and Gauges, to wear out over time. The speed with which the devices will begin to fail is represented by the variable CNT. The value of CNT is also used as the number of Pumps in the Primary Cooling System which must be ON to stabilize the Reactor Core temperature.

TEMP is at least as high as the value set by the Control Rods. This is the CTRL-RODS value in VIEW SIX. The conditions which simultaneously affect the Reactor Core temperature over time are:

(1) setting of the Control Rods.
(2) the number of pumps in the Primary Cooling System that are ON and delivering water through an OPEN valve.
(3) water level in the Core Vessel.
(4) water level in the Steamer.
(5) water level in the Condenser, if the Steamer is delivering water to the Turbines.

MELT-DOWN will occur at 2500 DEGREES.

The value of CNT is determined as a function of TEMP as follows. The minimum value of CNT is 1. A value of one is added to CNT for a value of TEMP in excess of each of the following levels:

TEMP > 400	CNT = 2
TEMP > 500	CNT = 3
TEMP > 600	CNT = 4
TEMP > 750	CNT = 5

ELECTRIC DYNAMICS

The program begins on day 1 at midnight, with an ELECTRIC DEMAND of 100 Megawatts. Approximately each hour (60 ticks), the ELECTRIC DEMAND will change. VIEW FIVE shows the current value for ELECTRIC DEMAND and ELECTRIC OUTPUT and the actual time the ELECTRIC DEMAND will change.

The ELECTRIC DEMAND builds up toward 2 PM to a maximum value of 1000 Megawatts, and then decreases after 2 PM toward midnight and a minimum value of 100 Megawatts.

The amount of ELECTRIC OUTPUT is determined by the temperature of the Reactor Core, whether steam is being provided to the Turbines, and how many Turbines are ON-LINE. Each Turbine can supply a maximum of 250 Megawatts. The Reactor Core temperature must be at least 400 DEG to provide enough steam to drive a Turbine. An additional 25 DEG of Reactor Core temperature above the minimum value of 400 DEG are required for EACH turbine to produce its maximum ELECTRIC OUTPUT. That is, the reactor must be at least 500 DEG to provide 1000 Megawatts of ELECTRIC OUTPUT with four Turbines.

TEMP	Turbines	Megawatts
400-425	one	0 to 250
425-450	two	250 to 500
450-475	three	500 to 750
475-500	four	750 to 1000

NOTICE: Extremely high Reactor Core temperature will adversely affect all components of the Reactor System, resulting in increased frequency of device failure and consequently higher maintenance costs.

PUMP DYNAMICS

Pumps are visible in VIEWS 0, 1, and 3 with labels A through X. A Pump is ON when it is shown in GREEN and OFF when shown in RED. When a Pump is in REPAIR it is shown in BLACK. The operation of Pumps is subject to the following constraints:

Each Pump is assigned a random Mean-Time-To-Failure. While a Pump is ON, it is aged at each tick of the system clock by the value of CNT. Therefore, a high TEMP will cause Pumps to fail at a faster rate. The time at which the Pump is expected to fail, with the current conditions remaining constant, can be determined from the MAINTENANCE STATUS for Pumps.

When a Pump is put into REPAIR, it is assigned a random Mean-Time-To-Repair. The time at which the Pump will come out of REPAIR and again be available for service can be seen in VIEW FOUR. A random Mean-Cost-To-Repair is calculated and added to the accumulated MAINTENANCE COST. Turning a Pump ON or OFF increases the likelihood of its failure.

A Pump goes OFF-LINE when it fails. When a Pump is put into REPAIR it is automatically taken OFF-LINE.

A Pump which has FAILED or which is in REPAIR can not be activated, and any attempt to do so is ignored.

VALVE DYNAMICS

Valves are visible in VIEWS 0, 1, and 3, and are identified by labels A through S. An OPEN Valve is shown in GREEN, while a Valve which is SHUT is displayed in RED. A Valve which is in REPAIR is shown in BLACK. The operation of Valves is subject to the following constraints:

Each Valve is assigned a random Mean-Time-To-Failure. Each tick of the clock ages a valve toward failure by CNT units. An OPEN valve on an EMPTY pipe (shown in GREY) will not be aged, since it is actually not being used. Also, the non-redundant valves, A, B, and C are not aged, but are subject to the activation decay.

When a Valve is put into REPAIR, it is assigned a random Mean-Time-To-Repair. The expected time for completion of REPAIR can be seen in VIEW FOUR. A random Mean-Cost-To-Repair is calculated and added to the accumulated MAINTENANCE COST.

When a Valve fails, it remains in whatever state it was in, either OPEN or SHUT. However, for each passing tick there is a 2% chance that a failed valve which is OPEN will SHUT.

When a Valve is placed in REPAIR, it is automatically SHUT.

A Valve which has FAILED or which is in REPAIR can not be activated or deactivated. Attempts to do so will be ignored.

Each activation or deactivation of a valve, whether by keyboard command or via automatic operation, increases the likelihood of failure.

CONTAINMENT DYNAMICS

The Containment of VIEW ZERO will change appearance depending upon activities and conditions in the building.

While Valve A is OPEN, radioactive steam is vented into the Containment. This is shown as a PINK cloud at the top of the building. If Valve A remains OPEN long enough, the Pressurizer will overflow onto the Containment floor. This is represented as a BLUE puddle at the bottom of the building.

Rising pressure in the Primary Cooling System will cause an automatic SCRAM when the pressure reaches 4800 PSI.

If the pressure in the Core Vessel becomes sufficiently high, the Primary Cooling System will spring a leak. The pressure necessary for this to occur is 12,000 PSI. A leak will result in additional accumulation at both the top and the bottom of the Containment. To conteract the loss of coolant due to the PCS leak, the ECCS must be ON, with Valve D OPEN.

When the atmospheric pressure in the Containment Building reaches 88.00 PSI, the Containment is SEALED automatically. An EMERGENCY NOTICE is issued when this occurs. If the pressure rises to 100.00 PSI, a rapid-disassembly (explosion) occurs, reducing the pressure to 1/16th its value, allowing the containment building valves B and C to be OPENed, to assist in cooling the reactor core.

When the Reactor Core temperature (TEMP) is less than 600 DEG, the steam at the top of the Containment will condense into water on the Containment floor. Ten units of radioactive steam become one unit of radioactive water.

Whenever water accumulates on the Containment floor, a siphon pump in the Pump House (V, W, or X) is automatically switched ON to draw the water into the smaller holding tank in the Pump House. This will cause the puddle to decrease in size each tick when the source of the water has been turned OFF.

The quantity of water on the floor of the Containment Building can can be monitored as the CNTMT WTR gauge of VIEW SIX.

CORE VESSEL DYNAMICS

The Core Vessel surrounds the Reactor Core with pressurized water. As part of the Primary Cooling System, it helps stabilize the temperature of the nuclear reaction by carrying the heat to the Boiler beneath the Steamer. The status of the Core Vessel can be determined graphically from VIEW ZERO or from the gauge readings of VIEW SIX.

If the feedwater supply to the Core Vessel is interrupted while the Reactor is "running", the water pressure in the Primary Cooling System will begin to decrease. This pressure is given as PCS PRES in VIEW SIX. The Pressurizer will attempt to compensate for the pressure drop (see PRESSURIZER DYNAMICS). Eventually, if the feedwater is not re-established, the Core Vessel will begin to boil dry. In VIEW ZERO, the BLUE in the Core Vessel above the Reactor Core will be replaced by GREY as the water level in the Core Vessel drops. When the BLUE has receeded to the top of the CORE itself, the temperature will begin to rise. When the temperature exceeds 600 degrees, fuel rod damage will begin to occur. Radioactive fission gases will form as a PINK bubble in the top of the Core Vessel. When the feedwater supply is eventually restored, the bubble will be carried from the Core Vessel into the Pressurizer, by the water flow. In VIEW SIX, fuel rod damage is signaled by the FRDAMAGE indicator.

PRESSURIZER DYNAMICS

The Pressurizer functions as a shock absorber for the Primary Cooling System (PCS). Because the PCS is under very high pressure (2400 PSI), changes in temperature could damage the PCS components. The gas bubble in the Pressurizer is able to adjust in size to cushion the effects of water pressure changes as a result of temperature changes.

The operation of the Pressurizer is subject to the following constraints:

If the pressure increases to the point where the bubble disappears, Valve A will open automatically, venting steam into the Containment and allowing the bubble to expand again.

If the bubble in the Pressurizer increases to the point where the water disappears and Valve A is OPEN, it will be SHUT automatically.

When Valve A is OPEN, pressure is vented first from the Pressurizer causing its bubble to expand, and then from the Core Vessel. Finally, if feedwater is being supplied to the Core Vessel, the Pressurizer will begin to flood with water. When the water level reaches 24,000 GAL, the Pressurizer will overflow onto the Containment floor through the OPEN Valve A.

When Valve A is SHUT, and the feedwater supply is OFF, and the Reactor Core temperature (TEMP) is greater than 400 DEG and less than 600 DEG, the water in the Core Vessel will begin to boil away. The Pressurizer will attempt to compensate for the drop in pressure in the Primary Cooling System, and the bubble will expand. If the Reactor Core becomes uncovered, Fuel Rod damage will result.

If the feedwater supply is ON, and TEMP is in excess of 600 DEG and increasing, the pressure of the water in the PCS will begin to increase, and the bubble in the Pressurizer will shrink.

The normal operating mode for the Pressurizer is to maintain a Core Vessel water pressure of 2400 PSI with TEMP less than 600 DEG and a Pressurizer water level of 6,000 GAL.

STEAMER DYNAMICS

The Steamer is the primary heat sink for the Reactor Core. That is, the Steamer contributes to stabilizing the temperature of the Reactor Core by utilizing the heat of the water in the Primary Cooling System to generate steam to drive the Turbines. This transfer of heat cools the water in the PCS. The loss of this function will result in a temperature instability, and the temperature will increase.

If the return water supply, through Valve C, is interrupted and the Reactor Core is active (TEMP greater than 400 DEG), the Steamer will begin to boil dry. This will occur if the Condenser loses its cooling system (see CONDENSER DYNAMICS), or if the return water supply from the Condenser is interrupted. When the Steamer is completely dry, steam is lost to the Turbines and ELECTRIC OUTPUT drops to zero.

Water can be introduced back into the dry Steamer by turning ON one of the pumps G, H, or I of the Emergency Secondary Cooling System (ESCS). Within one tick, steam will be restored to the Turbines, which will again provide electric output.

If the pressure in the Containment reaches 88.00 PSI, the Containment is automatically SEALED, closing Valves B, C and H. The Steamer will then, of course, boil dry.

When the pressure drops below this level from rapid disassembly or condensation of steam to water, the valves can again be opened to allow convection cooling through the Condenser to assist in controlling the Core temperature.

TURBINE DYNAMICS

The Turbines are viewed and controlled from VIEW ONE by selecting VIEW ONE (type a 1), and then selecting Turbine Control Mode (type a CTRL-T). A Turbine can then be brought ON-LINE or taken OFF-LINE by typing its letter name. A Turbine which is OFF-LINE is shown in GREY. When a Turbine is ON-LINE it is displayed in YELLOW. A Turbine in REPAIR is not visible since it is displayed in BLACK.

The following conditions describe the operation of the Turbines:

A Turbine goes OFF-LINE when it has FAILED. It can be put into REPAIR by selecting VIEW FOUR (type 4), and Turbine Control Mode (type CTRL-T. Typing the Turbine's letter name will cause the status of the Turbine to change to REPAIR.

If a Turbine is put into REPAIR while it is ON-LINE, it is automatically taken OFF-LINE.

A Turbine that is in REPAIR or which has FAILED can not be brought ON-LINE. Any attempt to do so is ignored.

Each activation/deactivation of a Turbine increases the likelihood of its failure.

When a Turbine has been repaired it is assigned a random Mean-Time-To-Failure. The time of expected failure can be seen in VIEW FOUR while the Turbine is ON-LINE.

When a Turbine is put into REPAIR it is assigned a random Mean-Time-To-Repair, which can also be seen in VIEW FOUR.

The MAINTENANCE COST is increased by a calculated random Mean-Cost-To-Repair, when a Turbine is put into REPAIR.

CONDENSER DYNAMICS

The Condenser is located directly under the Turbines in VIEW ONE. With the help of the Tower Cooling System, to the right of the Condenser, the steam used to drive the Turbines is converted back into water. The Pumps J, K, L are used to return the water to the Steamer through the Filter system.

If the Condenser loses the benefits of the Tower Cooling System it will begin to boil dry. This can be seen in VIEW ONE as a decrease in the water level in the Condenser. In VIEW SIX, the lighted or flashing CNDSER indicator provides a warning. As soon as the Tower Cooling System is restored, the Condenser will begin filling with water, and supply the water to the Steamer's return water supply.

The Condenser contributes to controlling the Core temperature by convection, when it is a part of the secondary cooling system water loop.

FILTER DYNAMICS

The Filters, visible in VIEW ONE below the Condenser, form an integral part of the return water supply for the Steamer in the Containment. A Filter is displayed in BROWN when ON-LINE and in GREY when OFF-LINE. These devices are subject to the following constraints:

While a Filter is ON-LINE, and water is circulating through it, sludge builds up at a random accumulation rate. A unit of sludge is displayed as a PINK spot in the Filter. The number of Filters ON-LINE at any one time affects this accumulation rate.

As each unit of sludge is added to a Filter, a new value is calculated for the pressure required to clear the sludge. This pressure is a function of the amount of sludge already in the Filter, and so it gradually increases. While the sludge is less then 11 units, this pressure can have a value of from 10 to 29 units.

If a Filter accumulates 11 units of sludge, it is automatically taken OFF-LINE, which may interrupt the return water flow to the Steamer. The flushing pressure required to clear the sludge is reassigned, and may reach a maximum value of 35.

The flushing pressure is a random function of the number of flushing pumps (P, Q, R) which are ON- LINE at one time, and the High Pressure Air Line. Three pumps alone can attain a maximum pressure of 24 units. Adding the HP AIR System can boost the flushing pressure to a maximum of 37 units.

The flushing action can not begin until the Filter is OFF-LINE and the water valve is OPEN.

If the High Pressure Air System (directly above the Filters and connected via Valves M, N, and O) is ON for more than 40 minutes with 3 Pumps to 120 minutes with one Pump, then the flushing water backs up through the Air System and causes ALL Filters to go OFF-LINE. This event causes the Emergency Secondary Cooling System to be activated automatically, with an EMERGENCY NOTICE to that affect.

The High Pressure Air System cannot be turned ON for a Filter unless that Filter is OFF-LINE and flushing water is being supplied to the Filter. Any attempt to circumvent this is ignored with a three bell warning. Similarly, the HP Air must be turned OFF before the water valve to the Filter can be SHUT.

When the HP Air System is ON, the AIR indicator will be lighted in VIEW SIX, and the elapsed time clock, FLUSH TIME, will show how long the HP Air has been ON. When the time reaches 01:30, the time will be lighted. If 02:00 is reached the AIR indicator will begin flashing.

Sludge is removed one unit at a time during the flushing operation, and can be monitored in View 1. The total clearing of sludge from a Filter is signaled by two bells.

The Filter can not be returned ON-LINE until the water valve has been closed.

PUMP HOUSE DYNAMICS

The Pump House, located to the left of the Containment, is a part of one of the automatic functions. Whenever a puddle forms on the floor of the Containment, one of the Pumps V, W, or X is activated to siphon the spill into the small holding tank in the Pump House. This action can only be defeated by manually SHUTing Valve H. The conditions in the Pump House are determined by the following constraints:

The small tank has a capacity of 71,000 gal. Each dot of BLUE in the tank represents 1,000 gal. When the small tank reaches capacity it will overflow onto the Pump House floor.

The large tank has a capacity of 171,000 gal. Again, each dot of BLUE in the tank represents 1,000 gal. The purpose of the large tank is to keep any overflow from the small tank from remaining on the floor of the Pump House.

Water pumped from the Containment into the Pump House is radioactive. While water is on the floor of the Pump House, radioactive steam can escape from the roof vent. Radioactive steam is represented by a PINK cloud at the top of the View. Over time, the radioactive steam will gradually dissipate. Should the radioactivity in the atmosphere exceed a preset threshold, an EMERGENCY NOTICE suggesting evacuation will be issued. This threshold is initially .5 millirem/hr and increases by .5 millirem/hr each time the current threshold is passed. Each increase in the cloud at the top of the View represents .01 millirem/hr of radiation exposure.

Both the water level on the floor of the Pump House, and the amount of radiation can be determined from the gauges of VIEW SIX, PMPHSE WTR and PMPHSE RAD, respectively. The existence of radiation is also indicated by the flashing RADLEAK indicator.

SAFETY FEATURES

There are six automatic operations to ensure the safety of the Reactor System.

1. PRESSURIZER AND VALVE A

The function of the pressurizer is to stabilize the water coolant pressure in the primary cooling system to 2400 PSI. If the pressure increases, the bubble in the pressurizer (PINK color), will decrease. When the bubble disappears, Valve A automatically opens to release the pressure. As the pressure decreases, the bubble will expand. When the bubble reaches 12 units in size, valve A will SHUT.

2. EMERGENCY CORE COOLING SYSTEM (ECCS)

If a loss of feedwater in the Primary Cooling System uncovers the Core, the Emergency Core Cooling System is automatically activated.

3. SEALING OF CONTAINMENT

If the pressure in the Containment increases to a sufficiently high value (88.00 PSI), the Containment will automatically seal itself. This results in Valves B, C, and H, being SHUT. Until the pressure drops to less than 64.00 PSI, any attempt to OPEN B, C or H will be resisted.

4. EMERGENCY SECONDARY COOLING SYSTEM (ESCS)

If the Filters are forced OFF-LINE due to water backup through the High Pressure Air System during a flushing operation, the Emergency Secondary Cooling System will be activated to supply water directly to the Steamer.

5. SIPHONING ON CONTAINMENT FLOOR

If any water leaks onto the floor of the Containment, a siphon pump in the small tank in the Pump House is automatically activated to clean up the spill.

6. PRIMARY COOLING SYSTEM SCRAM

When the pressure of the Primary Cooling System exceeds 4800 PSI, an automatic SCRAM occurs to help contain the increasing temperature.

An automatic SCRAM has a 1% probability of failing.

SIGNAL BELLS

The standard APPLE II signal bell is used by the program to indicate the occurrence of an event:

ONE BELL
A Pump, Valve, or Turbine has just FAILED, or a filter has gone OFF-LINE.

TWO BELLS
A Pump, Valve, or Turbine has just completed REPAIR, or, a Filter has been cleared of sludge.

TWO SETS OF THREE BELLS
Signals a change in ELECTRIC DEMAND, approximately each hour (60 ticks).

FOUR SETS OF THREE BELLS
Signals the start of a new day.

FIFTEEN BELLS
Signals an EMERGENCY NOTICE or a SAFETY DIRECTIVE will be displayed on the screen.

COLOR KEY SUMMARY

PIPES	GREY = EMPTY	any other color = FULL
PUMPS	RED = OFF	GREEN = ON
VALVES	RED = SHUT	GREEN = OPEN
TURBINES	GREY = OFF-LINE	YELLOW = ON-LINE
FILTERS	GREY = OFF-LINE	BROWN = ON-LINE

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