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P.O. Box 616
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CC: C. Tope, 703-43A
File(WSRC-RP-89-474)
BSF-ISG-89-0226

July 31, 1989

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U. S. Department of Energy
Savannah River Operations Office
Aiken, SC 29801

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WSRC-RP-89-474, "INTEGRATED INTELLIGENT SYSTEMS IN ADVANCED REACTOR CONTROL ROOMS," By R. R. Beckmeyer.

A paper proposed for presentation and publication at the Westinghouse Computer Symposium in Pittsburgh, PA on November 6-7, 1989.

Technical questions pertaining to the contents of this document should be addressed to the author(s) or

M. R. Buckner, Manager
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Savannah River Site

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OSR 25-82-W(4-89)

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BSF-PUB-890143

August 23, 1989

J. A. Strittmatter, WCCS, Host
Computer Symposium
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Energy Center Site
Bay E-205, MS2-32
P.O. Box 355
Pittsburgh, PA 15230-0355

Dear Mr. Strittmatter:

Enclosed are the originals of the paper **"Integrated Intelligent Systems in Advanced Reactor Control Rooms (U)"** (WSRC-RP-89-474) by R. R. Beckmeyer.

The paper is proposed for presentation at the Westinghouse Computer Symposium, Pittsburgh, PA., November 6-7, 1989 and for publication in the proceedings.

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BCC: R. R. Beckmeyer, 773-42A
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SRL File (WSRC-RP-89-474)

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August 23, 1989

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SRL File (WSRC–RP–89–474)

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WSRC-RP-89-474

INTEGRATED INTELLIGENT SYSTEMS IN ADVANCED REACTOR CONTROL ROOMS (U)

by

R. R. Beckmeyer

Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

A paper proposed for presentation
1989 Westinghouse Computer Symposium
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November 6-7. 1989

and for publication in the Proceedings of the meeting

INTEGRATED INTELLIGENT SYSTEMS IN ADVANCED REACTOR CONTROL ROOMS (U) *

by

R. R. Beckmeyer

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Savannah River Site
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ABSTRACT

An intelligent, reactor control room, information system is designed to be an integral part of an advanced control room and will assist the reactor operator's decision making process by continuously monitoring the current plant state and providing recommended operator actions to improve that state. This intelligent system is an integral part of, as well as an extension to, the plant protection and control systems. This paper describes the interaction of several functional components (intelligent information data display, technical specifications monitoring, and dynamic procedures) of the overall system and the artificial intelligence laboratory environment assembled for testing the prototype.

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* The information contained in this article was developed during the course of work done under Contract No. DE-AC09-76SR00001 (now Contract No. DE-AC09-88SR18035) with the U.S. Department of Energy.

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INTEGRATED INTELLIGENT SYSTEMS IN ADVANCED REACTOR CONTROL ROOMS (U)

by

R. R. Beckmeyer

Westinghouse Savannah River Company
Savannah River Site
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WESTINGHOUSE COMPUTER SYMPOSIUM
HOWARD JOHNSON'S HOTEL
MONROEVILLE, PENNSYLVANIA
NOVEMBER 1989

INTRODUCTION

An important application of AI (Artificial Intelligence) technology is planned for the NPR (New Production Reactor) to reduce the potential for reactor operator error. Normal operational experience has proven the need to reduce human errors; the accident at Three Mile Island and the disaster at Chernobly have dramatically highlighted the need to reduce human error in abnormal situations. While adherence to design guidelines will ensure a safe physical plant, reduction of human error achieves an even higher level of safety.

The HWR-NPR (Heavy Water Reactor-NPR) to be constructed at SRS (Savannah River Site) will have completely digital I&C (Instrumentation and Control). The design provides for centralized instrumentation and data processing facilities for plant control and plant protection. Plant control includes overall control and monitoring of the nuclear reactor, the balance of plant processes, and response to abnormal conditions. Plant protection includes automatic and manual initiation of emergency systems for reactor shutdown, reactor cooling, and service systems essential to reactor safety. The intelligent information system, hereafter referred to as IRIS (Intelligent Reactor Information System), is an integral extension to these systems. IRIS is an intelligent, interactive, computer system that provides advisory information for reactor operations by managing a data base of current reactor status information, logically analyzing that data, and recommending actions to assure the safest and most efficient reactor operation. IRIS interfaces to the plant control system providing both passive (advice only) and active (advice and control) responses.

IRIS goes beyond contemporary control room development in the nuclear industry. Two points are significant with respect to this: (1) methods for intelligent systems have been tested in several forum but not as integrated (into the other aspect of control room design) systems, and (2) operation for nuclear materials production vs. commercial power production, along with the basis reactor design differences, make SRS operational aspects different from environments in which methodologies for intelligent advisory systems have been previously prototyped.

DISCUSSION

High Level Concept.

Today, reactor control is provided by the safety computers (plant protection); control computers (plant control); and control room data displays, paper procedures, and the highly trained operators' interpretation of the data and procedures. In various degrees, these controls incorporate data analysis, first principles, correlations, experiential knowledge, engineering knowledge, etc. Artificial Intelligence technology allows the automated application and integration of many of these controls at a higher level than has been possible in the past (see Figures 1). AI technology has provided hardware and software that make practical the automated application of experiential logic and complex relations about relations.

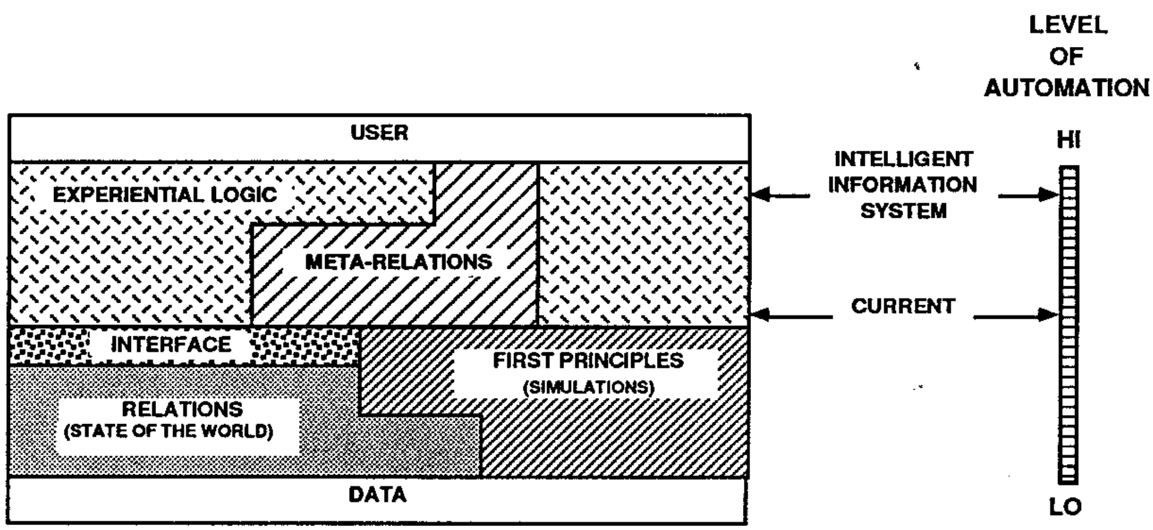

Figure 1. High Level Concept

Components.

In the following sections three components of IRIS will be discussed:

- Compliance Monitor,
- Intelligent Data Display, and
- Dynamic Procedures.

In addition, the aspects of component integration and the man-machine interface will be discussed briefly.

Compliance Monitor. The technical specifications monitoring subsystem will compare technical specifications to the status of the reactor and warn of actual or anticipated noncompliance. Today (see Figure 2) those specifications define the general "envelope of safety" with the most time-critical specifications being implemented through a set of operational limits which are implemented in an automated absolute/hardwired manner. For example the safety computer looks at the temperature readings from 2400 thermocouples that measure the effluent temperature of the 600 assembles and if any assembly exceeds a redefined limit the reactor is scramed. At the other end of the spectrum, less time-critical technical specifications are implement through a set of paper procedures that the operator handles; for example, surveillance and testing of the emergency diesels.

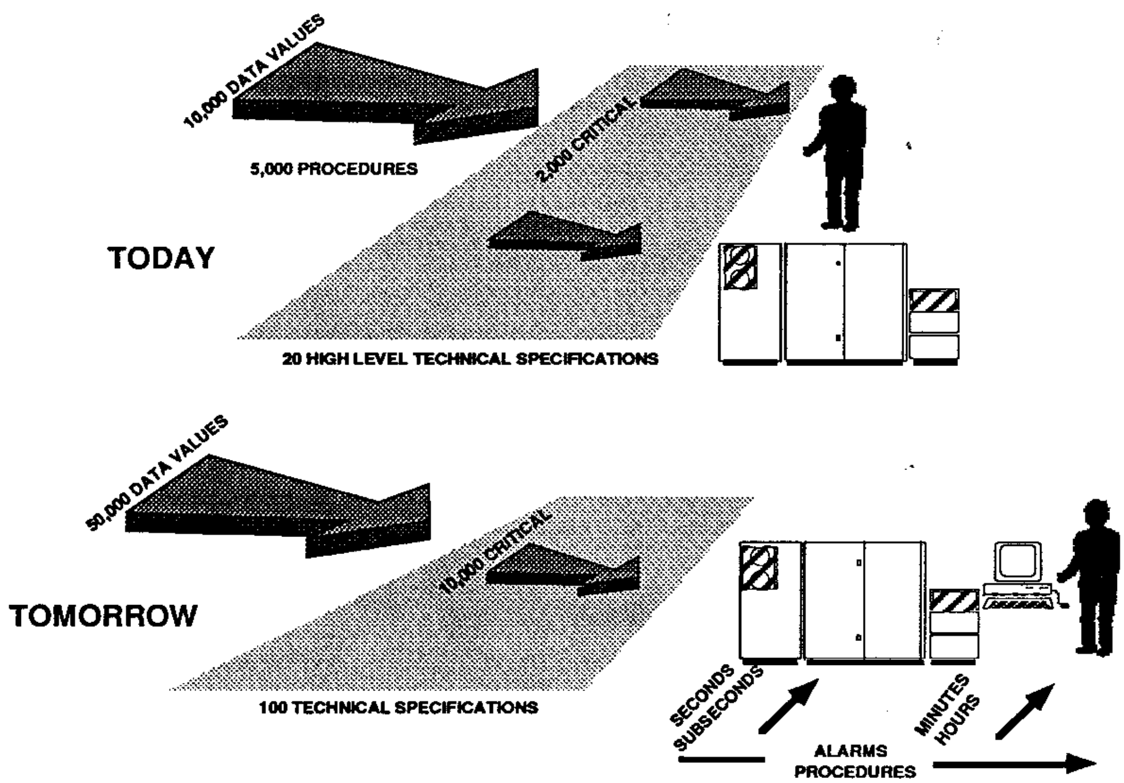

Figure 2. Compliance Monitoring; Today, Tomorrow

The HWR-NPR will have many more sensors; the technical specifications will be more specific (i.e. written in terms of directly observable data); as such, the compliance with technical specifications can be almost fully automated. The compliance monitor will track the operability status of all equipment and systems covered by the plant technical specifications and other operational constraints that could affect the safety, startup, operation, and shutdown of the plant (see Figure 3). Pending actions

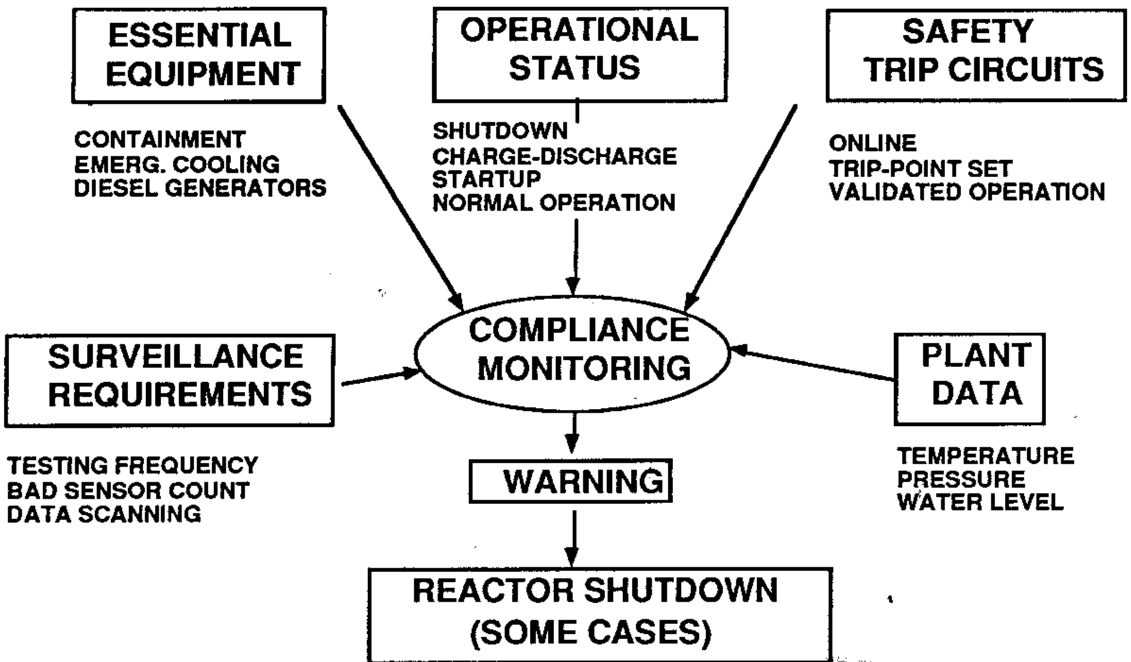

Figure 3. Compliance Monitoring

will be evaluated for compliance. Time-critical technical specifications will continue to be implemented in an automated absolute/hardwired manner with a dedicated plant protection computer. Less time-critical technical specifications will be monitored by the control computer and other distributed computers. Yet to be addressed are several critical issue:

- To what extent is the Compliance Monitor active (versus passive)? Does the the Monitor point to required actions as spelled out in the technical specifications? Does the Monitor go a step further and point to specific response procedures? How extensive is the diagnosis reasoning?
- How do the above issues impact the "comparable licensing requirements" for the NPR.

Intelligent Data Displays. The reactor information data display subsystem will provide a wealth of current and time-dependent information about the status of the reactor. The information system will provide a capability to monitor, interpret and predict reactor behavior. Current data will be displayed on a "soft" schematic of the reactor. Detailed component and subcomponent information will be available by "windowing in" on the objects in the mimics. Data for trend analysis will be available by menu selection.

Dynamic Procedures. A software tool that provides a high level, hypertext-like, interface for both creation and execution of reactor operating procedures will be available to the reactor operators. The system consists of two parts: a generic interface for functional level creation of text, and an object-oriented database. The system permits a procedure writer to develop procedural clauses to cover any reactor control situation. The clauses are constructed using a series of options that include objects, actions, and conditions. From the writers' clauses two things are developed: a textual description of the procedure and a code fragment. Clauses can be collected to form procedures, and clausal procedures can be combined to form higher level procedures. The simultaneous generation of code and text allows the writer to test his procedural clause at the time of writing and make any modifications necessary to insure proper performance of that fragment and clause. In addition, the automated generation of code from textual procedures permits the automated generation of a procedure monitoring system that tracks the reactor operators' activities in relationship to the dynamic status of the reactor thus providing intelligent operational advice in the form of dynamic procedures. As with the Compliance Monitor several similar critical issues are yet fully determined:

- To what extent is the Procedure Monitor active (versus passive)? Does the the Monitor audit the operator actions as spelled out in the procedure? Does the Monitor go a step further and execute the steps (with operator concurrence)?
- How do the above issues impact the "comparable licensing requirements" for the NPR.

Component Integration. The basic philosophy behind the IRIS design is that the system support both normal operations as well as abnormal conditions. While the components are similar to other developed and installed applications, IRIS is distinguished by the extent of its integration with established methods of control and monitoring.

Man-Machine Interface. In the current production reactors the reactor systems components are grouped by systems. For example, instrument readouts and controls associated with the process water and cooling water systems are grouped separately. If the operator wants to investigate a heat sink problem he maps (in his mind) the problem onto the components related to the two systems. A contrasting approach is for the operator interface to be function-based and the operator then works from the heat sink functional panel and maps the function to the components. In the HWR-NPR a compromise approach is being considered.

For normal operations for which detailed procedures are written and for which the operators have been specifically trained the systems approach is preferred. However, there is merit in the functional approach as it simplifies operator tasks in complex scenarios. The current thoughts are that the supervisor's console will be functionally oriented with systems grouped by critical safety functions while the main operators console will be system orientated.

Prototypic Facilities. IRIS consists of five major conceptual components (see Figure 4). The first is a data communications component that links to the control and protection computers and/or signal and control lines that relay to the control room cabinets. IRIS will access information about current reactor status and will initiate some closed-loop actions via this link. A second component is the storage disks which house the data and knowledge bases for IRIS. The data base represents the reactor status data and reactor description data. The knowledge base consists of rules, logic, and textual information that represent an engineering knowledge of the reactor operation. The third major hardware component is a digital computer for use with numerical models of the reactor. The models will range from fairly basic to complex. This computational machine will need a CPU speed comparable to todays mainframes. The fourth major component is the computer that houses the inference engine. The inference engine manipulates the knowledge bases, input data, and computed data to arrive at specific solutions and recommendations. The final component is the user interface.

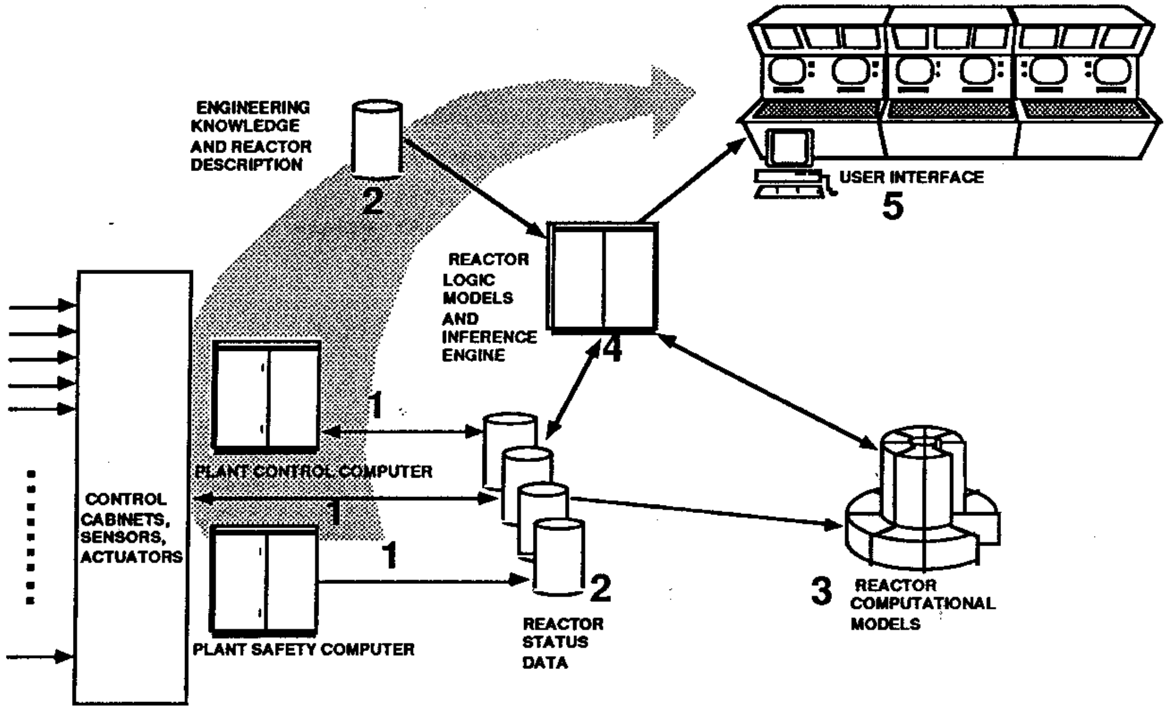

Figure 4. Components of Concept

The overall I&C architecture to be install in the actual plant is expected to be a distributed computer system with separate, and redundant, busses for data, controls, and power. For example, Westinghouse and Combustion Engineering both have such systems for their light water reactor designs; these systems should serve as a starting point in design considerations for the HWR-NPR. Special consideration is being given to the intelligent data system. Consideration is also being given to the increased data and processing requirements.

The laboratory that has been configured for testing the various concepts and components described in the above paragraphs includes: Real Time Modeling Computer (Gould / SEL 3785), training simulator software load, Flavors link to Symbolics Network, Network of Symbolics Machines, MacIvory Machines, Symbolics software tools, file servers, etc. (see Figure 5).

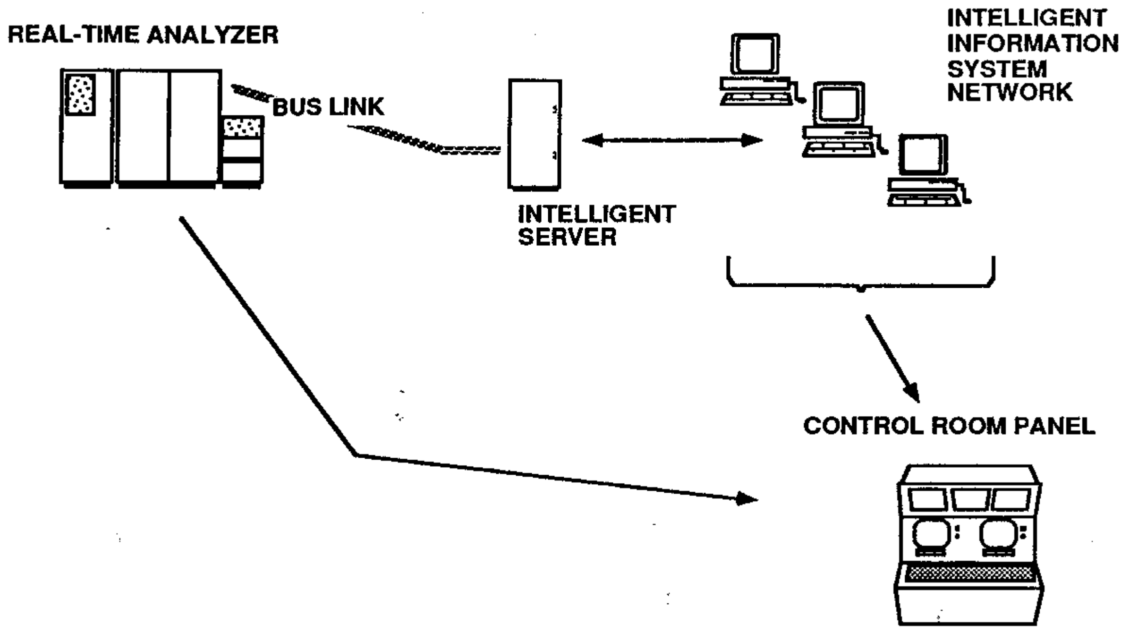

Figure 5. Prototype Test Facilities

SUMMARY

An important application of artificial intelligence technology is planned for the new production reactor to reduce the potential for operator error. This is know to be important from the accident at Three Mile Island and the disaster at Chernobly. While adherence to design guidelines will ensure a safe physical plant, reduction of human error achieves an even higher level of safety.

An intelligent, reactor control room, information system is being designed to support the operators' decision making process by continuously monitoring the current plant state and providing recommended operator actions to improve that state. This intelligent system is an extension to the reactor control and safety computers. This interactive, computer system provides information and operational advice by managing a data base of reactor status information, logically analyzing that data, and recommending actions to assure safe, efficient, and improved reactor operation.

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