Integrated Video Monitoring System for Spallation Neutron Source Target Hot Cell Remote Handling

Gary A. Armstrong
Maverick Systems, Inc.
165 Woods Lane
Kingston, TN 37763
gaa@mavsysinc.us

Thomas W. Burgess
Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831-6304
burgesstw@ornl.gov

Mark J. Rennich
Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831-6474
rennichmj@ornl.gov

Abstract – *A remote viewing system was needed for performing remote handling tasks at the Spallation Neutron Source (SNS) facility at the Department of Energy's site in Oak Ridge, Tennessee, USA. The hot cell viewing system would be required to withstand ionizing radiation levels up to 10^6 rads/h while changing out the source target, with a lifetime total absorbed dose requirement of 10^8 rads (1.4 MeV gamma). The remote viewing system was designed to be integrated with remote handling systems such as the hot cell overhead crane and bridge-deployed servomanipulator system. The system was designed for operation from a centrally located control room as well as from shielded window workstations located along the hot cell wall. In addition to remote viewing, the system provides audio capabilities, including communication between operator control stations and in-cell audio feedback. This paper summarizes the overall design of the SNS remote viewing system.*

I. INTRODUCTION

The Spallation Neutron Source facility currently under construction at the Department of Energy (DOE) site near Oak Ridge, Tennessee, USA, incorporates a large hot cell designed to enclose the flowing mercury neutron-generating target system. High radiation and complex in-cell operations demand tooling flexibility and comprehensive viewing. Consequently, the cell system incorporates the latest bridge-mounted servomanipulator technology with proven shield window workstations to take advantage of the best characteristics of both systems to cover the large cell volume and the wide variety of tasks. Operator viewing for these systems is achieved with an integrated video monitoring system based on distributed and mobile video cameras, audio monitoring and efficient operator communication.

To meet the operating needs of the facility, the video monitoring system design included two independent subsystems:

- *Hot cell monitoring system:* Remote viewing and remote listening systems will be used to support remote handling operations inside the SNS hot cell. Remote viewing systems will be mounted on the servomanipulator, the overhead bridge, and the walls inside the cell. The hot cell monitoring system will be monitored and controlled from the maintenance control room and the operations gallery.
- *Portable monitoring system:* Portable cameras will be used to reduce personnel exposure, especially during high bay operations involving

the target vessel components. The cameras will be mounted on a remotely operated portable manipulator system and/or temporary pedestals or tripods. The local viewing systems will be manually positioned or remotely deployed with a boom-deployed servomanipulator. The portable monitoring system will be deployed outside the target hot cell.

The general layout of the SNS hot cell is shown in Fig. 1. Figure 2 shows the approximate dimensions of the building that houses the hot cell.

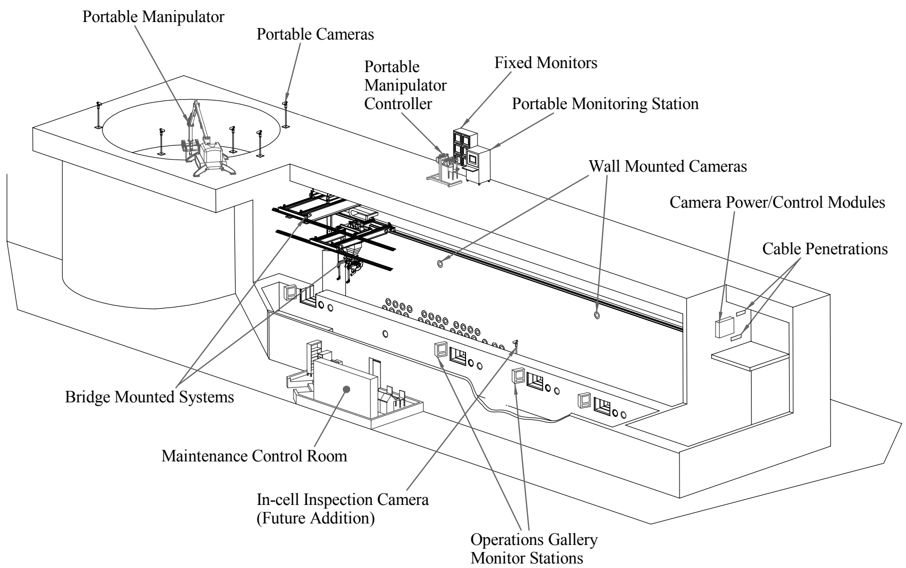

Fig. 1. General arrangement of hot cell video monitoring system in SNS Target Facility.

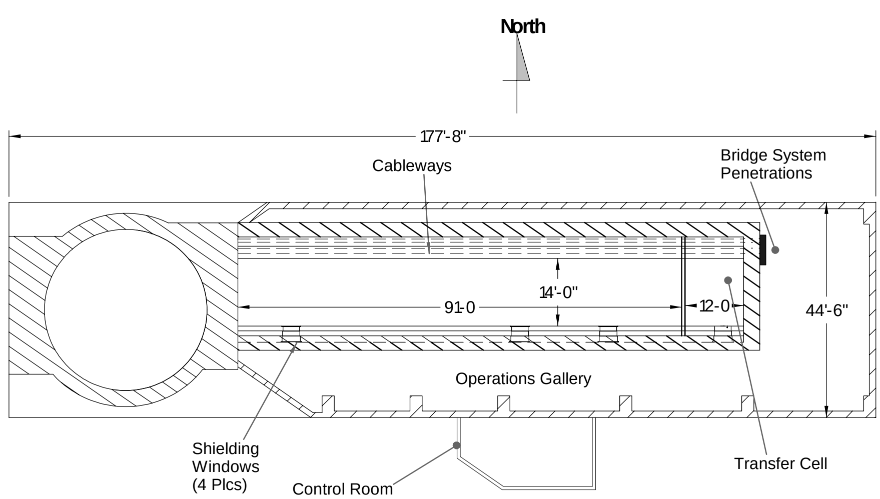

Fig. 2. Dimensional layout of Target Facility hot cell.

The hot cell monitoring system will be used primarily for tasks that preclude the presence of personnel in the hot cell. Such tasks would be conducted by remote handling operators from multiple control stations within the facility. Remote handling control stations with integrated remote viewing and through-the-wall manipulators are located at each of the four viewing windows along the hot cell wall in the operations gallery. Operation of in-cell remote handling systems will be performed from the maintenance control room.

The portable monitoring system is designed for use outside the hot cell only. The portable monitoring system will provide remote viewing while controlling the Target Facility portable manipulator system (Fig. 1). These remote viewing heads were designed for deployment on the portable manipulator system or on independent tripods that can be manually positioned.

II. DESIGN REQUIREMENTS

Four primary design requirements governed the design of the two systems:

1. The systems would have to be designed to cover a large area.
2. The system would have to deal with large dynamic ranges in lighting.
3. The system would have to survive high ambient temperature ranges.
4. Ionizing radiation levels would be difficult to predict over the life of the system.

The system design provides for cost effective coverage of the large hot cell. The hot cell is 103 ft long, 14 ft wide, and 30 ft high, and is illustrated in Figures 2 and 3. To provide general viewing coverage of the hot cell, four wall-mounted cameras can be installed in multiple locations along the north and south wall of the hot cell. The wall-mounted cameras can be relocated remotely in the hot cell by the in-cell servomanipulator.

Two of the three remote viewing heads on the servomanipulator are placed over each manipulator arm. Each remote viewing head is mounted to planar positioning arms with two degrees of freedom. The third camera is mounted to the underside of the manipulator, providing a central view from below. A fourth camera connector is included on the servomanipulator for the future addition of an arm-held inspection camera.

Remote viewing head placement is illustrated in Fig. 3. Lighting in the hot cell ranges from 20 to 350 ft-c. This is initially provided by twenty 400-W sodium lamps mounted to the hot cell walls, eight 500-W halogen lamps mounted on the two overhead bridge systems, and six 75-W halogen lamps mounted to the three servomanipulator cameras. Hot cell lighting can be increased later by adding lights to spare wall light mounting brackets, and by the use of portable lights powered via electrical outlets at the window workstations. The typical stainless steel surface encountered in the hot cell has a reflectance of 65%. The curved nature of industrial equipment (e.g., pipes and cylindrical storage containers) produces specular surfaces that will saturate most cameras even with modest lighting.

The upper light level of 350 ft-c is higher than typical lighting for a comparable structure such as a warehouse but may be somewhat low for radiation-hardened cameras with zoom lenses. As a result, camera placement for remote handling operations may prove to be a challenge. Caution must be exercised when increasing lighting further due to concerns of the resulting high temperatures and heat loads in the cell (not to mention the upper temperature limit of 125˚F on the cameras). As there are no controls on the sodium lighting for position, orientation, or intensity (other than on/off at the switches), lighting issues will need to be addressed with camera placement and lens control (remote iris and automatic gain control). (High pressure sodium lighting does not permit the use of variable energy supplies as does an incandescent light, but a mechanical baffle can be added to allow for varying the output intensity.)

High temperatures, which tend to reduce contrast in the image, will be more of a concern for the cameras located on the bridges in the upper regions of the hot cell. Currently, administrative controls will be used to address temperature issues. Lights as well as cameras can be turned off when not in use.

Gamma radiation levels are anticipated to range from 10^2 rads/h to 10^6 rads/h, with a lifetime total absorbed dose requirement of 10^8 rads. The anticipated energy level is approximated to be 1.4 MeV, with an ambient temperature of 90°F. The anticipated minimal background dose rate is 250 rads/h. However, the dose rate with the shield removed from the mercury process loop can be as high as 5×10^4 rads/h. The remote handling system will be required to inspect the mercury process loop with its shielding removed.

In addition, changeout of the target by the remote handling system is anticipated to expose the system to dose rates as high as 10^6 rads/h. As it will be hard to anticipate all scenarios experienced in the hot cell over the 40-year design life of the facility, the design placed heavy emphasis on a commercial supplier

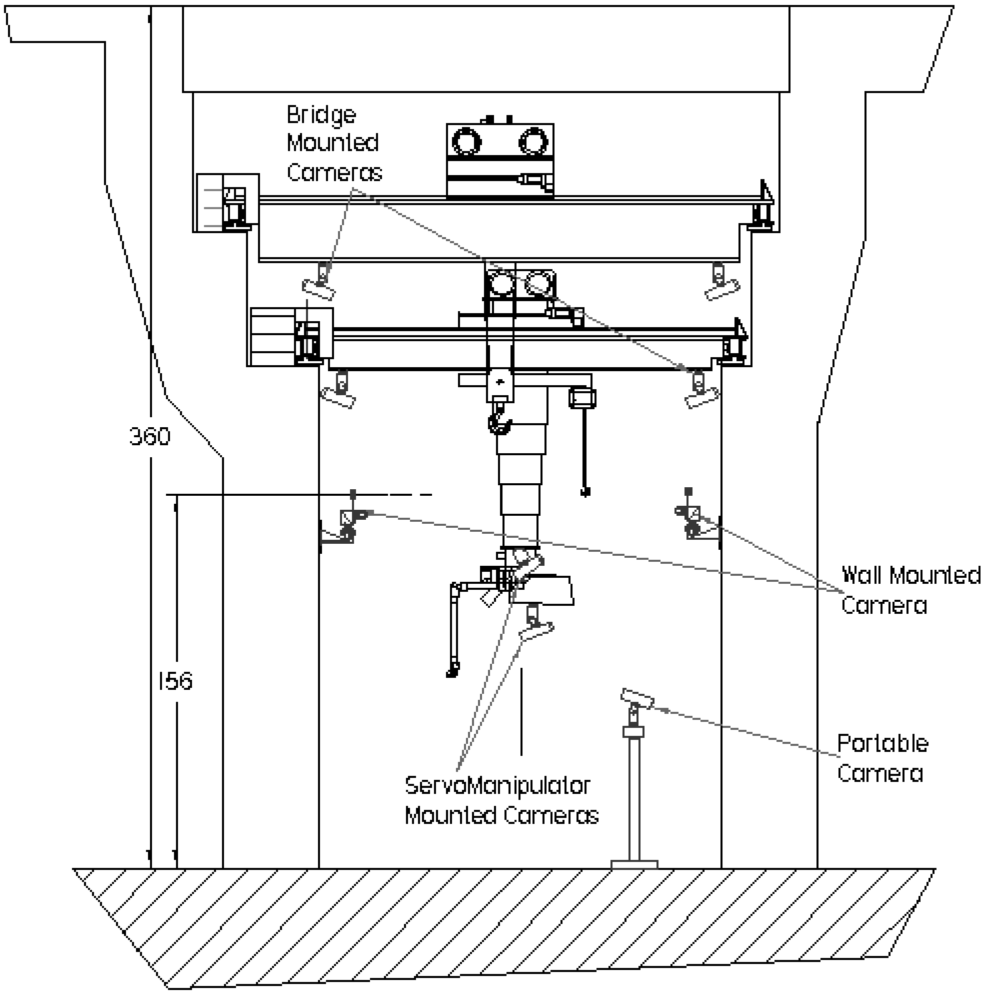

Fig. 3. Approximate locations of bridge and servomanipulator mounted cameras

with a good history of experience, as well as certified testing of remote viewing equipment in ionizing radiation environments.

During remote handling operations the most powerful tool is the human operator. Visual images from the video systems allow the operator to quickly determine the needed reaction during typical remote handling operations. Sound is another input that is quickly interpreted by the human operator. Microphones and lights are also distributed throughout the system to aid in remote operations. Table I lists the remote viewing head locations as well as resources at each location.

The control room comprises 21 video displays and a video matrix which can direct the video from any of the 19 video lines to the desired display. In addition, a control station is provided at each of the four hot cell viewing windows. The video matrix will provide control from either of six control pendants. The two control pendants in the control room allow the bridge operator and the servomanipulator operator to each have control of the video matrix. A block diagram for the video control system is shown in Fig. 4. The physical layout of the control room is illustrated in Fig. 5.

The portable monitoring system will be used to minimize operator exposure to low-level radiation tasks that arise in the facility. The system is designed to be easily set up and operated remotely. A block diagram for the portable monitoring system is provided in Fig. 6.

Table I. Hot cell camera systems at start of SNS operations

Camera system	No.	Pan & tilt	Zoom (optical)	Zoom range	Macro focus	Lights	No. with microphones	Use (h/year)
Wall-mounted	4	X	6:1	12–72 mm	X		2	2000
Bridge-mounted	4	X	6:1	12–72 mm	X		1	800
Servomanipulator-mounted (upper)	2	X	6:1	12–72 mm	X	X	0	800
Servomanipulator-mounted (lower)	1	X	3:1	8–24 mm	X	X	1	800
Inspection (future)	0	X	3:1	8–24 mm	X		0	800

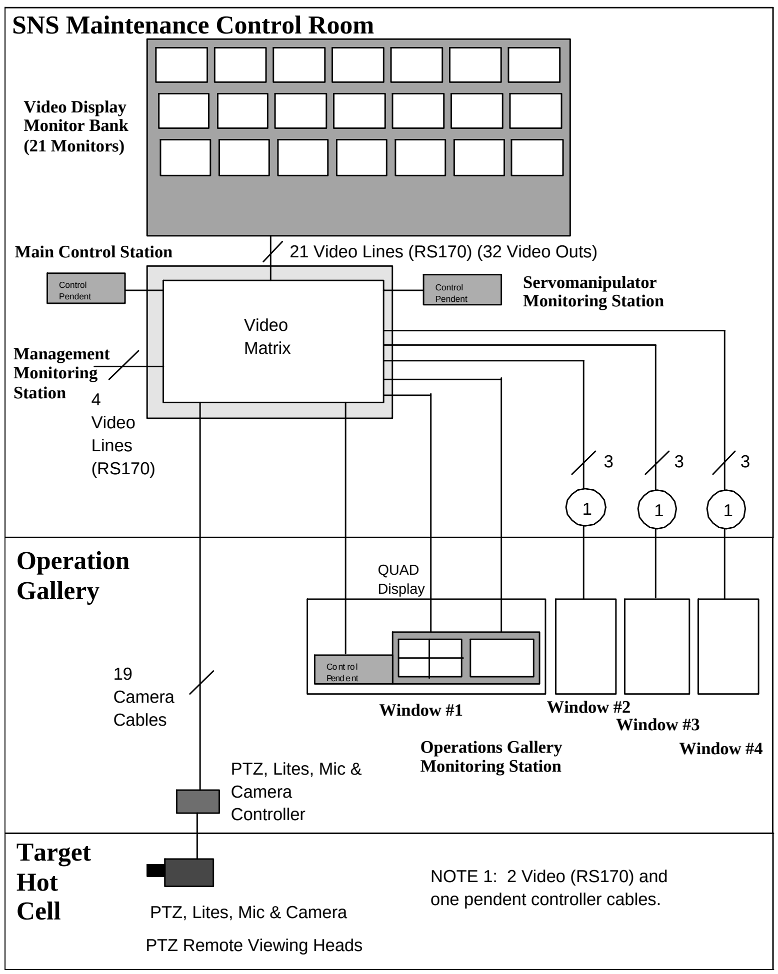

Fig. 4. Hot cell monitoring system control architecture.

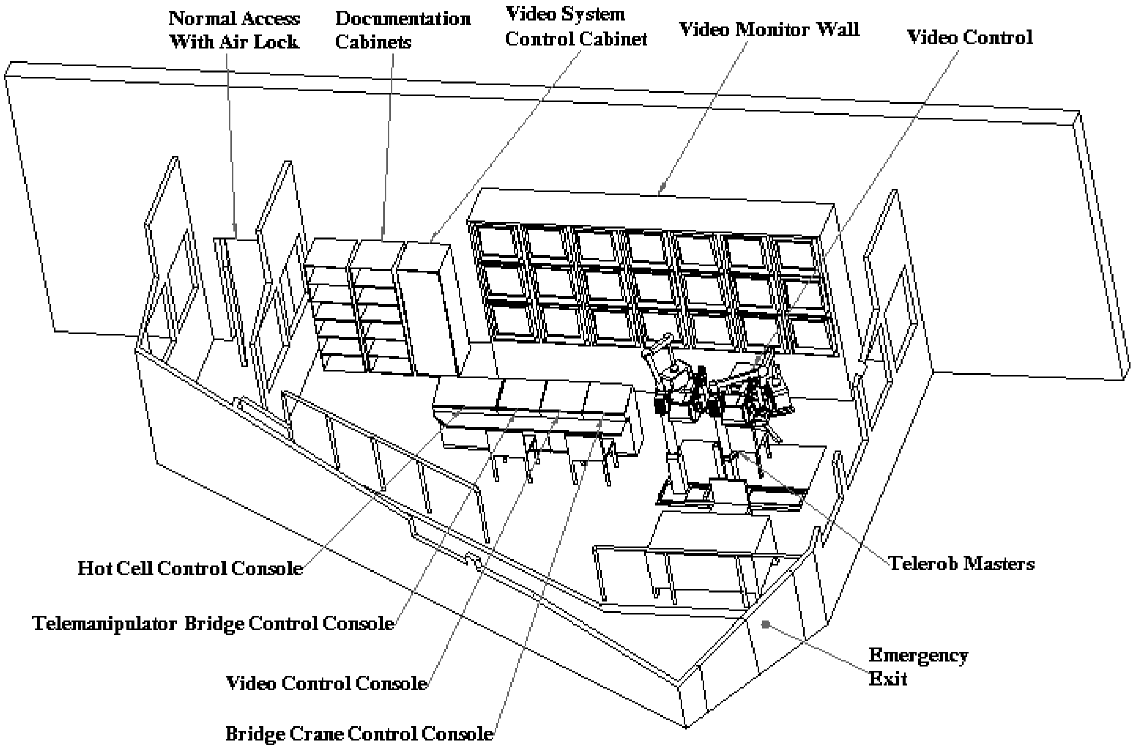

Fig. 5. Maintenance control room layout.

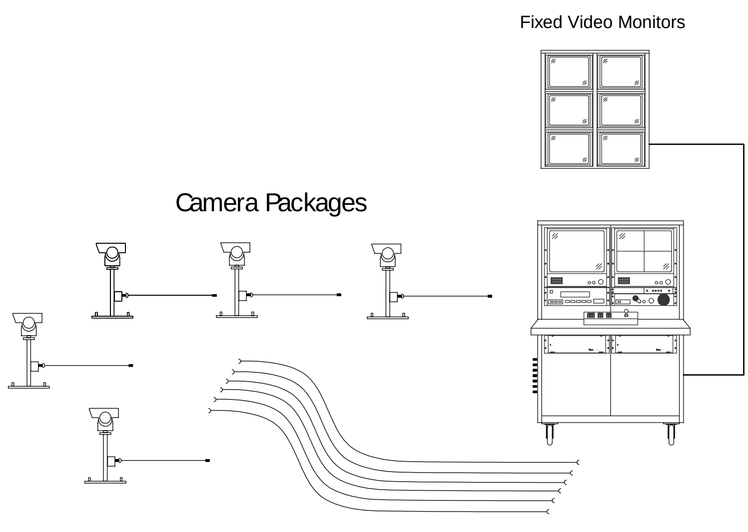

Fig. 6. Portable monitoring system layout.

III. CONCLUSIONS

Integrated control and adaptable configurability will permit the SNS viewing system to support a wide variety of remote operations inside the target system hot cell. Four pan-tilt-zoom wall-mounted cameras provide good cell coverage from six possible positions. Seven cameras mounted to the two bridge systems and servomanipulators, combined with the four shield windows, provide excellent viewing for all identified remote operations. The flexibility of the design permits remote viewing, sound, and/or lighting systems to be moved remotely around the hot cell to permit the best viewing angle and lighting for most remote handling tasks. Integration of the video control system with the bridge controllers and all four window workstations ensures optimal operator interface. The scalability of the design permits new remote viewing systems to be added to the system as new technology is developed or as operating requirements are refined.

AKNOWLEDGMENTS

This research is sponsored by the Office of Science under contract with Oak Ridge National Laboratory, managed by UT-Battelle, LLC, for the Department of Energy under contract DE-AC05-00OR22725.