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A High Capability Teleoperated Vehicle for Hazardous Applications (U)

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ABSTRACT

The Robotics Development Group at the Savannah River Site is developing a high performance teleoperated vehicle for use in radioactive and hazardous environments. The three-wheeled vehicle incorporates a highly dexterous 6 degree-of-freedom (DOF), hydraulically-powered manipulator made by Schilling Development, Inc. The teleoperator is called Little MoRT (MObile Radio-controlled Teleoperator) and is a modified version of a commercially available, battery-powered, warehouse vehicle. Little MoRT is controlled remotely by a universal robot controller either through a radio frequency link or a tethered cable. Six video cameras and a microphone provide the operator with audio-visual feedback of the vehicle and its surrounding environment. The vehicle also incorporates a hydraulic power unit consisting of a propane-driven engine for powering the Schilling manipulator. Little MoRT is capable of operating in outdoor as well as

indoor environments and is well-suited for decontamination and decommissioning activities such as dismantling, sorting and surveying of radioactive waste.

BACKGROUND

The Savannah River Site is an isotope production facility operated by the Westinghouse Savannah River Company(WSRC) for the United States Department of Energy (DOE). It was established in the early 1950s to produce nuclear materials for defense and space applications. The 300 mi^2 (777 km^2) complex, located in South Carolina, is composed of many separate plant operations, including fuel and target fabrications, nuclear reactors, chemical separations, and numerous waste handling facilities.

The end of the Cold War and the recent political changes in the former Soviet Union have allowed an increased interest in the area of Environmental Restoration and Waste Management (ER&WM). Specifically, more emphasis has been placed on dismantling and decommissioning of radioactive waste that has accumulated at various nuclear sites across the DOE complex. Remote teleoperators, such as Little MoRT, can play a major role in this cleanup effort since their usage reduces the need for humans to go into contaminated and hazardous environments.

VEHICLE DESCRIPTION

Little MoRT is a teleoperated mobile vehicle equipped with a high-dexterity manipulator. The base vehicle is a relatively-inexpensive, commercially-available, battery-powered, warehouse vehicle made by Cushman, Inc. and is called a Stock Chaser. Figure 1 shows the base vehicle before any modifications were made to it. The Stock Chaser weighs

approximately 385 kg (850 lbs) and costs about $6,000. It comes standard with a steering wheel and a speed control pedal and was intended for manual operation purposes. The vehicle is equipped with a series of batteries having a capacity of 240 A.H. The base vehicle has undergone extensive modifications and changes to become the remotely-controlled teleoperator known as Little MoRT.

Little MoRT as it exists today is shown in Figure 2. As can be seen, the most notable change to the vehicle has been the addition of a hydraulically-powered manipulator called the Titan 7F made by Schilling Development, Inc. A hydraulic power unit (HPU) has been added to the vehicle to power all of the hydraulic subsystems. Remotely deployable outriggers that improve vehicle stability during manipulator operation have also been added. The steering wheel and foot pedal have been removed and remote driving and steering of the vehicle has been accomplished through a proportionally-controlled servo motor and a speed controller. For safety considerations, front and rear bumpers with contact sensitive tapeswitch have been installed on the vehicle. The vehicle stops when either bumper is contacted. A fail-safe pneumatic brake system has also been incorporated into the vehicle and it performs the actual stopping. Furthermore, Little MoRT has been equipped with six video cameras and a microphone that provide the operator with audio-visual feedback of the vehicle's immediate environment. One of those cameras resides on a pan/tilt telescoping neck that can elevate to a height of 3.65 m (12 feet). All of the vehicle's various features and functions can be controlled remotely from a versatile control console that was designed and built at WSRC.

Manipulation of objects is accomplished through the dexterous Titan 7F. The Titan 7F is

a proven manipulator that has been used in undersea and terrestrial applications. The 6-DOF manipulator is capable of lifting 113 kg (250 lbs) at full arm extension. It weighs 68 kg (150 lbs) and has a reach of 200 cm (78 in). The manipulator is constructed primarily of titanium. A synthetic, non-hazardous, water-based hydraulic fluid is used to eliminate the "mixed waste" problem that would arise from using oil-based fluids. The Titan 7F is controlled through a portable master controller provided by Schilling Development. Inc.

HPU System

Little MoRT's Titan 7F manipulator, as well as the outriggers are powered through a modular, hydraulic power unit. This HPU resides in the middle of the vehicle base and consists of a propane-driven engine, a hydraulic pump, various solenoid valves, sensors, and an elaborate cooling system. To make space for the HPU system, the battery array has been reduced to a capacity of 75 A.H. from the standard 240 A.H. that comes with the Stock Chaser. This modification decreases the operating time of the teleoperator considerably, but is necessary and thus unavoidable. To compensate for the loss in battery capacity, a provision has been made to recharge the battery bank via the integral alternator on the propane engine. The alternator is capable of sourcing 15A of current while the engine is running.

The 11-HorsePower, single stroke, internal combustion engine was originally gasoline-powered. It has since been modified to operate off liquid propane to facilitate its use in some indoor environments. The engine can be started/shut-off either locally, or remotely

from the universal controller. A unique circuit board has been designed to achieve the remote starting of the engine, and a U.S. patent on this hardware is pending. The propane supply cylinder onboard Little MoRT can provide approximately 3 hours of hydraulic power before refueling is required. Many safety precautions have been taken to prevent the buildup and potential explosion of propane gas. The propane supply cylinder itself is placed outside the vehicle and tucked away underneath the shoulder of the Titan 7F manipulator. This puts the propane cylinder outside of the working envelope of the manipulator and thus prevents any accidental collisions between the manipulator and the propane cylinder. Furthermore, propane gas sensors as well as Hall Effect sensors constantly monitor for gas leaks and/or engine malfunction and automatically shut off propane supply to the engine should leaks or engine failures occur. Also, temperature and pressure sensors are used to monitor the engine's vital signs. Finally, a series of fans and a heat-exchanger that are used to cool the hydraulic fluid also provide fresh air purging of the engine cavity.

Vehicle Control System

The vehicle control system revolves around a 286-compatible STD bus computer card. The STD bus was chosen for many reasons. To begin with, it is a well-established computer standard supported by many software languages including C. It also has a wide variety of supporting vendors that produce function-specific cards. Furthermore, many user-friendly IBM-compatible development systems as well as C libraries are available for software development. The vehicle's computer system consists of the CPU card (with 3 onboard RS232 ports and 48 digital I/O lines), 2 relay cards, a D/A card with encoder

inputs, and the custom engine-starting card. One of the D/A channels drives the vehicle's speed controller. This speed controller comes standard with any Cushman Stock Chaser. Another D/A channel drives an amplifier that proportionally controls the steer motor. The Titan 7F arm utilizes its own separate control system that is provided by Schilling. C is used as the programming language. The CPU card has flash EPROMs and new code can be easily downloaded and burned in EPROM over a serial link. A watchdog timer and a voltage monitoring circuit ensure proper CPU operation and they generate a reset pulse to the CPU should abnormalities occur.

Two separate radio links are used to link the vehicle with the universal controller .One link is used for controlling the vehicle and the other for controlling the Titan 7F manipulator. Both links are RS232, full-duplex, and operate at 9600 baud. The radio links are the lifeline to the vehicle and thus the onboard software will automatically halt the vehicle and all of its functions when radio contact with the controller is disrupted. In environments where it's undesirable to transmit radio frequencies (such as a nuclear reactor control room), a tether link is available. This tether provides an RS485, 9600 baud link as well as an audio-video link with the controller. For vehicle transportation purposes, a small, handy, joystick pendant can be used. The pendant plugs into a connector on Little MoRT and drives/steers the vehicle in proportional control.

Another link is used to transmit video and audio signals to the universal controller via a microwave transmitter. Little MoRT supports six color video cameras and one audio microphone .Two cameras are mounted on the front of the vehicle, two on the Titan 7F manipulator, one on the telescoping neck, and one on the rear of the vehicle. Each camera

has an associated 20W light mounted near it. All of the cameras have fixed-focal-length lenses except for the telescoping neck camera which has controllable zoom, focus, and iris as well as pan and tilt features. All of these features may be controlled remotely. A video multiplexer on the vehicle permits simultaneous transmission of four of the six video signals. This multiplexer is also capable of transmitting four video signals in quad format, i.e., a video image can be displayed in a different quadrant on a video monitor. This allows the operator to view several scenes at once. Another data multiplexer superimposes sensor data such as: temperature, pressure, battery voltage, and telescoping neck elevation onto the video signal. The sensor data would then appear in text form on the control console's video monitor. Should any sensor value go beyond preset bounds, an alarm signal would appear on the video screen. Finally, the audio is carried on the main video signal using a subcarrier frequency and is fed into a speaker on the controller end. Our past experiences with teleoperators has shown that audio feedback is beneficial in remote applications.

OPERATOR CONTROL CONSOLE

Little MoRT is controlled remotely from a portable, versatile, control console (Figure 3). The console is housed in a rugged, aluminum extruded, weather resistant suitcase and weighs approximately 10 kg (22 lbs). The suitcase control console design emphasizes the system's portability and usefulness in field applications. The electronics of the console can be powered either by a 12 Vdc battery or from a 120 Vac source. The same control console also controls a host of other teleoperators in addition to Little MoRT, although not simultaneously.1,2 The console controls all of Little MoRT's functions except for the Titan 7F manipulator. The Titan 7F is controlled by its own vendor-supplied controller,

which is a compact, scaled kinematic replica of the Titan 7F with the same relative range of motion as that of the manipulator. Controlling the arm is thus a comfortable and intuitive task. This controller is referred to as the "mini-master " and is shown in Figure 4.

The main controlling elements of the console consist primarily of joysticks, rocker switches, an infrared touch-screen display , a video monitor and a speaker. The joysticks control the vehicle drive and steer functions while the rocker switches control the HPU functions such as engine power and outriggers extend and retract. The infrared touch-screen displays a series of buttons that control camera functions such as: pan, tilt, zoom, iris, and focus. An operator may also use the touch-screen to select which single camera view or multiple camera views are to be displayed on the video monitor. It is possible to have four camera views in quad form displayed simultaneously on the monitor. Also, sensory data may be selected to be displayed on the video monitor. The sensory data appears in alphanumeric form on the screen. An additional video connector is provided on the console to permit video hookup to a larger, external display monitor. The use of touch screen makes modifications and enhancements primarily a function of software. New commands or display information can be easily reprogrammed to accommodate new features that may be introduced into the teleoperator.

CURRENT STATUS

As of the writing of this paper, all of the subsystems on Little MoRT have been integrated and tested. Remote teleoperation under radio control of the vehicle has been demonstrated. Considerable re-emphasis has been placed on safety issues and some

redesign and reprogramming has taken place to address safety concerns. Initial tests showed that the hydraulic fluid overheated and thus the cooling system has since been enhanced. A thorough endurance test is planned for the teleoperator in the summer of 1995. Little MoRT will be used to supplement the existing fleet of teleoperators used for emergency response situations at the Savannah River Site.

FUTURE WORK

Future work for Little MoRT include a planned endurance test in a mockup area. This endurance test should reveal any design flaws and any drawbacks in the system. Another important item under consideration is to develop an interchangeable HPU unit that is powered from a 440 Vac source. This HPU unit will have the advantage of running the vehicle continuously but will require a thick power cable to be connected to Little MoRT. The 440 Vac power feature should eliminate the need for batteries as well as the volatile propane supply. Another item revolves around improving the navigation of the vehicle. Little MoRT's working environment is likely to be littered with obstacles of various shapes and sizes. One possibility for implementing collision avoidance is to put ultrasonic some transducers on the vehicle. These transducers would warn the operator of an impending collision with any obstacles.

The current Titan 7F arm comes standard with a parallel-jaw gripper as an end effector. Decontamination and decommissioning work requires size-reduction and sorting of nuclear waste. Schilling Development, Inc. offers a tool interchange system that allows for the operator to remotely exchange hydraulically-actuated tools. These tools include: shear, metal brush, drill, and eventually a plasma cutting tool. Adding these tools to the Titan 7F

will greatly improve its capabilities. Finally, Schilling also offers a force-feedback master controller. This force feedback provides an extra sensory dimension of "feeling" and allows the operator to perform complex tasks. In the hostile environment of radioactive areas, the force feedback would be a major benefit.

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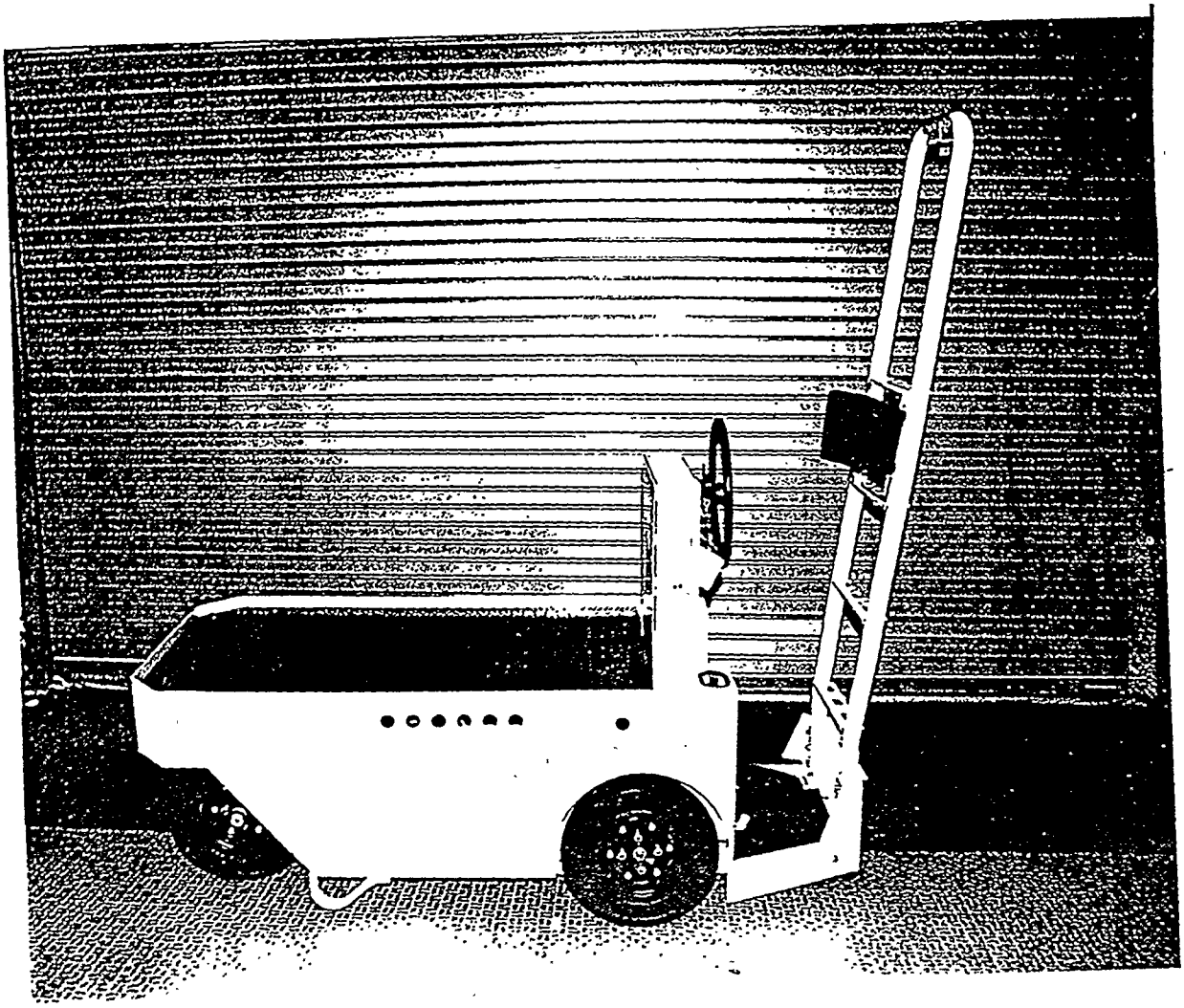

Figure 1. Cushman Stock Chaser Vehicle

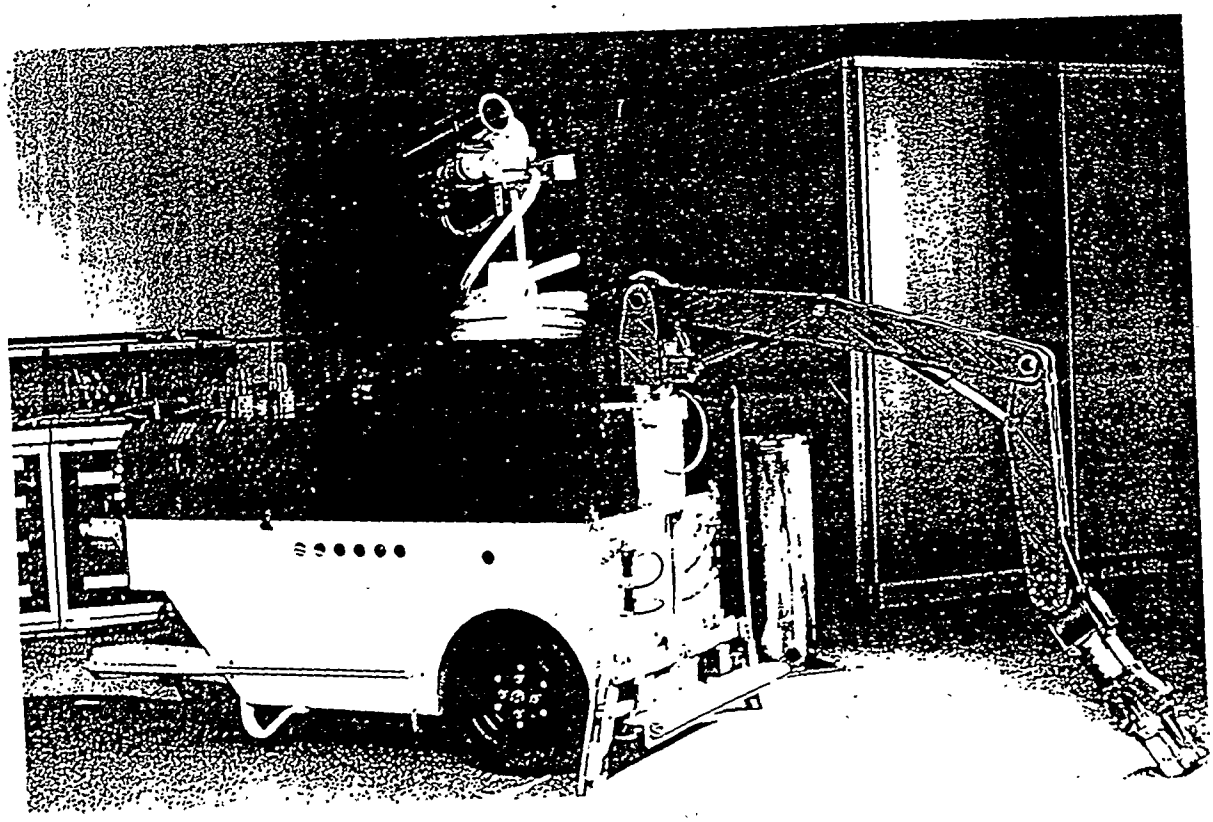

Figure 2. Little MoRT Teleoperator

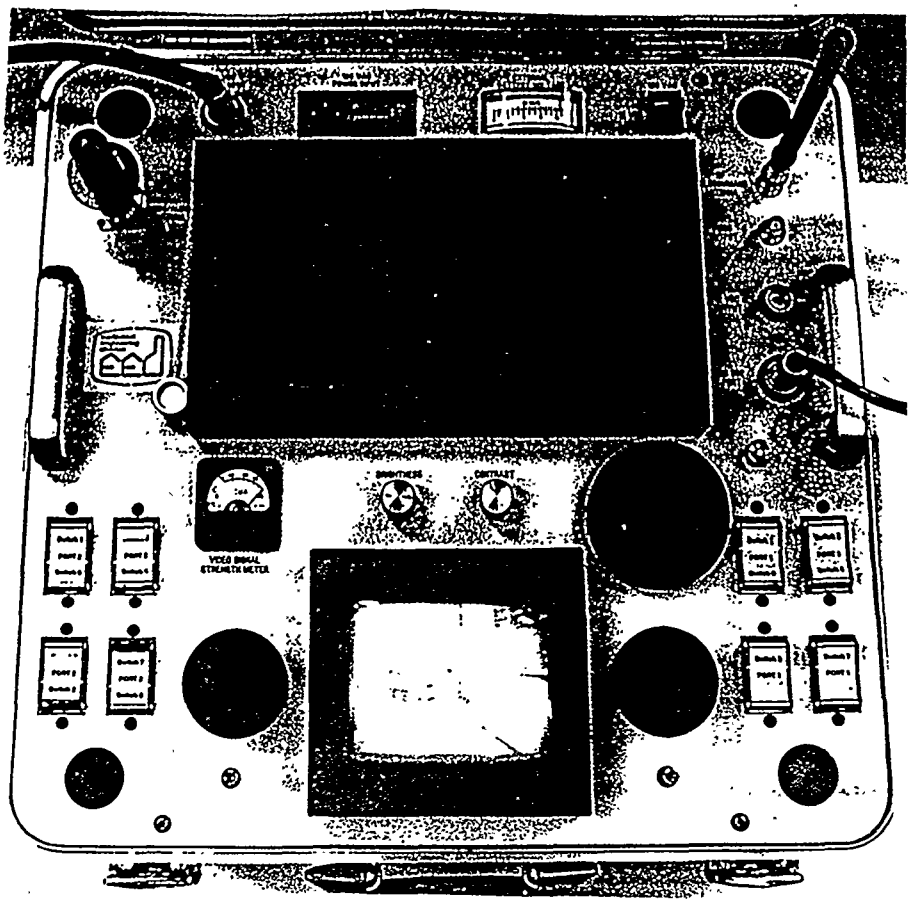

Figure 3. Control Console

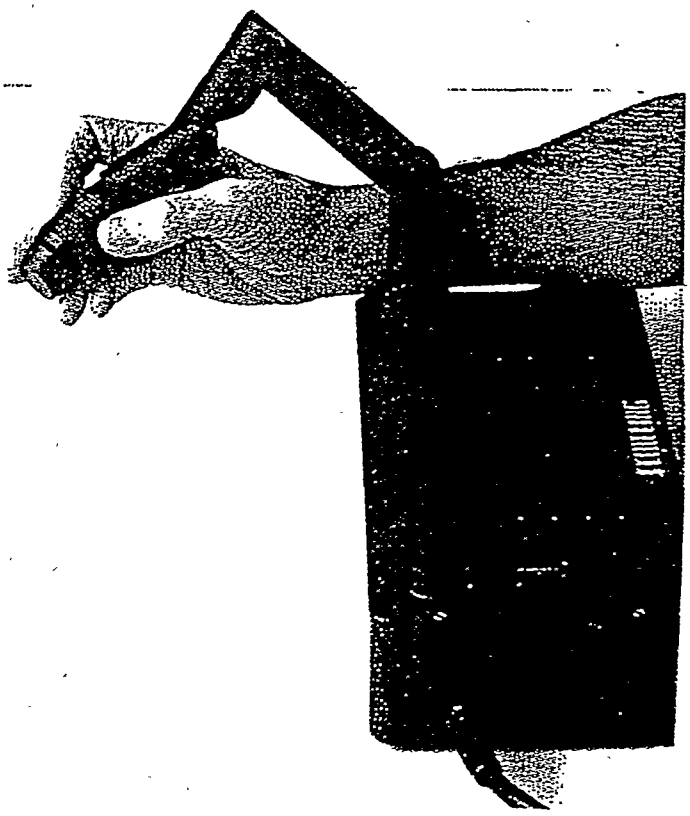

Figure 4. Schilling Manipulator Controller