CONF-840413- Draft

EDB ☑	INS ☑	TTR ☐	H ☐	CATEGORIES
ERA ☑	RIP ☐	DOE ☑	☐	1. 050800
EPA ☐	ATF ☐	LRF ☐	☐	2. 420203
WDA ☐	CRF ☐	SNI ☐	☐	3.
				4.
				5.
				6.

065489

AUGMENTATION:

SPLIT	DESCRIPTORS	FLAGS
	Control rooms	T1 02
	Consolidated Fuel Reprocessing Program)	
	Maintenance	
	remote handling equipment	
	remote handling	
	Man-machine systems	01
	optimization	
	Human factors) engineering	
	Design	01
	fuel reprocessing plants)	T2

FORM TI-70 (3-84)

Consolidated Fuel Reprocessing Program

ELEMENTS OF AN ADVANCED INTEGRATED OPERATOR CONTROL STATION*

M. M. Clarke
Clarke Ambrose Incorporated*
Post Office BOx 23064
Knoxville, Tennessee 37933-1064

and

J. G. Kreifeldt
Tufts University
Medford, Massachusetts

ABSTRACT

One of the critical determinants of performance for any remotely operated maintenance system is the compatibility achieved between elements of the man/machine interface (e.g., master manipulator controller, controls, displays, etc.,) and the human operator. In the Remote Control Engineering task of the Consolidated Fuel Reprocessing Program, considerable attention has been devoted to optimizing the man/machine interface of the operator control station. This system must be considered an integral element of the overall maintenance work system which includes transporters, manipulators, remote viewing, and other parts. The control station must reflect the integration of the operator team, control/display panels, manipulator master controllers, and remote viewing monitors. Human factors principles and experimentation have been used in the development of an advanced integrated operator control station designed for the advance servomanipulator. Key features of this next-generation design are summarized in this presentation. 7 ref., 4 fig.

*Research sponsored by the Office of Spent Fuel Management and Reprocessing Systems, U.S. Department of Energy, under contract No. W-7405-eng-26 with Union Carbide Corporation.

CONF-840413--13-DRAFT

Consolidated Fuel Reprocessing Program

ELEMENTS OF AN ADVANCED INTEGRATED OPERATOR CONTROL STATION

CONF-840413--13-Draft

DE85 002572

M. M. Clarke
Clarke Ambrose Incorporated*
Post Office Box 23064
Knoxville, Tennessee 37933-1064

and

J. G. Kreifeldt
Tufts University
Medford, Massachusetts 02155

To be presented to the
American Nuclear Society
Gatlinburg, Tennessee
April 23-26, 1984

*This presentation is based on work performed under work order 37X-73918V for Oak Ridge National Laboratory, Oak Ridge, Tennessee, operated by the Union Carbide Corporation-Nuclear Division for the U.S. Department of Energy.

Consolidated Fuel Reprocessing Program

ELEMENTS OF AN ADVANCED INTEGRATED OPERATOR CONTROL STATION*

M. M. Clarke
Clarke Ambrose Incorporated*
Post Office BOx 23064
Knoxville, Tennessee 37933-1064

and

J. G. Kreifeldt
Tufts University
Medford, Massachusetts

ABSTRACT

One of the critical determinants of performance for any remotely operated maintenance system is the compatibility achieved between elements of the man/machine interface (e.g., master manipulator controller, controls, displays, etc.,) and the human operator. In the Remote Control Engineering task of the Consolidated Fuel Reprocessing Program, considerable attention has been devoted to optimizing the man/machine interface of the operator control station. This system must be considered an integral element of the overall maintenance work system which includes transporters, manipulators, remote viewing, and other parts. The control station must reflect the integration of the operator team, control/display panels, manipulator master controllers, and remote viewing monitors. Human factors principles and experimentation have been used in the development of an advanced integrated operator control station designed for the advance servomanipulator. Key features of this next-generation design are summarized in this presentation.

---

*Research sponsored by the Office of Spent Fuel Management and Reprocessing Systems, U.S. Department of Energy, under contract No. W-7405-eng-26 with Union Carbide Corporation.

I. INTRODUCTION

This paper describes the work of the Remote Control Engineering (RCE) task of the Consolidated Fuel Reprocessing Program (CFRP) at the Oak Ridge National Laboratory (ORNL) to design an operator control station for an advanced integrated maintenance system. The CFRP concepts for future reprocessing facilities include large hot cells where radiation levels prohibit all human entry and make totally remote maintenance imperative. The RCE task includes the development of numerous man replacement systems: advanced electronic force-reflecting servomanipulators (ASMs), transporter for the ASM, remote viewing and remote sound sensors, and computer supervision. Control station design is a key issue because it is here that interfaces are specified between the human operator and other system components, and particularly between the operator's principal output device (the master arm) and principal information input (visual displays). The design incorporates several advanced state-of-the-art features in an original way. Each is discussed fully in the paper. Firstly, the manipulator operator (MANOP) selects major manipulator functions by moving a light cursor across a video display menu. Secondly, the camera operator (CAMOP) controls remote equipment like lights, cameras, transporter or crane, through a small, integrated hand controller. Thirdly, the system relies on advanced graphic displays for both control menus and information displays. Fourthly, all dimensions have been selected to accommodate body size and strength capabilities of the expected operator population. Incorporating such anthropometric data in design is not really an example of advanced technology. However, it has frequently been neglected in control

station layouts for other environments. By using such data, the present design, however, hopes to provide all necessary controls and displays in a nonfatiguing, safe, productive, and aesthetically pleasing work environment.

II. SUMMARY OF DESIGN REQUIREMENTS

Two major sources were used to generate these requirements. First, specific control station requirements for typical remote handling tasks were analyzed. Where possible these were verified by experimental work at the ORNL Remote Systems Development Facility.[1] Other more general requirements concerning human interface with control room equipment were gathered from standard human engineering reference documents.[2,3,4,5]

Before initiating the design concept, the task group thoroughly analyzed the operator interface requirements for remote maintenance tasks and a detailed list of design requirements was then drawn up. Some of the most critical of these are summarized below.

A. Operator-Related Requirements

1. Two person team: manipulator operator (MANOP) controlling all manipulator functions; secondary operator or camera operator (CAMOP) controlling lights, tooling, transporter, cranes, and all other functions necessary to support MANOP.

2. Operators must be physically close enough to communicate by direct speech and have a clear view of each other without obstructing each other's views. All MANOP TV monitor information will be duplicated on the CAMOP displays.

3. Accommodating design: the design must accommodate the anthropometric characteristics of the anticipated wide range of the work force population (5th percentile female through 95th percentile male).

B. Equipment/Architecture-Related Requirements

1. Aesthetically pleasing: the control station must provide a pleasant, nonstressful work environment for long maintenance tasks. A pleasing design also reinforces the operator's perception of the tasks' importance as well as operator's self-image.

2. All MANOP displays and controls must be out of reach of maximum extension of master to prevent interference.

3. Maximum use of advanced integrated controls/displays: touch, voice, graphics, etc.

4. Minimum reliance on discrete dedicated controls to minimize clutter and potential confusion.

III. MANOP STATION: KEY DESIGN ELEMENTS

Key design elements of the control station are shown in Figs. 1 and 2. The station is bounded by a decorated curved work area (suggested by the sweep of the master arm). Three 48.3-cm (19-in.) remote closed-circuit television monitors (lower rack), three 19-in. alphanumeric/colorgraphic displays (middle rack) and seven 22.9-cm (9-in.) closed-circuit television monitors comprise the visual display area, for MANOP. All manipulator functions are controlled by switches on the master handle. Handle details are discussed in Ref. 6. The operator sits in a chair between the arms of the elbows-down master. (Details of the master arms are described in Ref. 7 and illustrated in Fig. 3). The details of the work station surrounding MANOP are discussed below.

ORNL-DWG 83-17622R2

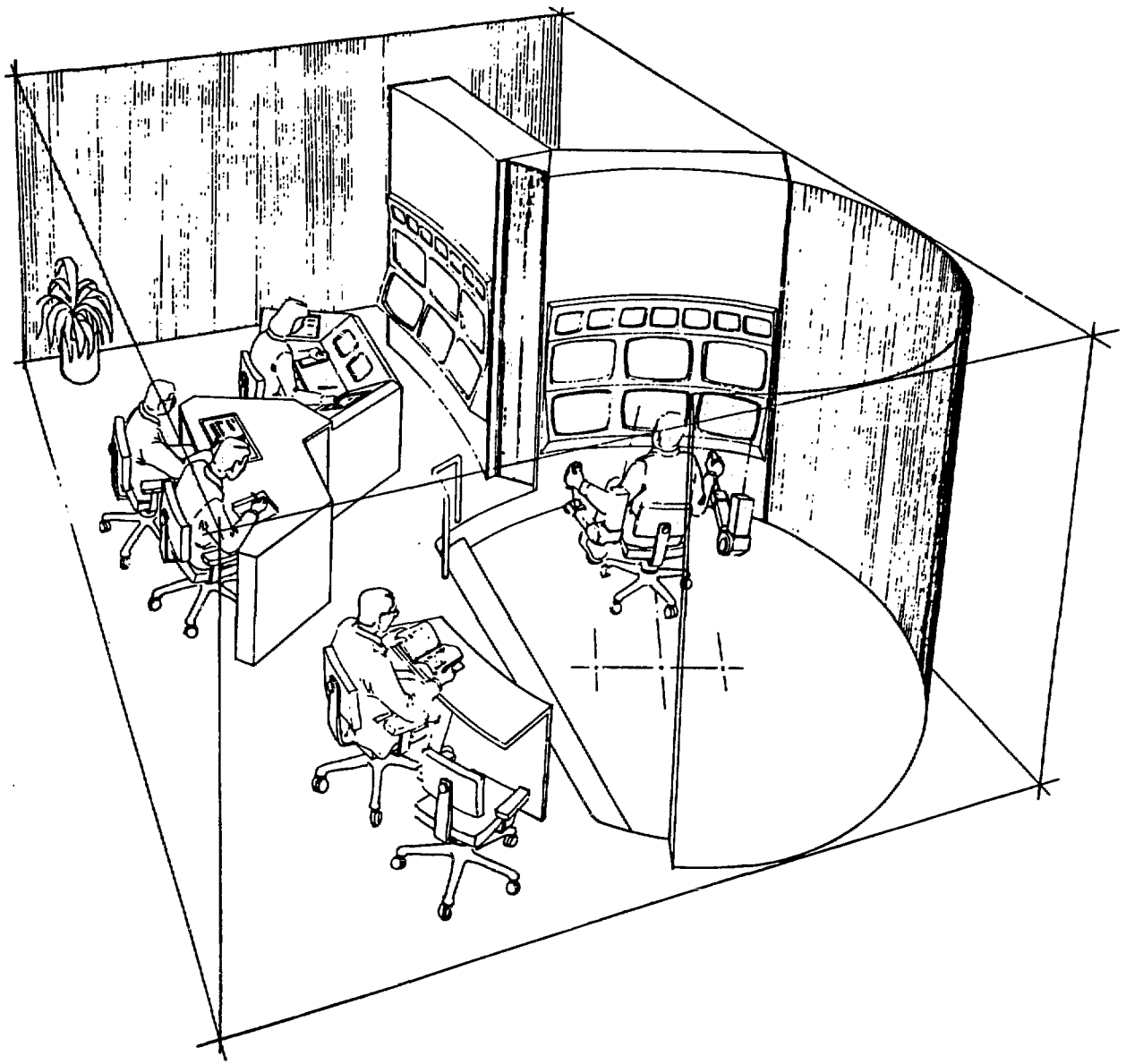

Fig. 1. Integrated operation control station.

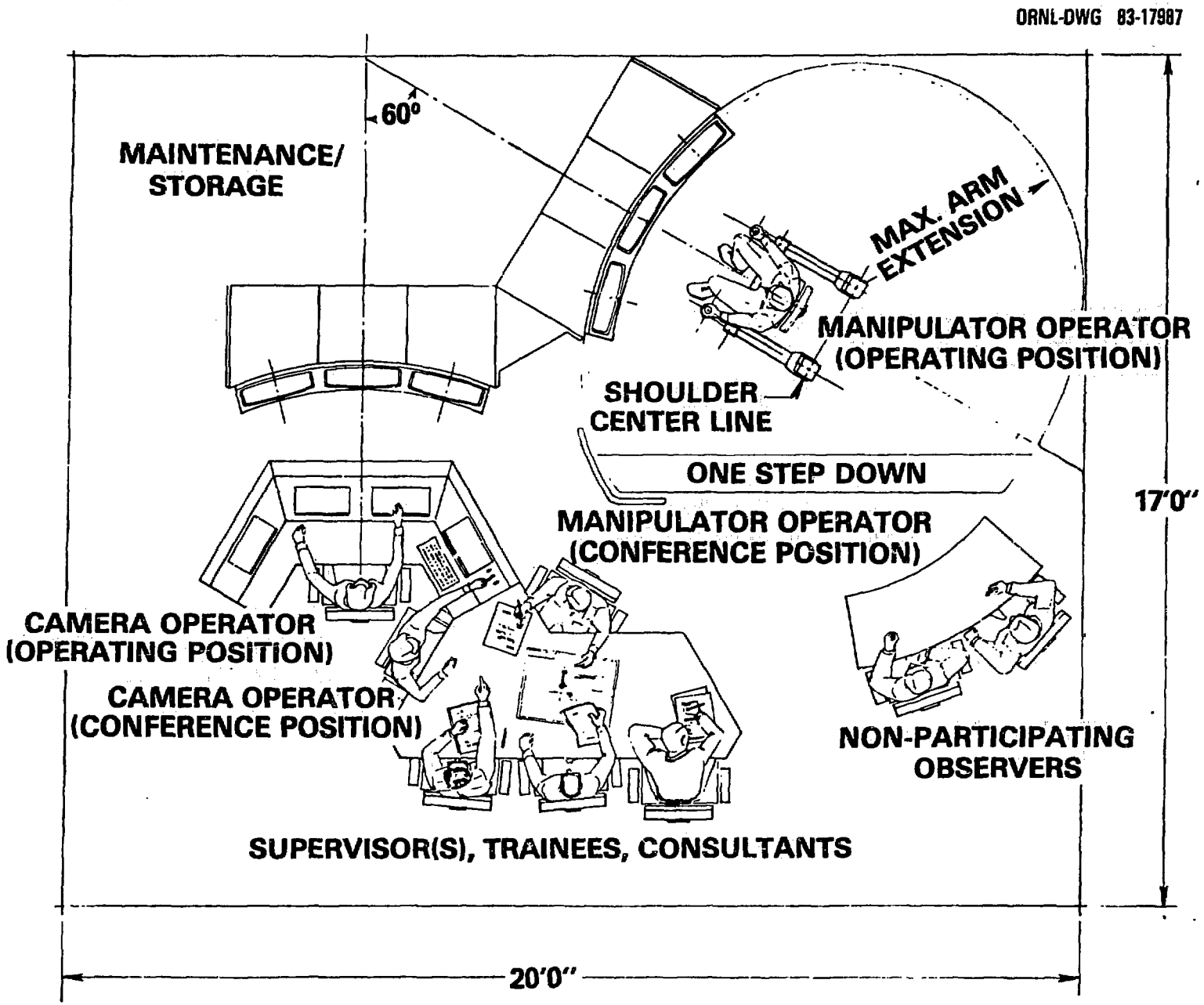

Fig. 2. Integrated operator control station: Plan View

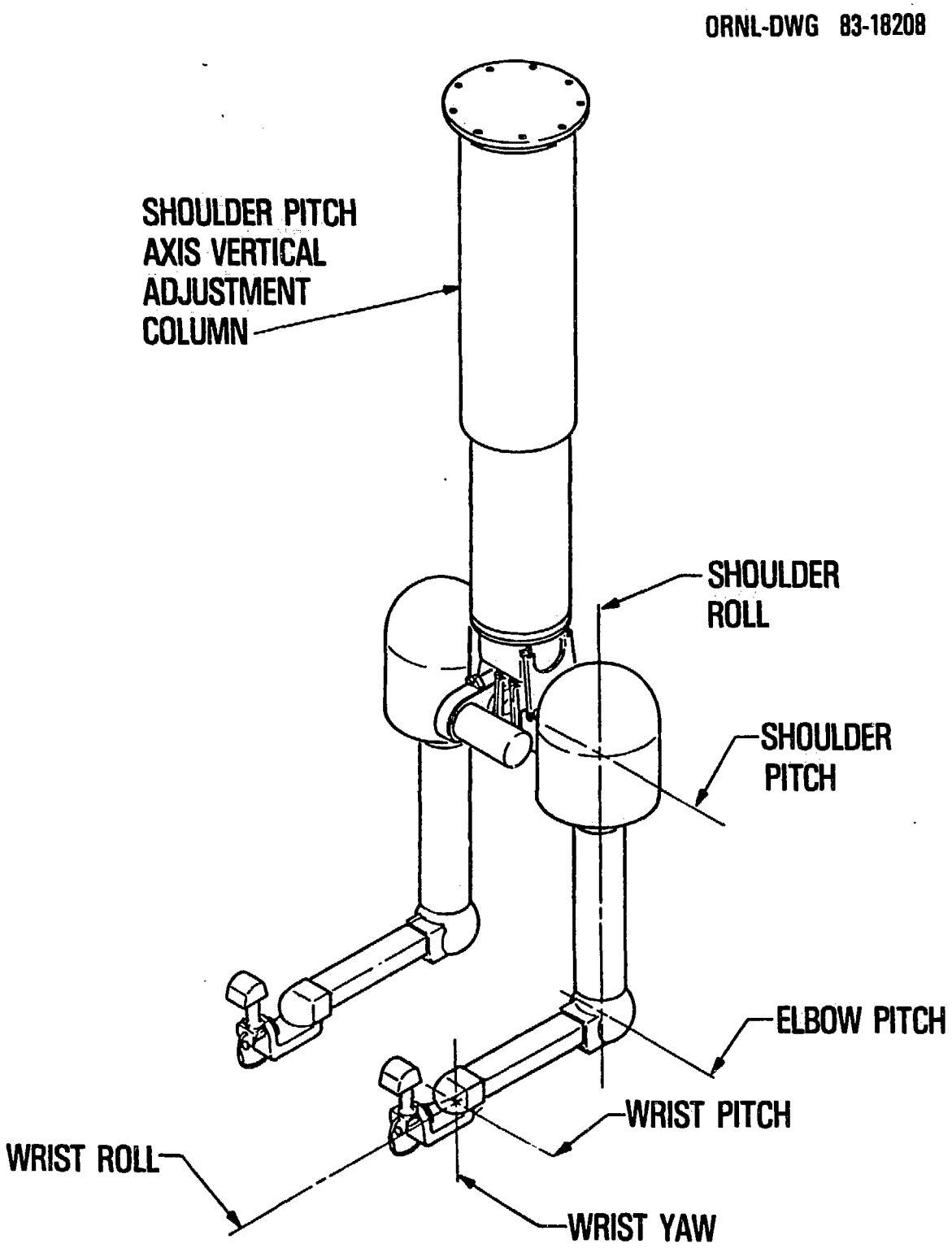

Fig. 3. Advance servomanipulator master arm.

A. Location

The MANOP station is located 3.0 m (10 ft) to the right of the CAMOP and 20.3 cm (8 in.) below the CAMOP floor level. This location is further discussed below.

1. Eight-in. step. The 20.3-cm (8-in.) step down places MANOP's eyes and hands within a 20^{o} angle of CAMOP's eyes, which provides an unobstructed view of MANOP's hands and eye gaze and would aid in CAMOP's anticipating MANOP's needs for assistance, particularly as regards change in visual information.

The 8-in. step would assume a CAMOP station raised 30.5 cm (12 in.) and a MANOP station raised 10.2 cm (4 in.), above normal floor level, providing ample space for cable routing under the floor..

2. Curved wall to MANOP's right. The wall sweep is dictated by the maximum reach of the master arms. As a safety feature the wall and all components (monitors, graphic displays) are outside the reach of the master.

B. Visual Displays

1. Lower rack. The display unit is composed of a lower rack of three 19-in. monitors, centered 76.2 cm (30 in.) above the floor and angled at 20^{o} to maintain a comfortable line of sight between eyes and screen center. It is assumed that MANOP will need information from TV monitors more frequently than information from graphics and menus (upper rack). The TV monitors were therefore placed in the lower and more comfortable line of sight. The TV monitors will normally display (from left to right) information from left, chest, and right on-board cameras.

Thus, a natural relationship will be preserved between the slave/camera and operator/monitor. In addition, MANOP can request other TV views (e.g., from wall cameras) on these monitors as desired.

2. Middle rack. These three 19-in. monitors centered at 121.9 cm (48 in.) above the floor and angled at 0^{o} will display graphics, menus, procedures, and other information as needed. High resolution alphanumeric/colorgraphic systems will be programmable to meet the characteristics and preferences of the small operator population. Information displays could include status of the manipulator system, exploded diagrams of parts needing repair, procedure cues and so on. The system will allow menus or other information to be displayed on any of the three screens, providing minimum interruption of task performance in case of screen failure. Since the menus on these monitors will be out of reach of the manipulator, they will also be out of reach of MANOP's hand. Therefore, the menus will be controlled by voice and/or a cursor activated by a control on both manipulator master handles. It is important that MANOP be able to activate the cursor by either the right or left hand because while he will never be controlling two menus at once, sometimes it will be more convenient to control the cursor by the right hand and sometimes by the left.

3. Upper rack. The upper rack of seven 9-in. monitors centered at 167.6 cm (66 in.) above the floor and angled down at 20^{o} (within a maximum recommended above eye level viewing angle of 40^{o}) provides a general scene overview from the facility fixed wall cameras. The MANOP can request that CAMOP turn these views off, or switch any of them to the 19-in. monitors.

C. Chair

The MANOP's task will involve body movement within the chair as well as moving the chair around on the floor. The chair must allow unencumbered body movement (no arms, and tiltable seat). Seat height and back height are adjustable to accommodate operators of varying leg and back heights. The chair is five legged with sturdy casters. The floor is nonskid industrial carpet, which allows movement when the operator wishes to move the chair, but restricts skidding when the operator applies force to the master arms. No foot controls are used, to prevent inadvertent activation by the operator when moving the chair or his feet.

IV. CAMOP STATION: KEY DESIGN ELEMENTS

The station consists of an operator console desk with place for three or more alphanumeric/colorgraphic screens, working surface, keyboards, and two integrated hand control units. The CAMOP large visual display panel is identical in dimension to the MANOP visual displays; however, all panel monitors are for remote TV viewing. Details of the CAMOP station are described below.

A. Location

The station is located 3.0 m (10 ft) to MANOP's left up an 20.3 cm (8-in.) step. Left placement ensures that CAMOP can glance at MANOP while using her right hand to control functions at the right side of her station. Most frequent CAMOP functions are placed at CAMOP station right side since it is assumed that most CAMOPs will be right handed. The CAMOP will be able to keep both her right hand and MANOP in a 20^{o}

viewing envelope. Placing MANOP to CAMOP's left would involve CAMOP looking at MANOP by turning her head to the left while activating controls with her right hand.

B. Console/Desk

The console desk is 91.4-cm (36-in.) high (floor to top back highest dimension) to allow the 5% female (worst case) to look over the top at the lower row of monitors on the screen. The console surface with screens on it is at an 50^{o} angle to the writing surface so the screen centers can be viewed at a 45^{o} specified for seated operation. The writing surface extends 25.4 cm (10 in.) allowing a 7.6-cm (3-in.) clearance between the operator's abdomen and desk, and also allowing the 5% female [arm reach of about 50.8 cm (20 in.)] to reach across the surface to the panels. The floor-to-writing surface height is 71.1 cm (28 in.) to accommodate the floor knee height [61.0 cm (24 in.)] of 95% male. The console is 35.5 cm (14 in.) deep, behind the mounting surface allowing space for the CRT tubes.

1. Screen functions. The console screens will display menus for control of cameras, tools, lights, transporter. The operator will use the touch screens to chose which function will be controlled; for example, touch "CAMERAS," then proceed to control the particular camera by a small integrated controller located in the CAMOP work area. A hand held pendant controller will also be available at MANOP station should he desire to assume control or any of these functions.

2. Integrated hand controllers. The integrated hand controller concept is illustrated in Fig. 4. Its dimensions are 24.1 cm (9-1/2

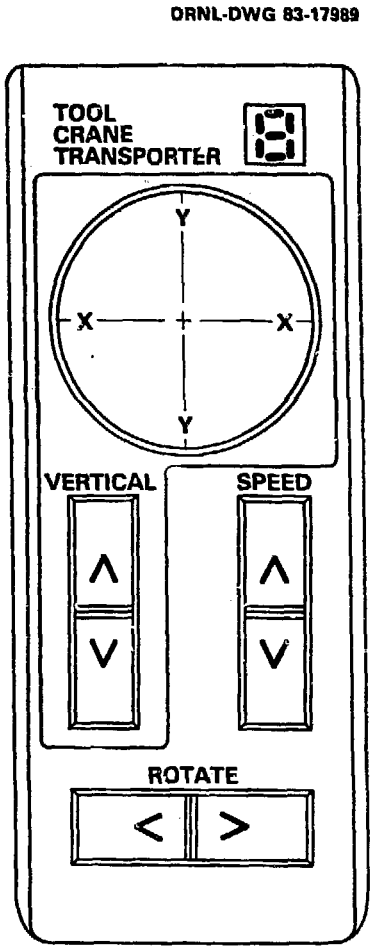

Fig. 4. Integrated hand controller concept.

in.) by 9.5 cm (3-3/4 in.) by 1.9 cm (3/4 in.). These dimensions comfortably accommodate the expected population hand sizes. Details of location and activation are under development.

3. Visual displays. The lower rack of TV monitors will display scenes from on-board remote cameras. The left on-board TV scene will be usually displayed on the left monitor (as with the MANOP) to preserve the operator's perception of a natural relationship between her stance and the remote system. Similarly, the middle and right monitors will display scenes from the middle chest) and right cameras, respectively. The middle display rack will normally be dedicated to wall cameras. Views from other wall and system cameras will be displayed on the seven small 9-in. cameras in the top row, as in MANOP station.

V. AUXILIARY FEATURES

The design takes account of other auxiliary needs. Electronic equipment must be stored out of sight but must be easily accessible for maintenance. Ample equipment storage areas are provided behind the two visual display racks. Operators, supervisors, and trainees require a place to meet to discuss task procedures. Finally, visitors or nonparticipating observers require an area where they can nonobtrusively see and hear all operations without interfering with the operators.

A. Conference Area

The CAMOP console extends into a seven-sided work table. The table will provide an efficient place for supervisors, trainees, etc. The area is also a convenient location for any pre-repair job planning or conference. MANOP can conveniently leave his station to join the planning activity while CAMOP need only swing her chair to the right.

Figure 2 shows MANOP and CAMOP in these conference locations, as well as at their normal work stations.

B. Visitor's Area

A small table and two chairs are provided at the control station right for nonparticipating observers. The location gives visitors a good view of all operations. They will be able to hear everything operators say to each other. However, they are out of both operators' sight and therefore their distraction potential is minimized.

VI. FABRICATION AND TESTING

Full-scale mockups of the basic control station design features of the CAMOP and MANOP station have been constructed from Fome-Cor and Gator Foam Board to refine the basic anthropometric dimensions of the original design through subject testing and comments during simulated operation.

VII. DISCUSSION

Designing the control station to be functional, efficient, and aesthetic has been an exciting challenge made considerably easier by a full list of requirements for the design. A number of radically different designs were first conceptualized by the second author and a team of designers working from a list of requirements provided by the first author. Frequent meetings between the two groups refined the initial concepts and resulted in the one presented here. Many innovative features were incorporated into the design of the consoles, display units, and hand controllers. The next step is now in progress: the realization of the actual hardware and software designs.

References

1. M. M. Clarke, W. R. Hamel, and J. V. Draper, "Human Factors in Remote Control Engineering Development Activities," Remote Systems Technology Division Proceedings, American Nuclear Society, 1983.

2. Harold P. Van Cott and Robert G. Kinkade, "Human Engineering Guide to Equipment Design," Washington, DC, U.S. Government Printing Office 1972.

3. K. Mallory, S. Fleger, J. Johnson, L. Avery, R. Walker, C. Baker, and T. Malone, "Human Engineering Guide to Control Room Evaluation," NUREG/CR-1580.

4. "Human Engineering Design Criteria for Military Systems, Equipment, and Facilities," MIL-STD01472C, May 1981.

5. Wesley E. Woodson, "Human Factors Design Handbook: Information and Guidelines for the Design of Systems, Facilities, Equipment, and Products for Human Use," New York, McGraw-Hill, 1981.

6. D. P. Kuban and G. S. Perkins, "Dual Arm Master Controller Concept," Robotics and Remote Handling in Hostile Environments, American Nuclear Society, April 1984.

7. H. L. Martin and W. R. Hamel, "Control and Electronic Subsystems for the Advanced Servomanipulator," Robotics and Remote Handling in Hostile Environments, American Nuclear Society, April 1984.