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REMOTE HANDLING FACILITY AND EQUIPMENT USED FOR SPACE TRUSS ASSEMBLY*

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REMOTE HANDLING FACILITY AND EQUIPMENT USED FOR SPACE TRUSS ASSEMBLY

The ACCESS truss remote handling experiments were performed at Oak Ridge National Laboratory's (ORNL's) Remote Operation and Maintenance Demonstration (ROMD) facility. The ROMD facility has been developed by the U.S. Department of Energy's (DOE's) Consolidated Fuel Reprocessing Program to develop and demonstrate remote maintenance techniques for advanced nuclear fuel reprocessing equipment and other programs of national interest. The facility is a large-volume, high-bay area that encloses a complete, technologically advanced remote maintenance system that first began operation in FY 1982. The maintenance system consists of a full complement of teleoperated manipulators, manipulator transport systems, and overhead hoists that provide the capability of performing a large variety of remote handling tasks. This system has been used to demonstrate remote manipulation techniques for the DOE, the Power Reactor and Nuclear Fuel Development Corporation (PNC) of Japan, and the U.S. Navy in addition to the National Aeronautics and Space Administration (NASA).[1]

ACCESS truss remote assembly was performed in the ROMD facility using the Central Research Laboratory's (CRL) model M-2 servomanipulator. The model M-2 is a dual-arm, bilateral force-reflecting, master/slave servomanipulator which was jointly developed by CRL and ORNL and represents the state of the art in teleoperated manipulators commercially available in the United States today. The model M-2 servomanipulator incorporates a distributed, microprocessor-based digital control system and was the first successful implementation of an entirely digitally controlled servomanipulator.[2,3] The system has been in operation since FY 1983.

The model M-2 servomanipulator system consists of two major assemblies: (1) the slave package, shown in Fig. 1, and (2) the master control station, shown in Fig. 2. The model M-2 is described in more detail in the following two sections.

ORNL–PHOTO 3549–83B

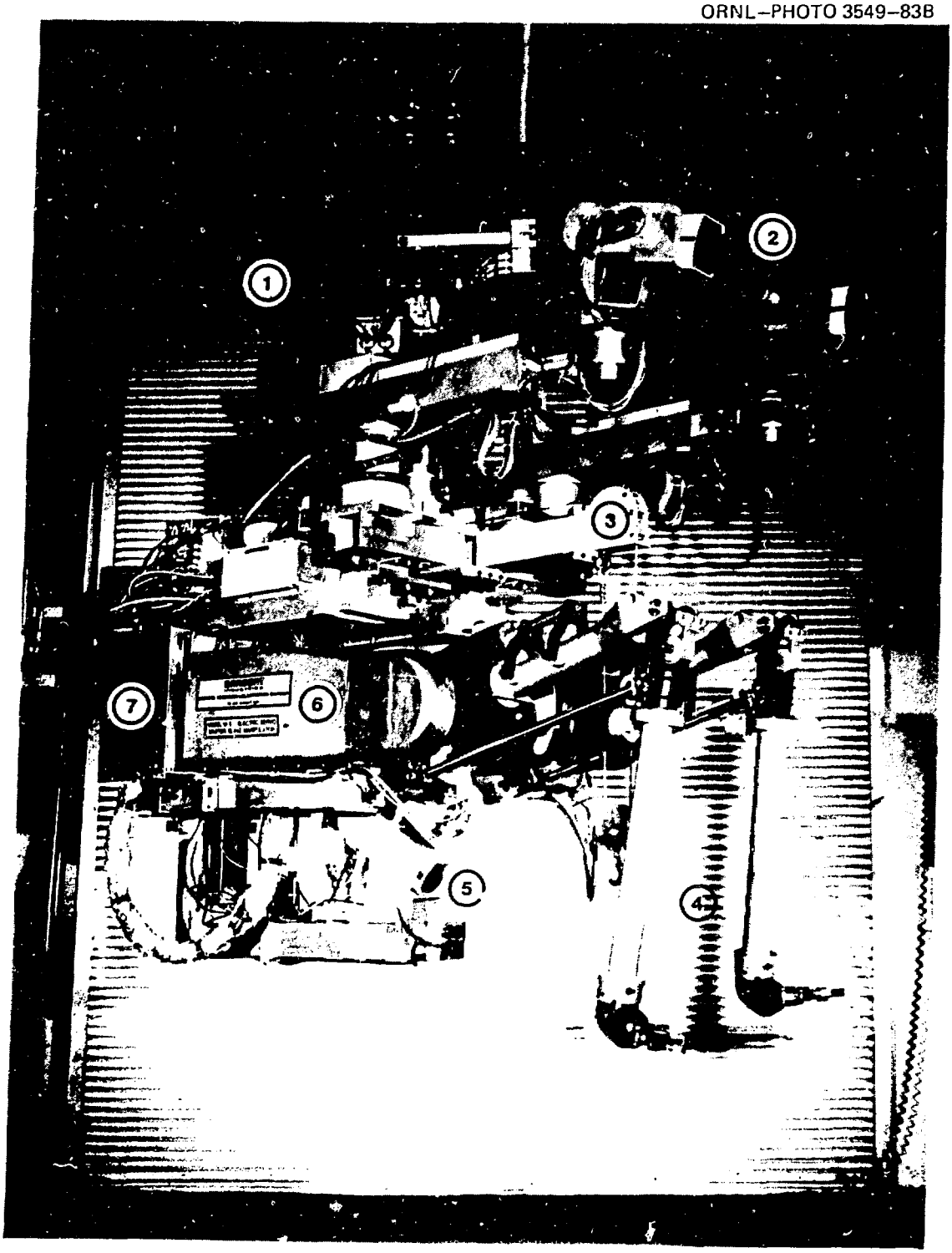

Fig. 1. The model M-2 slave - (1) transporter interface, (2) movable overhead cameras, (3) auxiliary hoist, (4) slave arms, (5) fixed lower camera, (6) servomotor housing, and (7) control electronics rack.

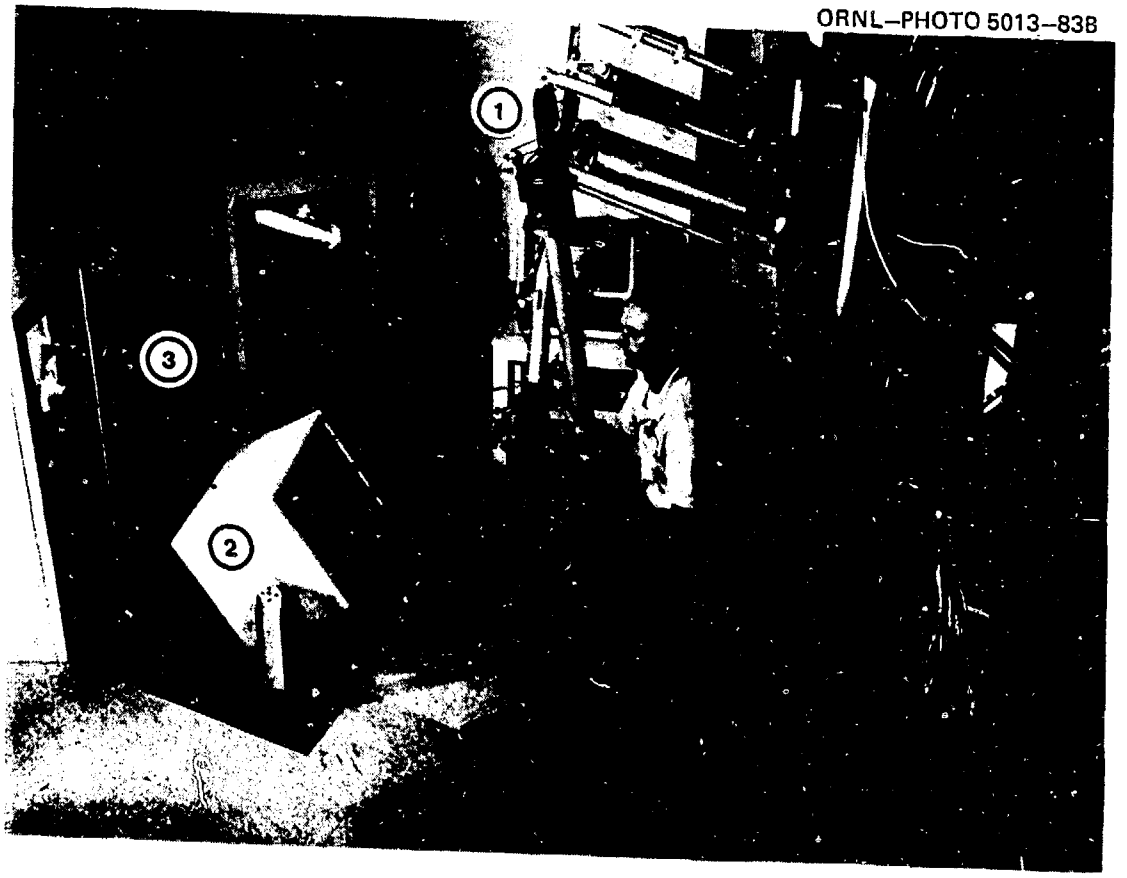

Fig. 2. The model M-2 master control station - (1) master control arms, (2) operator console, and (3) remote viewing monitors.

Model M-2 Slave

The model M-2 slave is used to perform "man-like" handling tasks in the remote environment. The slave package consists of a pair of force-reflecting servomanipulator arms, three television viewing cameras, lighting, and a 230-kg (500-lb) capacity auxiliary hoist. Each slave arm has a 23-kg (50-lb) continuous capacity, a 46-kg (100-lb) time-limited (peak) capacity, and seven degrees-of-freedom (joints), which are each driven by a brushless dc servomotor. The servomotors are mounted at the base of the arm and transmit power to the upper three degrees-of-freedom through gears and linkage, and the lower four degrees-of-freedom (including a standard tong end-effector) by cable and pulley arrangements passing through the arm tubes. Each servomotor has a servoamplifier and joint processor mounted in racks on the slave. The slave arm joint processor communicates with its respective master arm joint processor through a high-speed digital serial link. The basic control method used is a closed-loop, position-position error technique.

Master-to-slave arm control is in real time with slave arm tip velocity capabilities up to 152 cm/s (60 in./s). The minimum slave arm loading which can be detected or "felt" at the master control arm is on the order of 0.45 kg (1 lb) or 1% of peak capacity. All seven arm joints are force reflecting.

Operator viewing of the remote work site is provided by closed-circuit television cameras mounted on the slave package; two overhead boom-mounted cameras with four-positioning degrees-of-freedom (pan, tilt, boom extend-retract, and boom pivot) and motorized lens controls (zoom, focus, and iris); and one fixed camera mounted between the slave arms. The cameras provide standard resolution color videos to 19-in. monitors at the master control station. The two overhead cameras provide views in an orthogonal fashion to effect depth perception and viewing flexibility. The lower camera produces a wide angle view of the work site from a fixed position to provide additional viewing information and information concerning master-to-slave arm spacial relationships.

Model M-2 Master Control Station

Control of the model M-2 slave is performed by a single operator from the master control station. The master control station consists of a pair of master control arms, three 19-in. color television monitors and an operator console (see Fig. 2).

The master control arms are kinematic replicas of the slave arms with seven degrees-of-freedom. Each master arm has an 11-kg (25-lb) peak capacity. The master control arm servomotor drives, amplifiers, and joint processors are essentially the same as those for the slave which are described in the previous section. The master control arm handle is a pistol grip and trigger type that provides slave tong control. Switches on the master handles allow the operator to perform functions such as slave tong lock, slave arm lock, master-to-slave "all joint" indexing, and electrical tool power control without releasing the handle.

The operator interfaces with the control system primarily through a CRT and touch-screen system mounted in the operator console. Operating mode selection, force-reflection ratio selection, camera/lighting control, and system status diagnostics are examples of features provided by this operator interface.

Camera and auxiliary hoist controls are also located on the operator console. A joystick is used for overhead camera positioning and spring-loaded potentiometers provide camera lens zoom, focus, and iris control. Likewise, a potentiometer is used to control the hoist drive. An additional switch on the console rotates the entire slave package at the transporter square tube interface through a maximum of 540° for positioning at the task site.

Camera views selected to the three control station monitors are primarily the on-board slave camera views, but views can also be selected from several other facility- and transporter-mounted cameras as desired by the operator. The control station monitors are standard resolution, 19-in. color monitors.

Control Station Conditions During ACCESS Remote Handling

The ACCESS truss remote assembly operations were performed in accordance with standard NASA procedures, which require a two-person team. The two people position themselves at two stations (an upper and lower) from which they construct the truss in a coordinated effort. Compliance with the NASA procedures required that a person work locally with the manipulator slave to complete the two-person team. The model M-2 slave and remote site operator were alternated between the two assembly stations and repeated the assembly tasks numerous times to ensure that task completion time data were representative of experienced personnel. The remote site operator and model M-2 operator had continuous two-way communication using radio transmitter/receiver headsets.

Operations at the model M-2 control station consisted primarily of arm manipulation tasks with no adjustment in camera views or slave position required. The initial setup of camera views and slave position was adequate at each station to perform all tasks required. Operation of the model M-2 was performed by a single operator at a time. Two operators experienced with the model M-2 participated in the test program.

Three television monitors were arranged at the model M-2 control station in addition to the normal three that receive views from the slave-mounted cameras. The additional views consisted of wide angle views (typically a field of approximately 10 ft by 10 ft) of the work site. The extra views assisted operators in seeing and orienting the entire truss strut length. Two of the three views were generally considered redundant by the operators and not used.

The handling and assembly of the truss struts and nodes were performed without the use of tools and without modification to the ACCESS components or the remote handling equipment. The manipulator tongs were fitted with standard finger pads. A flat-faced finger and a V-groove-type finger were used on each tong. This finger combination produced a good grip on the tubular shaped struts and countered any pivoting action at the finger contact points. Remote handling operations were performed at a four-to-one slave-to-master force reflection ratio as preferred by the manipulator operators.

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