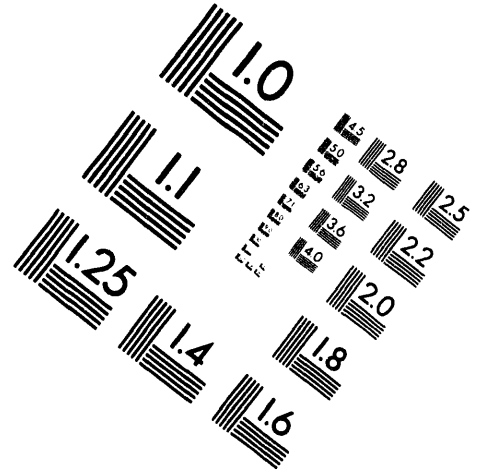
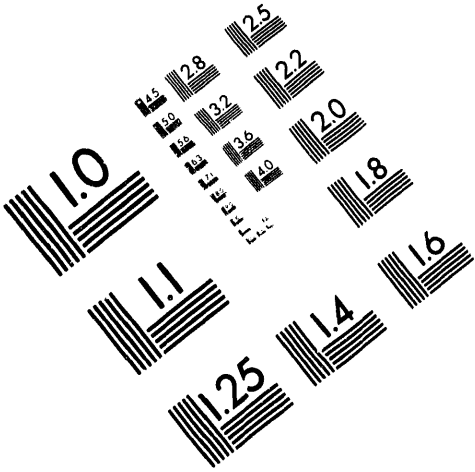




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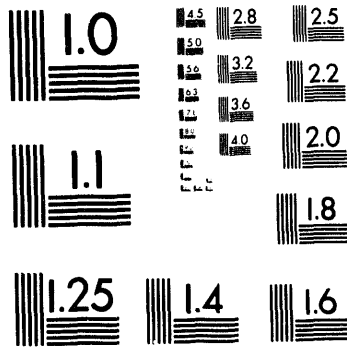
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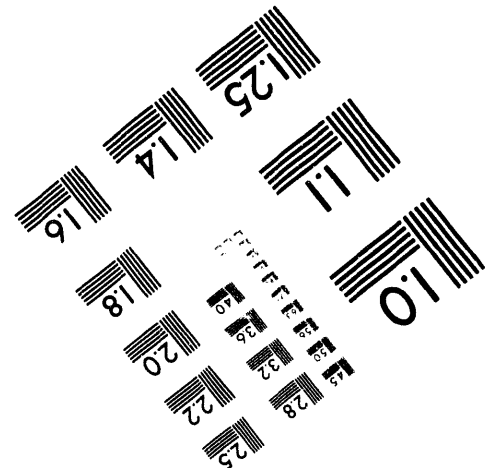
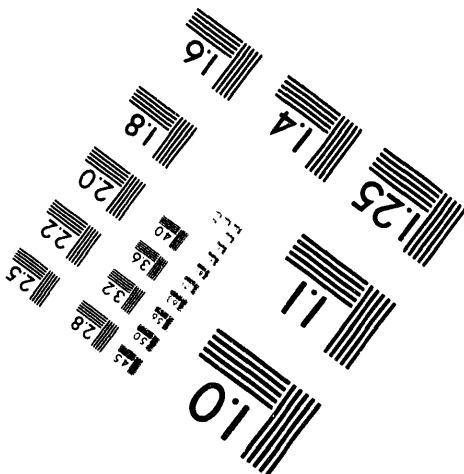
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IMPLEMENTATION OF ABNORMAL OPERATION SCENARIOS INTO THE DWPF PROCESS PLANT SIMULATOR

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IMPLEMENTATION OF ABNORMAL OPERATION SCENARIOS INTO THE DWPF PROCESS PLANT SIMULATOR

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ABSTRACT

The Defense Waste Processing Facility (DWPF) will be used by the Department of Energy to process high level liquid radioactive waste into a stable and manageable solid form. The facility requires a performance-based operator training program to satisfy DOE orders and guidelines. The control room operator training portion of this program is conducted on the DWPF Process Plant Simulator and is divided into normal and abnormal operations training. Normal operations training reflects the normal manual and automatic operations of the process. Abnormal operations training initiates equipment failures and process upsets in order to train the operators on transient operation and safe shutdown of a specific DWPF process.

Abnormal operations training requires the capability of the DWPF Process Plant Simulator to initiate and manage predefined malfunction scenarios as needed by the training instructors.

This paper will discuss the implementation of abnormal operation scenarios capability into the DWPF Process Plant Simulator.

INTRODUCTION

The DWPF is a complex chemical process consisting of batch, semi-batch, and continuous process operations. The chemical processing and balance of plant operations of the DWPF are controlled by a Texas Instruments® D/3™ Distributed Control System (DCS). Approximately 7000 digital and analog input/output (I/O) points are processed by the DCS including some 200,000 lines of code in sequence programs that provide process and equipment interlocks as well as automated process operations.

The DWPF Process Plant Simulator consists of eight simulation packages which cover the sections of the DWPF as shown in Figure 1. These include Low Point Pump Pit,

Precipitate Reactor, Melter Feed Preparation, Melter, Melter Off-Gas System, Recycle Waste System, Balance of Plant, and HVAC. The packages have been designed to run stand-alone or with other packages wherever process flows connect them. For instance, the Melter simulation package is designed to run stand-alone or with the Melter Off-Gas System and/or Melter Feed Preparation simulation packages. The primary purpose of the simulator is to provide initial operator training and subsequent retraining in specific DWPF process operations.

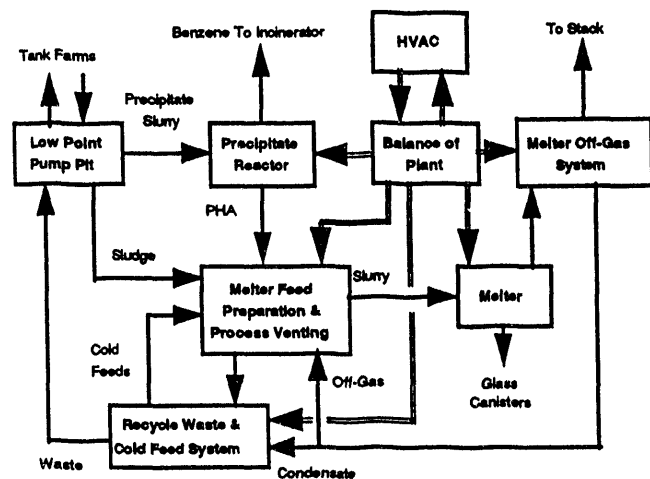


Figure 1. DWPF Process Plant and Simulation Package Layout

The simulator was developed under a phased approach to allow turnover of deliverables to the customer to support schedule training requirements and milestones. Three phases were employed for this project: 1) Phase 1 - development of process models and executive programs for controlling the simulator; 2) Phase 2 - the expansion of Phase 1 to include equipment and personnel protection software to allow normal operations training; and 3) Phase 3 - the expansion of Phases 1 and 2 to include the capability to initiate and manage failure and/or emergency process scenarios to allow abnormal operations training.

ORGANIZATIONAL ROLES

- DWPF Training Group - primary user of the simulation packages, developer of the Functional Performance Requirements, and author of the Phase 3 scopes of work.
- DWPF Simulation Group - responsible for the development and maintenance of the simulation packages. The Functional Design Criteria was developed by this group.
- DWPF Operations - primary end user of the process simulation packages and owner of the DWPF Process Plant Simulator.

SIMULATOR HARDWARE DESCRIPTION

The DWPF Process Plant Simulator is a stand-alone Texas Instruments D/3 Distributed Control System consisting of four Display Control Modules (DCMs), fifteen 2Mb-80386 Process Control Modules (PCMs), fourteen Operator Console Modules (OCMs), one VAX™ 4200 Configurator Display Control Module (CDCM), and one VAX 4400 HOST (Figure 2). DCMs are used to drive the OCMs which provide various process and alarm displays. Keyboard control of the process is done at the OCM and is transmitted to the PCM where the I/O points are processed and control logic and models are configured.

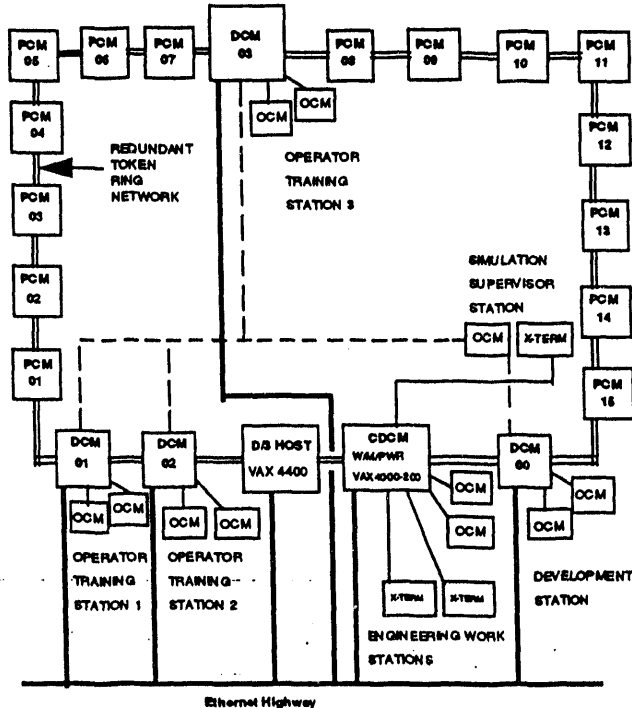


Figure 2. DWPF Simulator Hardware Layout

The simulator is partitioned into two areas of usage:

Development Area

This area of the system is used by the Process Simulation Group to develop and maintain the different phases of the simulation packages. It consists of six PCMs, four OCMs, one DCM, and two X-Windows terminals.

Training Area

This area of the system is used by the Training Group for operator training, evaluation, and certification. It has four station areas: three for operator usage and one for the simulator instructor (Figure 3). It consists of nine PCMs, ten OCMs, three DCMs, and one X-Windows terminal.

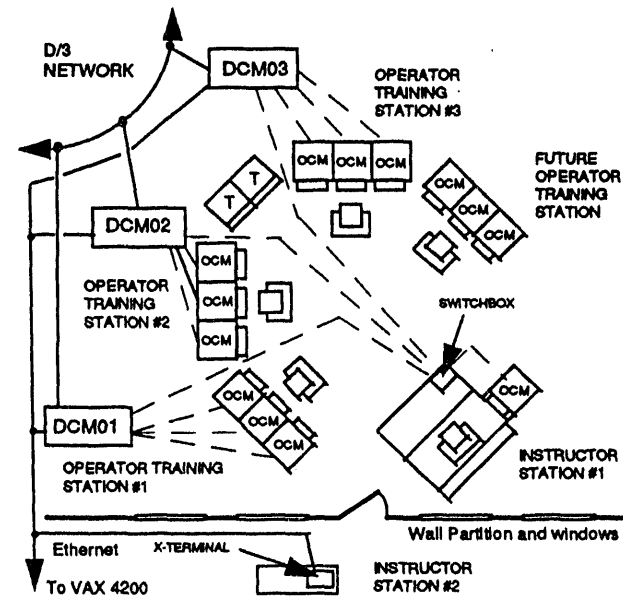


Figure 3. Simulator Control Room Layout

SIMULATOR SOFTWARE DESCRIPTION

Simulation Packages

The simulation packages are made up of three main software areas: 1) Control configuration and programs; 2) Simulation and model configuration and programs; and 3) User interfaces. In Phases 1 and 2 development and maintenance, all three software areas require continued modifications as reference plant changes and model improvements are implemented. Phase 3 development and maintenance generally only affect the model configuration.

Control Software Configuration is made up of analog and digital function blocks written in the D/3's native language. In addition to analog and digital point definitions, an overlay of sequence programs run in the DCS to manage process and equipment interlocks, and automate various process operations.

Model Software Configuration is written in the D/3's analog function block language and is coded adjacent to the control software configuration. Figure 4 shows the typical relationship between field hardware and the DCS configuration of a single control loop and associated model. The model software I/O replaces the field hardware I/O within the control system software.

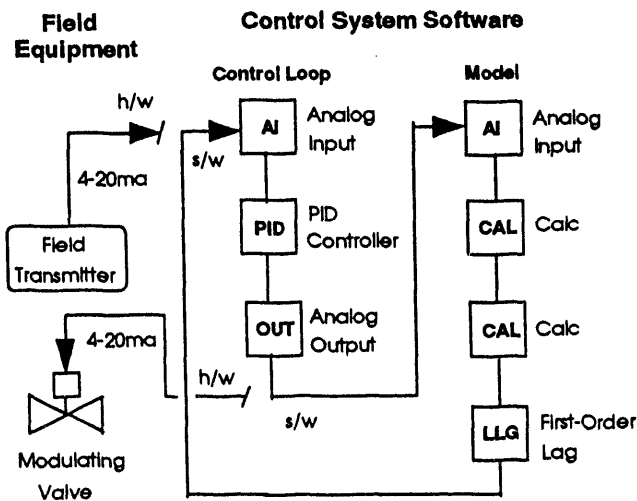


Figure 4. Software Control Loop and Model in D/3 Control System Analog Function Block Language.

Simulator Control Programs are written in either the D/3's sequence and batch language (SABL) or in 'c'. The following simulator features are written in one of these languages:

- Simulation Freeze (SABL) - stops processing of models and PID controllers.
- Simulation Fast/Slow (SABL and c) - varies the time scale of the simulator models and processes.
- Initial Condition (SABL and c) - restores the simulator to a saved set of model and process conditions (see snapshot).
- Snapshot (c) - captures all model and process values and stores them into a database file for later recall.
- Package Link (c) - allows simulation packages to transfer model and process data between each other. Used for isolating models of selected process plant areas from the rest of the simulator for testing purposes or specific operator training.

Simulator Statistics

- 500,000 lines of code
- 4500 instrument and control points
- 2500 process models
- 19 simulation packages scoped

PHASE 3 FUNCTIONAL PERFORMANCE REQUIREMENTS

The DWPF Training Group established the simulator's Functional Performance Requirements (FPR) to support abnormal operations training (Phase 3) for their control room operators. These Phase 3 requirements are detailed in this section.

The simulator must be capable of simulating, in real time, abnormal and emergency events which result from malfunctions to demonstrate inherent process response and functioning of automatic controls. A list of malfunctions and their causes is submitted to the simulator development group.

Malfunctions consist of a variety of equipment failures. Certain malfunctions are required to be variable in nature such as heat exchanger tube leaks and filter clogging. The severity of malfunctions can be increased or decreased over a realistic time span, with the instructor determining the magnitude. Where applicable, the simulator provides the capability for the DCS operator to take action to recover the facility and/or mitigate the consequences of the malfunction. Process response to the malfunction is carried out to a reasonable and stable operating condition as determined by analysis of the training value of each malfunction.

The simulator provides the capability of simulating multiple malfunctions simultaneously. This is to provide the Simulator Instructor the capability of "building" simulator exercises and customizing each exercise to the Trainee's ability and/or training needs.

PHASE 3 PLATFORM SELECTION

An evaluation of several Phase 3 platform options was conducted (Weeks and Edwards 1991) to determine which one provided the greatest long-term flexibility, lowest costs, and shortest implementation time on the simulator project. Some of the options evaluated were D/3 sequence programs, 'c' programs, and object-oriented expert system packages. The objectives and criteria used to select the most beneficial platform are listed below:

Objectives

- Expansion of Phase 1 and 2 simulation packages to handle defined training scenarios.
- Initiate training scenarios from an X-Window based Operator Training Station run by the Training Supervisor.
- Monitor operator performance during a training scenario.
- Maintain complete log of all responses as a function of time and scenario process conditions.
- Provide summary statistics of operator responses.
 - Time to identify process upset condition
 - Time required to correct situation and/or shutdown process.
 - Number of unnecessary and/or incorrect actions
 - Actions performed out of sequence.
- Provide permanent performance record and/or training record for operator.

Selection Criteria

- Implementation Feasibility
 - Hardware implementation
 - Software implementation
 - Installation Complexities (size, cabinet modifications, etc.)
 - Compatibility with existing Operating Systems and Software
 - Compatibility with existing Configuration Management Practices/Procedures
- Projected Costs
 - Hardware
 - Software
 - Additional Code Development Time (LOE)
 - Training Costs for Simulation Group
- Long Term Implications
 - Flexibility for Future Needs
 - DWPF Software Support
 - Vendor Support
- Vendor Performance
- Procurement Issues

M/POWER™ Software Package

Of five Phase 3 platform options evaluated, Mitech® Corporation's M/POWER software package was selected. It met the selection objectives and criteria with the only negative being a lack of personnel training on the software.

M/POWER's strengths are the ease of programming through use of its object-oriented design and potential as

an expert system (its advertised purpose is as a real time process management tool). It comes packaged with a D/3 interface and runs on DEC® VAX/VMS computers.

M/POWER additionally provides the ability to create graphical user interfaces through the use of static and dynamic color graphic displays. An instructor station graphic can be created to allow an interface to the simulator in order to manage the malfunctions.

PHASE 3 DEVELOPMENT

Scope Evaluation

Phase 3 simulation package scopes are provided to the Simulation Development Group and identify the following:

- Malfunction name
- Malfunction number
- Malfunction cause
- Primary effects
- Data references

To date, one hundred ninety-five (195) malfunction scenarios have been defined in the initial scopes of work. An evaluation of each malfunction scenario is performed to determine the momentum, mass, and energy effects caused by the malfunction. All anticipated operator responses to the malfunction are evaluated to ensure that the simulator can support their actions. The malfunction is further evaluated to determine its type, either discrete or variable.

Discrete Malfunction A discrete malfunction is defined as the insertion of a single point failure such as an open circuit or equipment failure. Most discretely require one modification to the model configuration in the simulation package.

Variable Malfunction A variable malfunction is defined as the insertion of a failure that permits an adjustable value or quantity that alters the rate or magnitude of a malfunction. Some variable types require the addition of a model in order to "track" the state property affected by the malfunction.

Model Software Configuration Modifications

For both discrete and variable malfunction scenarios, the D/3 analog function block structures which make up the model require either additional blocks or slight modifications to the parameters of an existing block. An

example of discrete and variable malfunction links into a model are shown below (Figure 5).

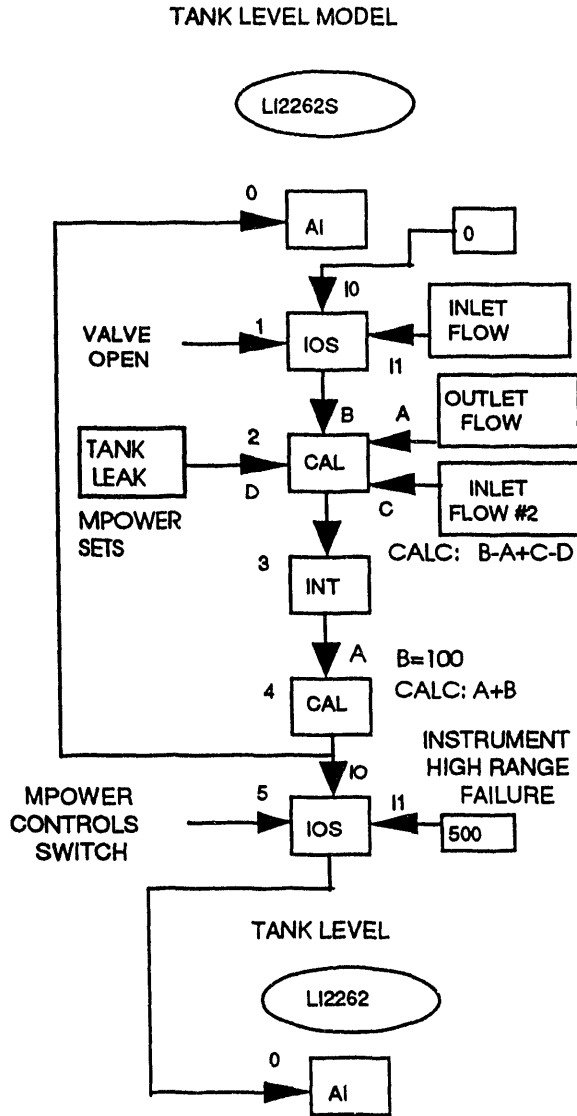


Figure 5. Analog block diagram of a level model and indicator with a variable malfunction link (tank leak) and discrete malfunction link (instrument failure).

Malfunction Scenario Management Program

An M/POWER application program is developed to manage the insertions and removals of malfunctions. It acts as the interface between the D/3 simulation packages and the instructor station. The program consists of various program shells or objects to perform different functions.

The program is object-oriented in nature and various object types perform specific functions. Input objects

define data links into the program from simulation package models or control points or from an instructor station graphic. Likewise, output objects define data links from the program to simulation package models and control points or to an instructor station graphic. An activity object defines the rules or conditional logic that is used on the input and output objects. One of the major features of M/POWER is the ability for an activity to chain to other activities based on the first activity's rules. Each malfunction scenario uses an activity object to monitor the instructor station graphic for mouse button action and chains to another activity object to insert or remove a malfunction from the simulator.

Malfunction Scenario Selector Graphics

The Dv-Draw™ software package is used to develop three types of graphic displays used by each simulation package in order for the simulator instructor to control the Malfunction Scenario Management Program: 1) An overview graphic of the process with locations of the malfunctions indicated in circles; 2) a menu with "button" gadgets to control the insertion, removal, and setup of each malfunction; and 3) a setup menu to control the severity of the malfunctions and their time delay parameters (Figure 6).

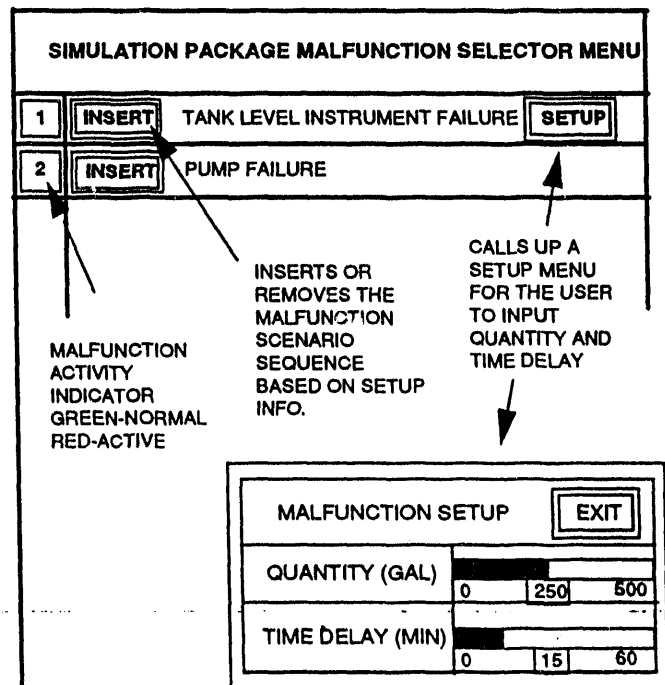


Figure 6. Malfunction Scenario Selector Graphic

PHASE 3 TESTING

Using the scope of work and generic test procedures, each malfunction is tested for the proper process responses by observing the effects on modeled equipment, instrumentation, and state properties. The package is also tested to insure the original model integrity has not been compromised by new models.

PHASE 3 DOCUMENTATION

Simulation Package Manual

The Analog Block Diagram is used to reflect the D/3 block structure of the control and model configuration in the simulation package. All M/POWER links are noted in the appropriate model along with inputs, outputs, and key parameters.

The Scenario Block Diagram (Figure 7) is used to reflect the M/POWER application program logic on a per malfunction scenario basis.

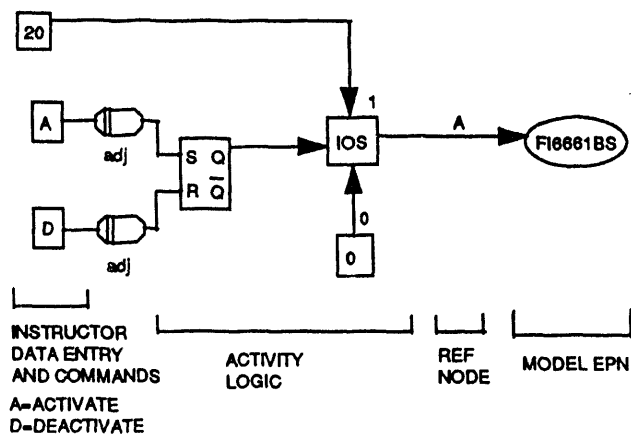


Figure 7. Scenario Logic Block Diagram

PHASE 3 VALIDATION

Acceptance Test Results

Following the simulation package turnover, the Training Group reviews the work and identifies problem areas that must be addressed before the package is accepted. They are categorized into either action, clarification, or modification items. An action item requires attention before the package is accepted; a clarification item needs further review by the developers; and a modification item alters the original scope of work, but does not require resolution prior to package acceptance.

PHASE 3 STATUS

Currently, the Phase 3 project is 50% complete with turnover of all simulation packages expected by January 1995. Several demos have been given to Training which were subsets of the actual scopes of work with positive results.

Data from tracking operator responses are currently extracted from two system log files and manually edited to create operator summary statistics. Plans for automating this process are forthcoming.

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