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THE LOFT AUGMENTED OPERATOR CAPABILITY PROGRAM

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ABSTRACT

The outline of the LOFT Augmented Operator Capability Program is presented. This program utilizes the LOFT (Loss-of-Fluid Test) reactor facility which is located at the Idaho National Engineering Laboratory and the LOFT operational transient experiment series as a test bed for methods of enhancing the reactor operator's capability for safer operation. The design of an Operational Diagnostics and Display System is presented which was backfit to the existing data acquisition computers. Basic color-graphic displays of the process schematic and trend type are presented. In addition, displays were developed and are presented which represent "safety state vector" information. A task analysis method was applied to LOFT reactor operating procedures to test its usefulness in defining the operator's information needs and workload.

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INTRODUCTION

A near consensus has been reached on the need to apply state-of-the-art technology to the safe operation problems of a commercial light water reactor (LWR) under upset or faulted conditions. The two major elements of this technology are: (1) computer technology and (2) functional analysis of operations.

COMPUTER TECHNOLOGY

Under off-normal operational conditions, the operator in a nuclear power plant is presented with an enormous amount of information which must be collected, processed, and evaluated in order to make appropriate control decisions as to whether the plant can be restored to normal operating conditions or should be shutdown.

Under emergency conditions, the active area of the control panel and the volume of raw data can exceed the saturation point of the operator. This data is presented to the reactor operator without prioritization in a short period of time. Yet, the operator needs more, not less, information concerning the status of crucial plant systems. Thereby, a dilemma exists in balancing a recognized need to reduce operator data overload against a perceived need by the operator for more data. This dilemma can be resolved by the use of computers to reduce raw information to significant information which can be displayed in recognizable form.

An Operational Diagnostics and Display System (ODDS) has been designed for use with the Loss-of-Fluid Test (LOFT) reactor at the Idaho National Engineering Laboratory. The ODDS is presently being evaluated during small break (loss-of-flow) tests conducted on the LOFT reactor. The ODDS will improve the operator's capability for making correct and timely control decisions.

LOFT is a scaled-down version of a commercial pressurized water reactor (PWR) (one sixty-fourth size). It is felt LOFT resembles a commercial PWR in man-machine factors which permits evaluation of computer-based graphic displays for their potential use in commercial LWR applications. The LOFT man-machine factors representative of typical LWRs are shown in Table I.

TABLE I
LOFT MAN-MACHINE FACTORS REPRESENTATIVE OF TYPICAL LWRs

1. Reactor Facility	2. Operational Framework
a. Nuclear Steam Supply System	a. Technical Specifications
b. Main Control Room	b. Operating Procedures
c. Automatic Protective Systems (RSS, ECCS, CIS)	c. Operating Crew
d. Instrument and Control Equipment	d. Training
	e. Maintenance Practices

DESIGN CONFIGURATION

The hardware components of the LOFT Operational Diagnostics and Display System (ODDS) are shown in Figure 1. The ODDS consists of a central processing unit (CPU), asynchronous multi-line controller (AMLC), memory unit, disk storage unit, magnetic tape unit, and display terminals. The CPU is a PRIME 550, a machine near the upper end of the performance range of minicomputers. The system is configured with 512 kilobytes of main memory and possesses two kilobytes of high speed cache memory to speed program execution. Both on-line and off-line storage capability are provided for the data files and programs. Three cathode ray tube (CRT) terminals provide an interface with the various users and user interaction with the system. The CRTs are RAMTEK devices interfaced with the PRIME by serial lines and are capable of graphics in eight colors. The same type of serial interface used with the CRTs is also used to connect the PRIME 550 with the LOFT Plant Log and Surveillance Subsystem (PLSS) computer through which data are dynamically acquired.

Initially, The ODDS has been configured to take advantage of the existing LOFT PLSS, a system built around a MODCOMP-IV computer already used to acquire plant information from process instruments in order to provide historical plant log and real-time monitoring functions. The software design approach with respect to data acquisition was to view the data as being comprised of two types: analog and event.

Analog data acquired by the PLSS are routinely buffered so a data point representing an average of several seconds of data for each analog channel is available for processing or presentation. Data transmitted from the PLSS to the PRIME are updated every five seconds. All analog data have been converted to floating point, engineering unit values before being sent to the ODDS.

Event data are discrete data which relate to a physical condition such as a breaker switch or valve position. They are updated to the ODDS every two seconds.

In keeping with the design approach of separating the event and analog data, each type of information is passed over a different physical line by an independent PLSS-resident program and is acquired by an independent program on the ODDS. Complexity of the communication process is kept to a minimum by use of a serial interface with all data transmitted at 9600 baud (bits per second).

Programs resident on the ODDS acquire data from the communication lines, reformat the data, and place the data into storage files on a disk storage unit. Analog and event data are each stored into circular files of approximately 10 hours duration. These data files may be spooled to tape for off-line storage and subsequent retrieval for replay purposes.

A package of display-oriented software exists which accesses the circular disk files and creates the various color displays seen by the user on the CRTs. At the heart of the display package is a set of routines known as the graphics display library. The application programs constructing the various displays all use the graphics display library.

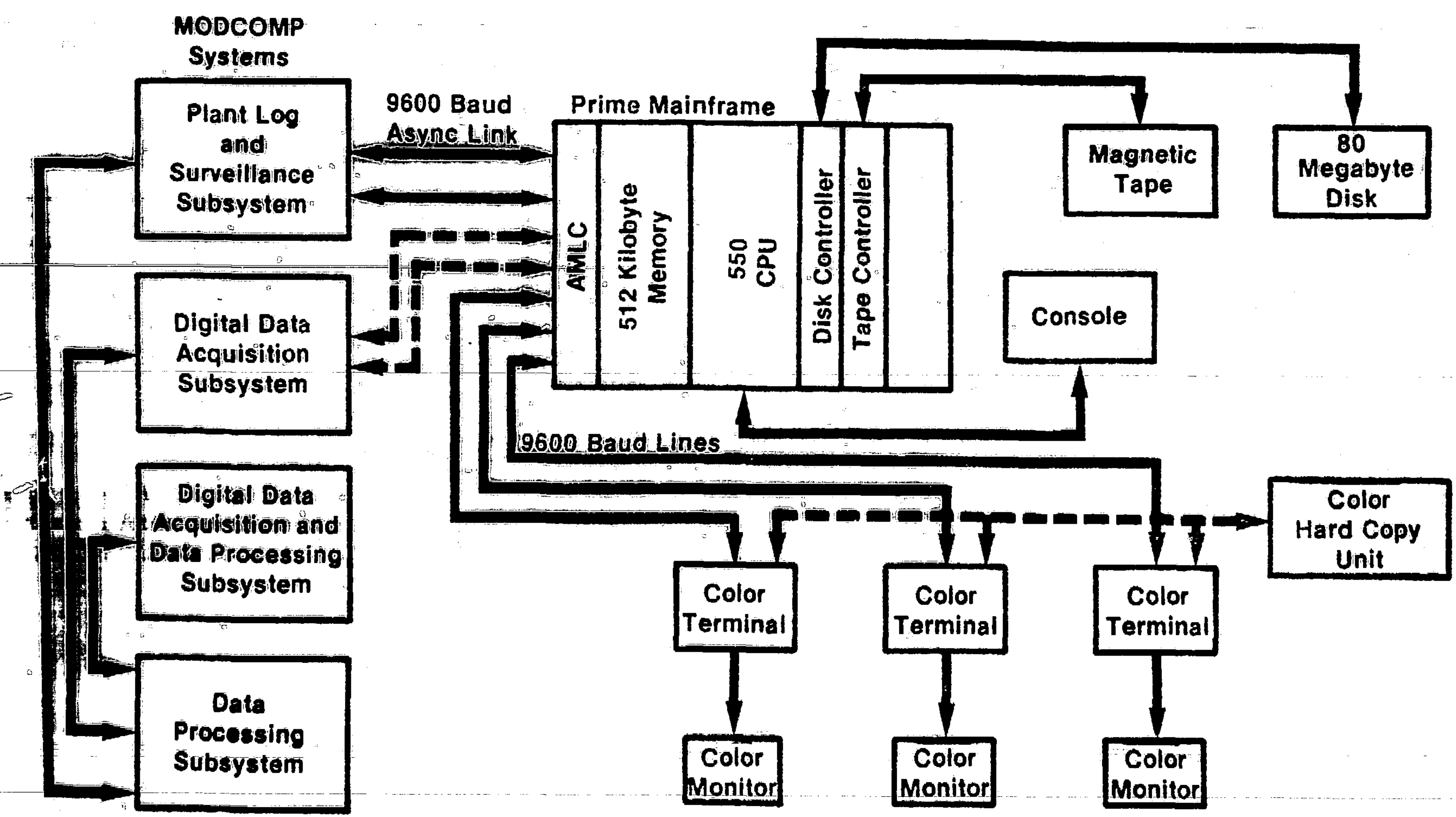

Figure 1. Operational diagnostics and display system (ODDS).

Expansion and enhancement of the software capability is planned. Some items under consideration are: (1) increased data update rates, (2) increased data base to support additional instrumentation, and (3) numerous new applications in the display program package.

BASIC DISPLAYS AND TREND INFORMATION AVAILABLE

A demonstration set of color graphic displays has been implemented on the LOFT ODDS. These displays were chosen to encourage immediate use of the ODDS by the reactor operator. Status-type displays were implemented first to get the ODDS into service rapidly (diagnostic or other complex programs take longer to design and implement). The general criteria used for the selection of LOFT displays were:

a. Displays should present information which is frequently used by the reactor operator during normal reactor operation,

b. Displays should also be of potential use in following the course of a small LOCA (loss-of-coolant accident) or operational transient,

c. Status-type displays should be implemented first,

d. Information should be presented in an integrated fashion to support specific plant evolutions or operation of crucial plant systems,

e. Displays should present information in formats which are complementary to those presently available for the conventional process instrumentation in use at LOFT, and

f. Baseline displays should use information derived from process (non-experimental) measurements.

The demonstration displays can be grouped into two sets: process schematics and status or trend plots. Process schematics exist for the primary coolant system, secondary coolant system and emergency core coolant system. These displays are simplified schematic diagrams with parameter values and component status (e.g., valve position) shown at the appropriate locations on the diagrams. Initial conventions are established for the representation of component status through the use of colors (e.g., pump on or off, vessel level) and symbol shape (e.g., valve open or closed).

Status and trend plots generally show three types of information: (1) present status of one or more crucial plant parameters, (2) recent past history of these parameters, and (3) operating limits for these parameters appropriate for the mode of operation for which the display was intended. Demonstration displays of this type include:

a. Plant heatup (actual vs technical specification limits)

b. Plant cooldown (actual vs technical specification limits)

c. Pressure vs temperature (hot leg conditions vs power operation limits)

d. Minimum pressure vs temperature (cold leg conditions, including pump operation limits)

e. General X-Y plot (any two parameters).

Typical demonstration displays of process schematic, safety state vector, and trend information available on the LOFT ODDS are shown as Figures 2, 3, 4, and 5. Small-break LOCA data from Experiment L3-2 are displayed.

Each of the baseline displays exists in two versions: a "control room operator" version and an "engineering" version. Each version of each display can be called up for viewing on any display terminal either by typing a simple mnemonic (e.g., "PCS" for the Primary Coolant System process schematic) or by pressing a special function key on the terminal keyboard. The control room operator displays have fixed formats and parameter ranges, and display only current data. The engineering displays allow the user to alter such features as the scaling of plots or the indicated status of components; they also allow the replay or display of historical information stored in the computer. This information base includes several hours of the most recent plant data as well as data from previous LOFT tests.

A number of limitations of the present display capabilities are recognized at this time. Some of the more significant ones are:

a. Development of display hierachy and structure has just begun; consequently the present displays are related only through the training and experience of the plant operator.

b. Nuclear industry standards for the use of color, symbology, and other display conventions for such systems have not been established.

c. Some information desired for the demonstration displays is not part of the available data base. (Over 60 status and parameter values have already been added to the LOFT data acquisition system to support the baseline displays.)

d. The displays can be regenerated at will by replaying historical data; however, no simulation capability presently exists to allow varying indicated plant status from that which actually occurred during LOFT operation.

FUNCTIONAL ANALYSIS OF LWR OPERATIONS

Task analysis is being used to determine the operator's information needs during normal and emergency operation of the LOFT facility. Task analysis is a systematic method for analyzing the operation of a system by (1) breaking the operation into its component parts and (2) extracting useful information concerning the operation of the facility. Task analysis is performed in four steps. First, the overall characteristics of system operation are examined to define relevant operating modes of the system and potential transfers between modes. Second, procedures are developed for

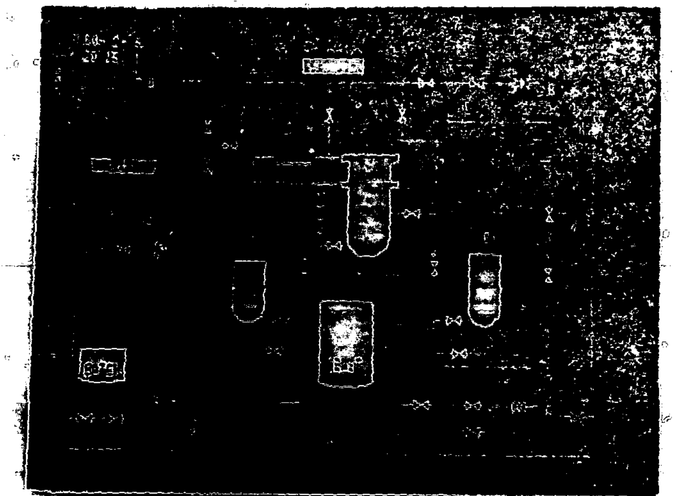

Fig. 2. Emergency Core Cooling System

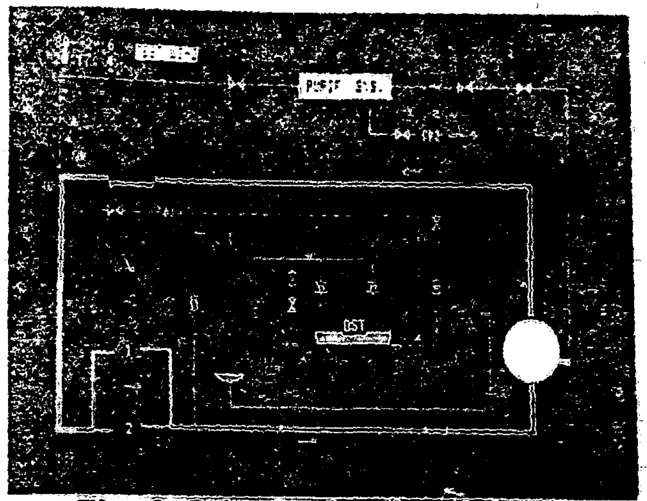

Fig. 3. Primary Cooling System

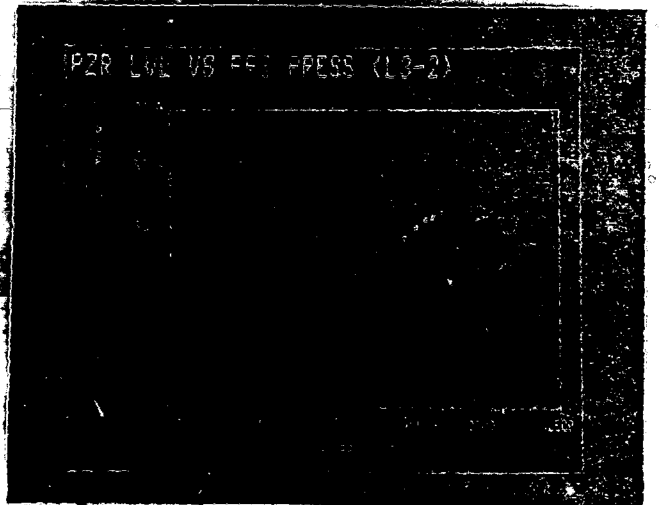

Fig. 4. Pressurizer Level vs Primary Pressure

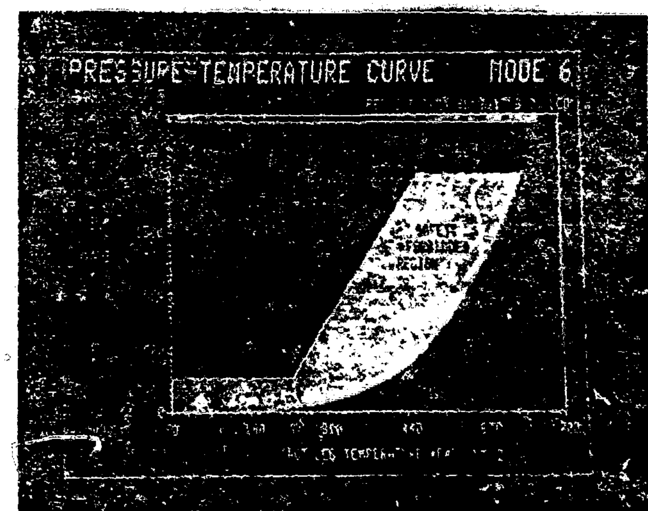

Fig. 5. Pressure-Temperature Curve

Note: The figures show actual data taken during LOFT small-break test L3-2. The figures are arranged left to right in time sequence.

each mode-to-mode transfer; the LOFT plant operating manual is being used as a basis for this step. Third, each procedure is flow charted to illustrate the operator's decision points and the potential paths through the procedure. Fourth, a tabular form is used to list information from the flow chart including: (1) required decisions, (2) information required to make the decision, (3) source of the information, (4) time available to act, (5) feedback associated with the correct action, and (6) alternative actions available if a malfunction occurs.

The results of LOFT task analyses are used: (1) to make recommendations to improve existing procedures and (2) to make recommendations for the design of CRT displays to be implemented on the ODDS. Representative results of this type of analysis are discussed in Reference 4.

CONCLUSION

The LOFT ODDS was placed in operation in January 1980 and was used by the reactor operators in conducting the LOFT L3-2 small-break test in February 1980. The ODDS is being readily accepted by the LOFT reactor operators as an aid in controlling the plant. Although only a limited number of baseline displays of process schematics and trend information are available at present, computer-based graphic displays are expected to gain acceptance in the future as a useful source of information to assist the reactor operator in his decision-making processes required for normal and off-normal reactor operations.

Functional analysis of operations appears to be as applicable to the LWR operational safety problems as to other modern man-machine control problems. Functional analysis and computer-based graphic technologies are being developed for the LOFT program to permit this unique facility to be used as a workshop and test bed for LWR operational safety problems.

REFERENCES

These references were used as definitions of where reactor operator capabilities should be augmented.

1. NUREG-0585, October 1979, TMI-2 Lessons Learned Task Force Final Report.

2. Report of the President's Commission on the Accident at Three Mile Island, John G. Kemeny, Chairman, October 1979.

3. NUREG/CR-1270, Vol. I, January 1980, Human Factors Evaluation of Control Room Design and Operator Performance at Three Mile Island-2, Final Report.

4. W. R. Nelson, "Response Trees for Emergency Operator Action at the LOFT Facility," 1980 ANS/ENS Meeting on Thermal Reactor Safety, Knoxville, TN, April 7-11, 1980.