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TO: IEEE

The following statement applies to my conference paper entitled, "LOFT Advanced Control Room Operator Diagnostic and Display System (ODDS)", to be presented at the Nuclear Science Symposium sponsored by the Institute of Electrical and Electronics Engineers.

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LOFT ADVANCED CONTROL ROOM OPERATOR DIAGNOSTIC AND DISPLAY SYSTEM (ODDS)

by

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Summary

The Loss-of-Fluid Test (LOFT) Reactor Facility in Idaho includes a highly instrumented nuclear reactor operated by the Department of Energy for the purpose of establishing nuclear safety requirements. The results of the development and installation into LOFT of an Operator Diagnostic and Display System (ODDS) are presented herein. The ODDS is a computer-based graphics display system centered around a PRIME 550 computer with several RAMTEK color graphic display units located within the control room and available to the reactor operators. Use of computer-based color graphics to aid the reactor operator is discussed. A detailed hardware description of the LOFT data system and the ODDS is presented. Methods and problems of backfitting the ODDS equipment into the LOFT plant are discussed.

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Text

The Three Mile Island (TMI) incident has triggered an interesting and far-reaching change in the nuclear industry. Ensuing investigations following TMI confirmed what many in the industry, particularly the control room personnel, already knew: the complexity of operating a nuclear plant was becoming more than plant operators, armed with conventional control room instrumentation, could handle. Discussions with plant operators indicated that more information was needed. Those same discussions also pointed out that under emergency conditions, the operator was unable to cope with the amount of data he was currently receiving. Thus, the dilema is how to get more information to the operator without overwhelming him in the process. The problem was not in what information he was receiving, but how he was receiving it.

All who have seen typical nuclear power plant control rooms are duly impressed by the myriad of meters, dials, gauges, flashing indicators, and other eye-catching and ear-prodding indicators. LOFT personnel who have experienced the mounting tension of an impending "transient" and observed the intensity with which the operators pour over their charts, procedures, and read-out devices are impressed with the complexity of the operator's job. When something deviates from the expected, followed by the varying element of confusion, we sympathize with the operator who must maintain order in these plants. The operator's job often moves from continuing boredom to near-havoc in the course of his day. In many instances there cannot be a procedure for or sometimes even the time to meet each challenge.

A method of supplying the operator with more efficient data in a better form is clearly needed. The obvious observation is that some interim device must be employed to arrange the data into meaningful and more easily understood display patterns. These display patterns must be readily available and contain enough, but not too much, information. They must be logically and hierarchically ordered so that the operator can rapidly descend through them to the level of detail that best meets his current needs. It follows easily that the interim device be the computer and, after some deliberation, that the method of information display be primarily the graphics display terminal. The addition of color to the graphics display not only provides an increased variety of display entities but also proves to be more aesthetically pleasing and thus enhances the operator's endurance and efficiency. The general acceptance of these conditions spurred on by the memory of TMI gave direction to this new industry program.

A decision was made to expand the use of computers in the nuclear plant control room. This was not an easy decision for an industry that has traditionally distrusted the computer. The optimism for this new approach was also tempered by an understanding of the reasons that the computer was distrusted. Computers are amazingly fast and thoroughly efficient, but not wholely dependable. Any computer, because of hardware or software weaknesses, can break down or provide erroneous information. In order to gain the trust of the nuclear community the computer must be configured so that it always works, or at least has an acceptably low failure rate.

Thus, the stage was set for the development of advanced nuclear plant control room techniques. As is always the case, time was of the essence. The following guidelines for this development are generally accepted.

1. Use the speed and efficiency of a computer.

2. Provide information readout on color graphic display terminals.

3. Provide accessible and understandable displays and information transmission techniques.

4. Provide fail-safe computer-based systems, using redundancy or networking techniques.

5. Implement, as far as possible, radiation and physical hardening; ensure against seismic and environmental disturbances.

6. Provide secondary levels of operations support facilities such as technical support centers, emergency operating facilities, safety parameter display systems, and nuclear data links.

The LOFT AOC (Augmented Operator Capability) Program is in the process of investigating advanced control room techniques for the Nuclear Regulatory Commission (NRC). The LOFT nuclear reactor is a highly instrumented reactor operated by the Department of Energy for the purpose of establishing nuclear safety requirements. As such, the LOFT program is an excellent test bed for developing man-machine and advanced control room requirements. The distinct advantage that LOFT has in this area is the existence of an accessible operating nuclear plant. Information techniques can be developed under actual operating conditions. LOFT is part of the Idaho National Engineering Laboratory and has both the manpower and technical expertise to support such an endeavor.

The LOFT AOC approach to investigating advanced display techniques is as follows:

1. Secure the services of a qualified company with expertise in the area of display systems who could develop the appropriate operator oriented color display.

2. Provide the necessary equipment to develop these displays. Employ actual plant data as input.

3. Develop a hardware system that could be backfitted into the LOFT plant. This development would serve two purposes. The first would provide actual control room use of the displays generated in (1) above. The second would extend the hardware investigation.

4. Establish and use a technical support center (TSC).

5. Evaluate the safety parameter display system.

6. Establish hardware fail-safe criteria.

7. Establish software data validation and verifications techniques.

8. Close the nuclear power plant control loop using computer techniques.

9. Establish the functional requirements for the LOFT advance control room.

10. Develop the LOFT advance control room.

11. Evaluate advance control room techniques using the LOFT reactor.

The resolution of items 1 through 5 comprises the LOFT Operator Diagnostic and Display System (ODDS). Items 6 through 11 are being addressed as part of the LOFT advanced control room conceptual studies.

The ODDS Program began with the securing of Nuclear Services Corporation (NSC) of Palo Alto, California, in August 1979, as a software consultant charged with the development of color CRT displays. EG&G Idaho, Inc., as requested by NSC, procured a PRIME 550 CPU supported by RAMTEK 6200 color displays. The PRIME Computer was interfaced to the LOFT data acquisition system by two 9600 baud serial asynchronous communications channels. Figure 1 shows the configuration of the ODDS hardware.

The LOFT data system acquires both analog and digital information from the plant. The analog data is digitized and together with the digital data is formatted into buffers and transmitted to the ODDS. System display generation and color coding is accomplished on the PRIME and stored in the display terminals refresh memory at 9600 baud by a serial data link. The ODDS presently supports color monitors in the control room, the technical support center, and the visitors' display room.

The system shown in Figure 1 represents the current configuration of the ODDS equipment. When the system was initially brought on-line and plant operators began familiarization exercises, a problem with response time became apparent. The overall system response time, meaning the time expended between the identified need for information display and the completion of display geneation was too slow. This response time could run as high as 25 seconds for some displays. Operations personnel found this delay unacceptable. This response time is divided into two parts. The first, call-up time, is the time required for an operator to identify the need for a certain display from the library and to type in the instructions required to call up the display. The second part of the response time, draw time, is the time required for the hardware to generate the display on the screen. The operator call-up time and the hardware draw time comprises the response time. Human factors studies indicate that an operator can comprehend the content of a typical mimic display in approximately 3 seconds. These 3 seconds became the response time goal. Further refinement of this goal identified 2.5 seconds as operator call-up time and 0.5 seconds as machine draw time.

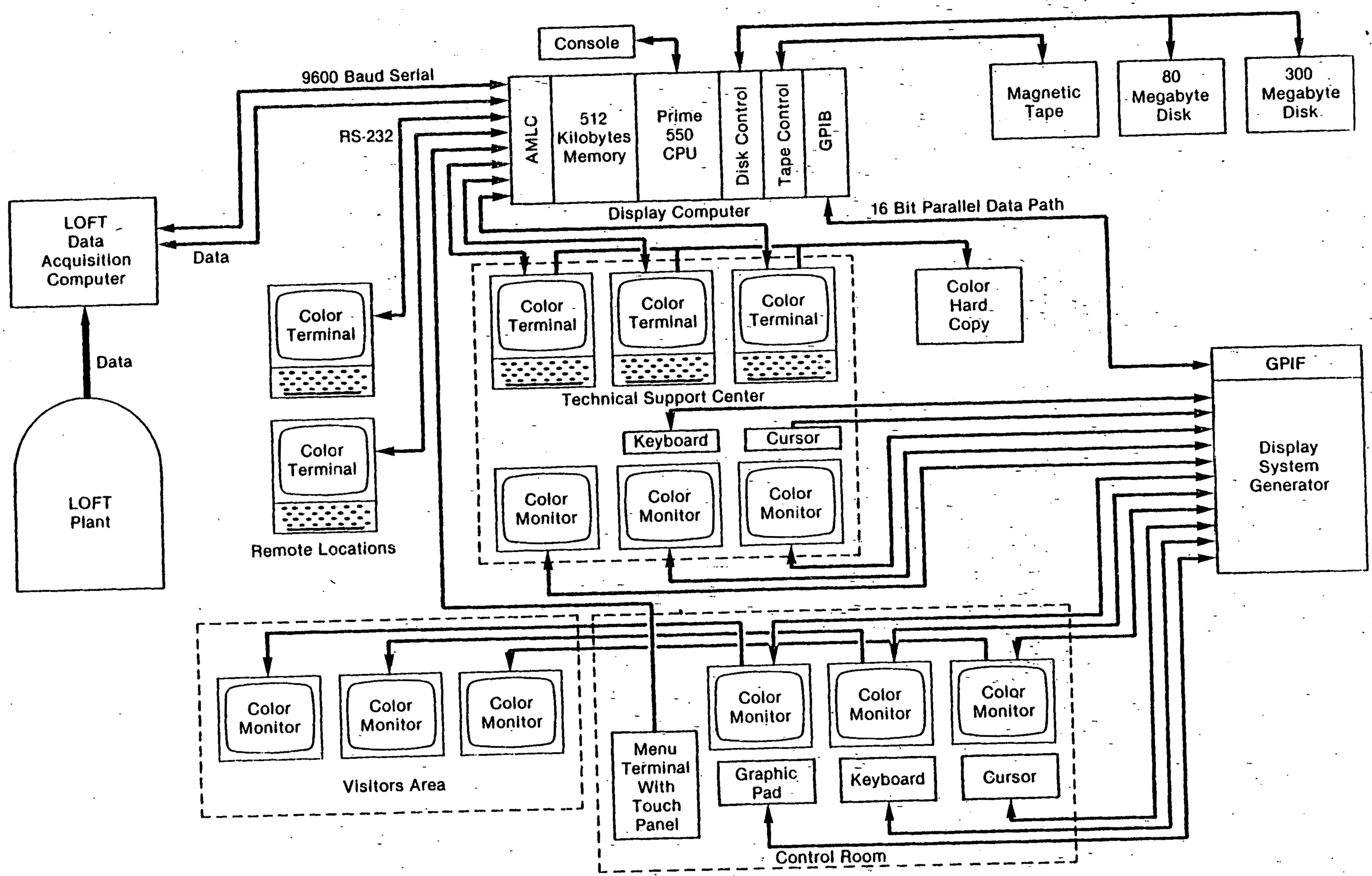

Figure 1 LOFT Operator Diagnostic and Display System Block Diagram

Call-up time was considered first. The Reactor Operations personnel found the keyboard extremely intimidating. Typing the instructions needed to define the required display produced excessive errors, especially under conditions of stress. Several methods were studied to improve this man-machine interface, among them pre-programming the function keys for basic displays, a light pen using a menu, a separate push button function panel, and a touch panel using a dedicated monitor displaying a programmable menu. The touch panel menu approach was chosen as the most effective under all conditions of stress. The touch panel hangs directly over the monitor screen and is thin enough not to hamper the operator's view of the screen. This monitor screen is divided into a grid pattern with display information written into each grid. Menu selection information and readout device assignment is located at the bottom of the screen on each menu page. Keeping this section at the bottom of the screen constant and unchanging allows the operator to rapidly page to the proper menu. Paging, display selection, and readout device assignment is accomplished simply by the operator's touching the screen with his finger in the area outlined by the grid pattern. Color can also be used to aid in menu information recognition.

The second portion of response time, draw time, was determined to be the result of the limited speed at which the host computer can write the display information to the display terminal over the 9600 baud serial line. Because of this serial link, this draw time could run as high as 20 seconds for more involved displays. The conclusion was that the serial link must be replaced by a high speed parallel data link. Because the RAMTEK 6200A's could only be interfaced serially, new equipment that could provide the parallel data link had to be procured. After investigation of several systems, the RAMTEK 9400 Color Display System was selected, and procurement was initiated. The 9400 system allows display generation within the 0.5-second draw-time requirement.

During the draw-time investigation, an additional hardware response problem related to the computer itself was identified. The PRIME 550 generally requires from 2 to 10 seconds to assemble from disk, core memory, and incoming data the necessary display generation information to be transmitted to the display device. This CPU response time rapidly grew worse as additional display terminals were added. This problem is currently being investigated. Our conclusions are that the CPU used in the display generation must be a better-than-average real-time system.

The conclusions of this response study are the following: (1) a menu type touch panel must be used for display selection, (2) data transmission must be high speed parallel, and (3) a CPU that will support high speed real-time multi-task applications should be selected.

In this initial phase of development no attempt was made to provide redundancy or system backup in the hardware. This equipment was procured in support of a display development program. The emphasis of the ODDS I program was to provide the minimum hardware as quickly as possible to support the development of the CRT displays. Fail-safe redundant hardware development is currently being addressed under Phase II of the ODDS program.

Several problems were encountered in backfitting the ODDS into the LOFT plant; these problems are probably typical of most existing plants. Space was a major problem. In the LOFT plant, because of limited floor space, it was difficult to determine where to put the computer system, where to locate the display terminals for easy access for plant operators, where to locate the Technical Support Center, etc. At LOFT, the display computer was located in an 8 by 12-foot room constructed at the rear of the control room; this space is cramped but has proven adequate. Computer room AC power and grounding techniques were followed.

Air conditioning was also a problem. The existing LOFT control room air conditioning system was used but was found to be changeable and unreliable. Hardware failures due to improper air conditioning have been both numerous and embarrassing.

Despite early acceptance and support by the plant operators, their confidence in the equipment eroded rapidly with each failure beyond a certain acceptable downtime for a non-redundant system.

An additional problem was the location of the display system. Initially the monitors were located outside the computer room at the rear of the control room. It soon became apparent that the equipment would never be accepted as a viable operations tool until it was located within the operator's work space. Figure 2 is a sketch showing the proposed location of this equipment. It is hoped that the location of the display equipment within this work space will produce general acceptance of the color display system techniques.

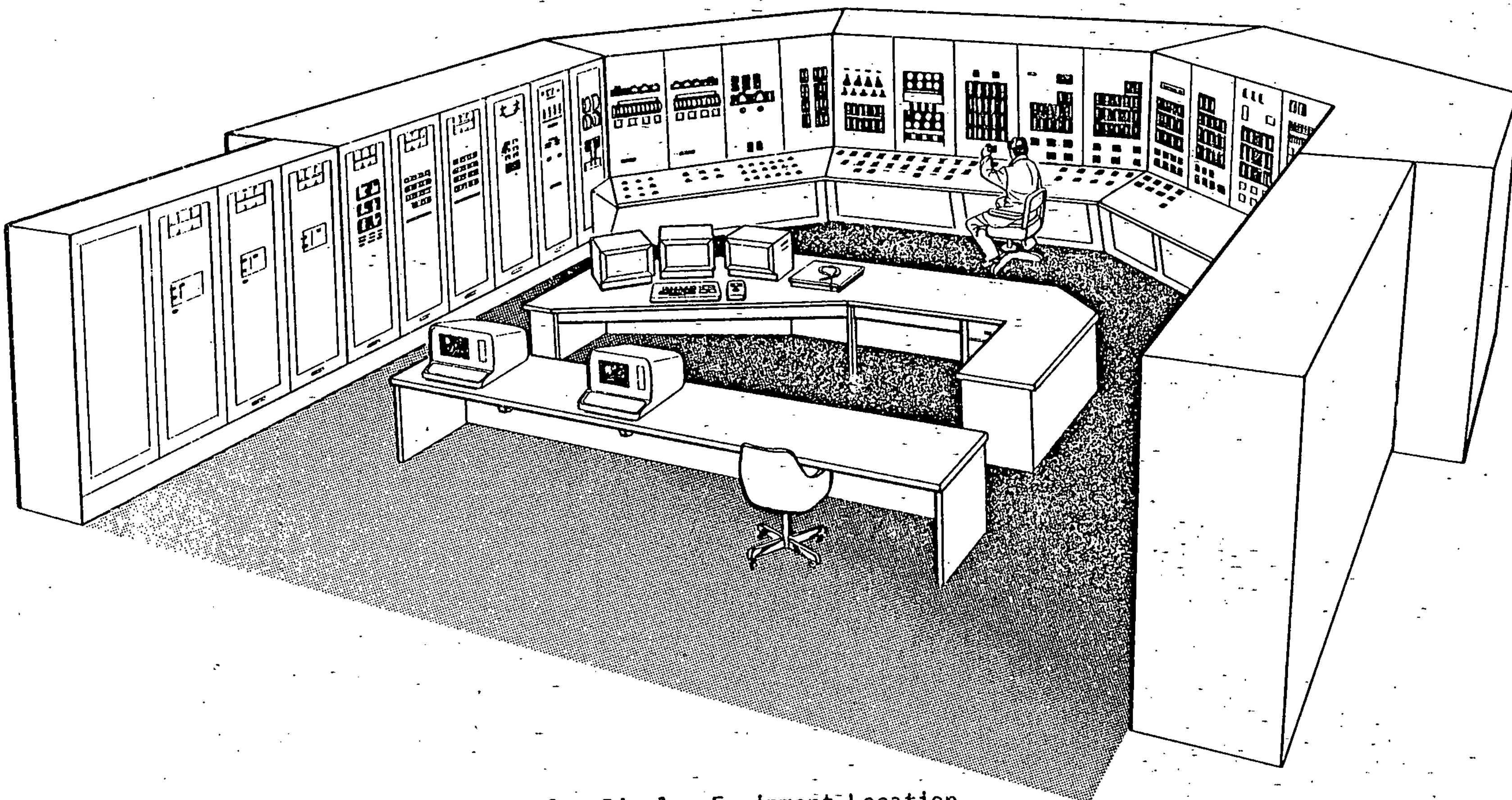

Figure 2 Color Display Equipment Location
in LOFT Control Room