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ANS MAIN CONTROL COMPLEX THREE-DIMENSIONAL COMPUTER MODEL DEVELOPMENT

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ABSTRACT

A three-dimensional (3-D) computer model of the Advanced Neutron Source (ANS) main control complex is being developed. The main control complex includes the main control room, the technical support center, the materials irradiation control room, computer equipment rooms, communications equipment rooms, cable-spreading rooms, and some support offices and breakroom facilities. The model will be used to provide facility designers and operations personnel with capabilities for fit-up/interference analysis, visual "walk-throughs" for optimizing maintainability, and human factors and operability analyses. It will be used to determine performance design characteristics, to generate construction drawings, and to integrate control room layout, equipment mounting, grounding equipment, electrical cabling, and utility services into ANS building designs.

This paper describes the development of the initial phase of the 3-D computer model for the ANS main control complex and plans for its development and use.

INTRODUCTION

The Advanced Neutron Source (ANS) is a new experimental facility planned to meet the national need for an intense, steady-state source of neutrons. The facility will provide neutron beams for measurements and experiments in the fields of materials science and engineering, biology, chemistry, materials analysis, and nuclear science.

The facility will be built around a new 330-MW steady-state research reactor that is heavy-water-cooled, moderated, and reflected. The reactor will include cooling systems with many passive safety features that make it similar in concept to the advanced light-water reactors (ALWRs) currently being designed for commercial power generation. This reactor will provide a source of unprecedented flux that will have the most intense beams of steady-state neutrons in the world—five to ten times more intense than those at the current world leader at the Institut Laue-Langevin in Grenoble, France. Combining the higher source flux with improved experimental facilities will create a neutron flux more than ten times higher than that now available in the United States for most scattering experiments. There will be three times more scattering instruments than at either of the present high flux reactors; consequently, the scientific output should be about 30 times greater than that at the High Flux Isotope Reactor (HFIR) at Oak Ridge, Tennessee, or the High Flux Beam Reactor (HFBR) at Brookhaven, New York. The potential also exists for developing entirely new lines of scientific research based on the advanced capabilities that will be available in the ANS facilities.

Further, ANS will provide facilities for materials irradiation testing and irradiation capabilities for the production of radioisotopes for medical applications, research, and industry. These irradiation facilities will match or exceed the capabilities of HFIR, which has been operated at the Oak Ridge National Laboratory (ORNL) since 1965.

In addition to meeting U.S. Department of Energy (DOE) programmatic needs, the ANS will be a national facility with an open-user policy attractive to scientists from universities, other national laboratories, and industry. It is anticipated that these facilities will be used by 700–1000 individuals annually for neutron-scattering experiments in solid-state physics, chemistry, metallurgy, ceramics research, polymer research, colloid research, biology, and nuclear physics. In addition, a wide community of isotope and materials irradiation users will be supported both on-site and throughout the world.

A detailed description of ANS is given in the Conceptual Design Report Summary.[1]

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MAIN CONTROL COMPLEX FUNCTION AND MODEL USAGE

The main control complex to be modelled provides supervisory control for all facility (reactor and balance-of-plant) operations and materials irradiation operations. It includes the main control room, the technical support center, the materials irradiation control room, computer rooms, input/output and communications equipment rooms, cable-spreading rooms, and some support offices and breakroom facilities. Plan and elevation views showing the ANS facility and the main control complex are shown in Figures 1 and 2.

ANS instrumentation and control functions will be performed by three control computer systems which are interconnected to meet operational and safety requirements. A Class 1E qualified reactor protection system (RPS) provides primarily reactor shutdown functions, a Class 1E qualified plant control and data acquisition system (1EPCDAS) provides primarily engineered safety feature actuation, and a plant control and data acquisition system (PCDAS) provides non-safety-related controls and display functions for all systems. The RPS and 1EPCDAS will be connected to the PCDAS with qualified isolation devices to allow the PCDAS to provide as much of the normal operation man-machine interface as possible in a highly integrated display format. The RPS includes a primary reactor shutdown system (PRSS) that scrams three control rods inside the core by releasing a magnetic latch and a secondary reactor shutdown system (SRSS) that releases eight control rods located immediately outside the core via a hydraulic system. The PRSS, SRSS, and 1EPCDAS each have four channels for instrumentation, and the PCDAS is a two-channel fault-tolerant system. Five computer rooms meeting appropriate separation criteria will be provided adjacent to the main control room—four for the RPS and 1EPCDAS safety-related systems and one for the non-safety-related PCDAS systems.

The model is expected to be a key tool for numerous applications that require visualization of the actual arrangement of equipment. It will provide a visual "walk-through" capability, with views similar to that shown in Figure 3 for the ABB Combustion Engineering Nuclear Power NUPLEX 80+™ design. Some applications are as follows:

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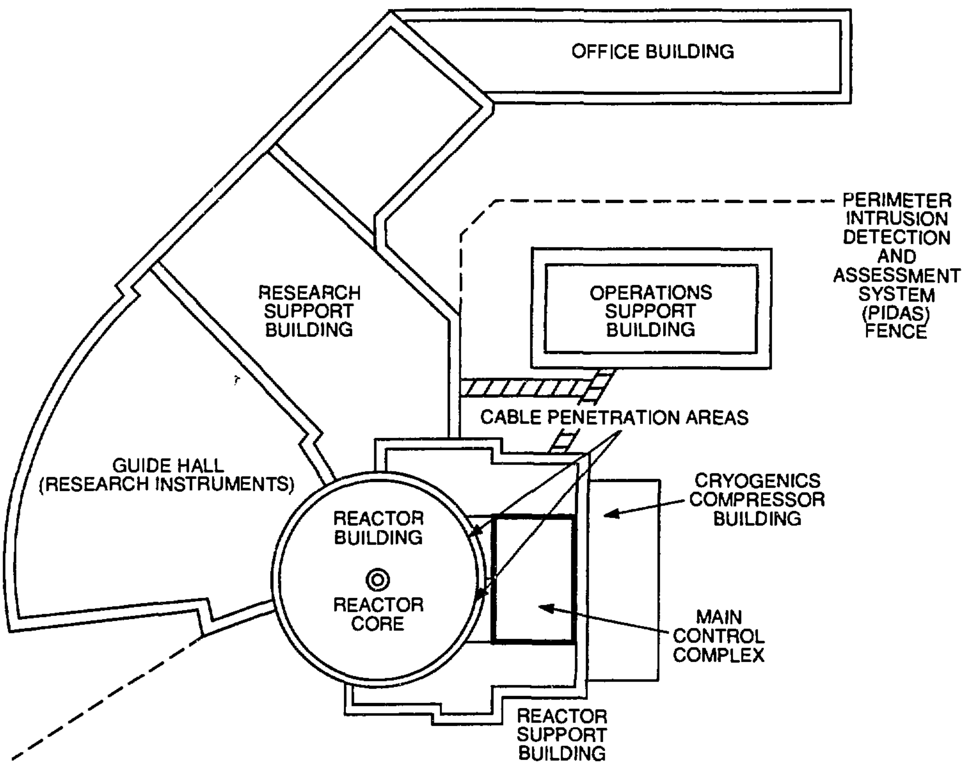

Figure 1—ANS Facility Plan View.

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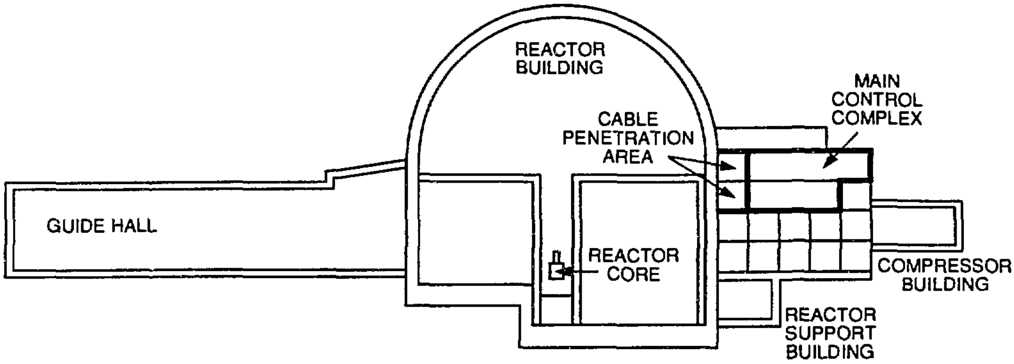

Figure 2—Section Through Main Control Complex.

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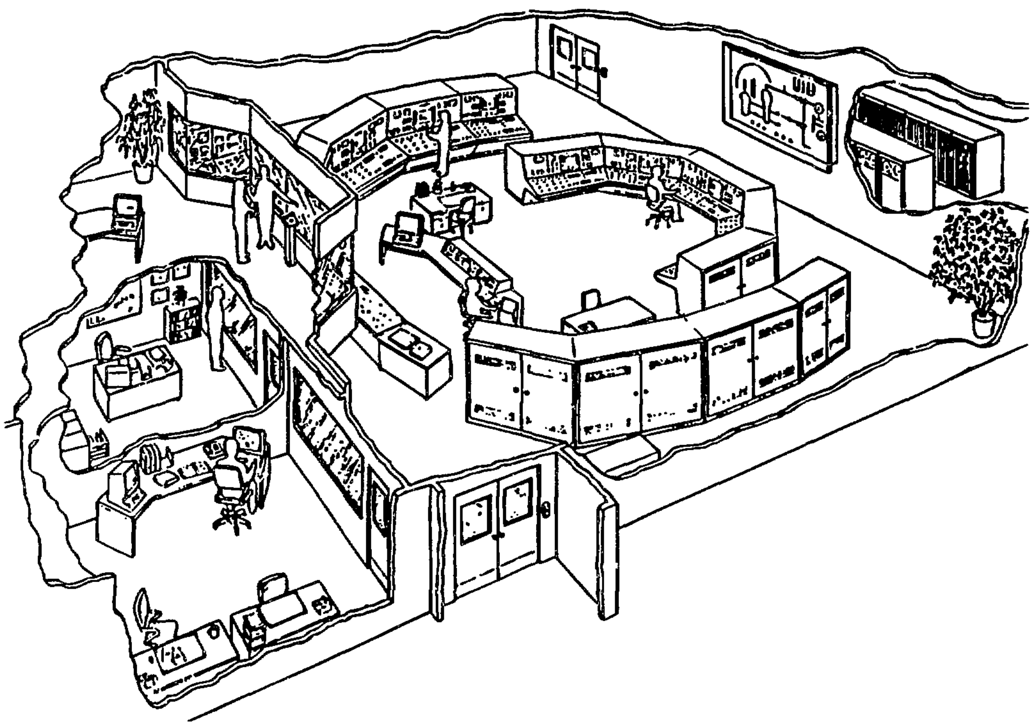

Figure 3—Main Control Complex for ABB Combustion Engineering Nuclear Power NUPLEX 80+ Design. (Figure from "NUPLEX 80+™: The CE Advanced Control Complex," *TIS-8483.* Used by permission of ABB Combustion Engineering Nuclear Power.)

- involving operation personnel in main control room design and obtaining buy-in early in the design phase;
- support for ANS Human Factors Program activities to develop an operating philosophy,[2] task descriptions, and operating procedures;
- performing the human factors design analysis required by chapter 18 of the Nuclear Regulatory Commission (NRC) Regulatory Guide (RG) 1.70, *Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants—LWR Edition*;
- communicating requirements to plant control and data acquisition systems, reactor protection systems, and other control system equipment suppliers;
- communicating requirements and design criteria to facility architect/engineers (A/Es) and reactor manufacturers (RMs);
- training plant construction, operations, and maintenance personnel;
- confirming proper fit of the complex into the facility buildings and confirming compliance with DOE orders and NRC regulations on separation of cabling and equipment;
- properly integrating control room layout, equipment mounting, grounding equipment, electrical cabling, heating and air conditioning, lighting, and other utility services into ANS building designs;
- generating construction drawings electronically by transferring data directly from the model to two-dimensional drawings used in the field for construction;
- providing an effective review mechanism for the main control room and technical support center for use in interacting with licensing agents;
- maintaining control of control room arrangement changes and control room construction drawing revisions by placing the model under configuration control and forcing construction drawing changes to be generated from the model;
- display of control room technology and capabilities to ANS users and outside agencies needing to incorporate advanced human engineering techniques and highly integrated displays.

BACKGROUND

Martin Marietta Energy Systems, Inc. (MMES), has extensive experience in 3-D computer modelling and has established a Center for Applied Engineering Visualization at its Oak Ridge facilities. This technique has already been used to successfully model control room type facilities. Until recently, however, most modelling was performed using the Interactive Graphics Robotics Program (IGRIP) software package, which was developed primarily for mechanical equipment. MMES recently decided to convert the computer-aided design (CAD) system it uses for designing facilities to an Intergraph-based system to provide a better interface with systems used by A/E firms. Since most A/E firms with nuclear facility experience use Intergraph, it is expected that the ANS facility design will be performed on an Intergraph-based CAD system. In order to provide the most efficient method of generating construction drawings directly from the model, it was decided to train appropriate Engineering personnel to use the Intergraph 3-D modelling functions and develop the ANS model with Intergraph rather than with IGRIP.

It should be noted that IGRIP has more human factors analysis capabilities than Intergraph. However, Intergraph models can be translated and used by IGRIP if IGRIP's additional capabilities (such as using human figures to check reachability) are needed.

Design and construction of the ANS facility will be performed by a team that includes an A/E, an RM, and a construction manager with nuclear construction experience. MMES will advance the recently completed conceptual design in appropriate areas, transfer design tasks to the A/E and RM, and provide technical oversight throughout project design, construction, and start-up. MMES will operate the facility once it is completed.

The initial model for the main control complex will be developed as part of the work performed to advance the facility's conceptual design. The model will then be transferred to the A/E for further development and for use in the design and construction of the facility. Requirements for development and use of the model are being included in functional specifications for the ANS instrumentation and control computer systems that will occupy the computer rooms and provide operator controls and displays in the main control room and several local control rooms. Similar modelling for the plant simulator and other control rooms will also be required.

APPROACH

The initial phase in the development of the model will consist of preparing a list of requirements for the area, usage, and arrangement of control complex facilities and developing a civil and architectural model of all the main control complex rooms, including a depiction of control consoles and the large graphic display in the main control room; furniture, display equipment, etc., in the technical support center; and proposed equipment in the control complex computer rooms. Further modelling activities will be integrated into the program for human factors and facility design tasks.

The civil and architectural model of the control complex spaces and rooms will be developed using the Intergraph Project Architect software so that this model can easily be integrated into future models of the reactor support building that will house the control complex. This will ensure proper room dimensioning and proper interface with the power, grounding, heating, ventilation, and air conditioning, and lighting utilities provided for the building.

Models of control consoles, large graphic display screens, and computer equipment will then be generated and located in appropriate rooms. The number and arrangement of control consoles and cathode ray tube (CRT) displays will be based on the conceptual design drawings and operational philosophy that resulted from extensive consultation with operators at HFIR. Equipment sizes are based on those presently supplied by industry and being considered for use in ALWR designs.

After rooms, doors, viewing windows, passageways, and equipment have been placed in generally acceptable locations, lighting equipment and heating and ventilation duct inlet and outlets will be added. At this point, the Intergraph Model View software will be used for a number of purposes:

- to display lighting on consoles and displays;
- to display viewing capabilities from the technical support center, the supervisor consoles, the shift supervisor's office, and other strategic locations;
- to evaluate clearances provided for equipment maintenance; and
- to provide the initial "look and feel" of the rooms modelled.

The model will then be reviewed with personnel with extensive experience in operations and maintenance of research reactors for further refinement. If time and funding permit, the conduit and raceway layout in the cable-spreading room will be added to ensure that sufficient space is available in these rooms, to determine the minimum acceptable room size, and to define interface requirements for raceway systems carrying cabling from the main control complex to equipment throughout the facility. If this task is not possible during this modelling phase, it will be performed by the A/E during further facility design.

At this point, the model will reflect the best knowledge available from the facility conceptual design. Further modelling will be dependent on information as to what operations will be performed by each operator in the main control room and irradiation control room and the actual control computer equipment to be used. Detailed decisions on operating philosophy—such as local versus remote control of equipment, automatic versus manual operation, and the role of supervisory control—will also affect the model. After the operation and maintenance personnel responsible for determining operational requirements have been selected, an operating philosophy will be determined primarily through their participation in the project's Human Factors Program. The development of software requirements for the instrumentation and control computers and the main control room human factors analysis required to support chapter 18 of the safety analysis report will also contribute to this effort. The model will be an extremely effective visual aid in developing and testing operating philosophy alternatives, performing human factors analyses, confirming equipment maintainability, and developing software requirements. Equally important, it will serve as documentation that can be used to generate construction drawings and will be readily accessible to all project participants for viewing. The extensive IGRIP capabilities for human factors analysis will be used as needed.

Configuration control measures to be developed for the model will allow sufficient flexibility for support of ad hoc analyses and design tasks. Formal controls will be used for models that are used to generate construction drawings, support safety analyses, or other similar tasks.

HARDWARE AND SOFTWARE

The model will initially be developed on an Intergraph Interpro 2430 workstation with a UNIX operating system and a 1-Gbyte PEM box. If needed as the model becomes more complex, an Interpro 6480 workstation will be used. Application software will include the following Intergraph products:

- Microstation for basic drafting capability,
- Project Architect and Project Layout for model building,
- Model View for shading and other display techniques,
- I Plot for plotting, and
- PE HVAC, PE PIPE, PE ELECT, and PE LIGHT for developing air conditioning, cabling, lighting, sprinkler piping, and other engineering details.

Information and data needed to drive the model will be stored in a data base constructed with Informix data base management software. For consistency with other data bases used in the ANS project, this data base will be migrated to the Foxpro data base management product as soon as Foxpro is compatible with UNIX operating systems. The Intergraph application software and Network File Service (NFS) resides on a server. The server, workstation, and plotter are connected to an Ethernet local area network (LAN) running TCP/IP.

REFERENCES

1. "Conceptual Design Report Summary," *ORNL/TM-12184*, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory (1992).

2. M. M. HOUSER, "Advanced Neutron Source Operating Philosophy," Conference Paper, Topical Meeting on Nuclear Plant Instrumentation, Control, and Man-Machine Interface Technologies, Knoxville, Tenn., April 18–21, 1993.