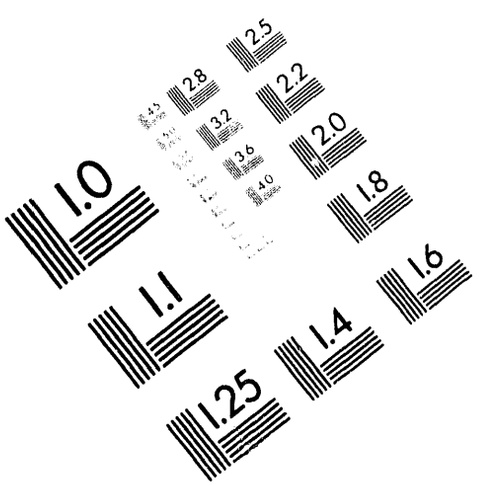

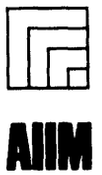

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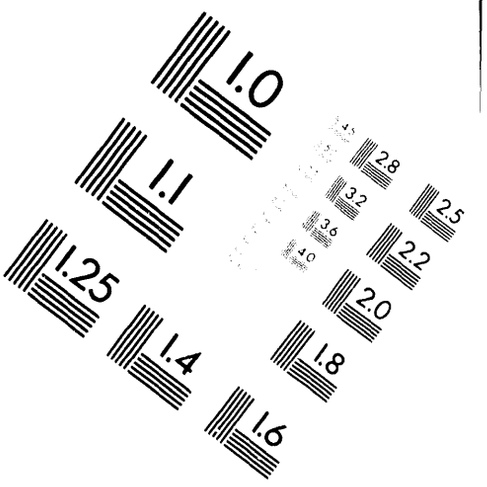

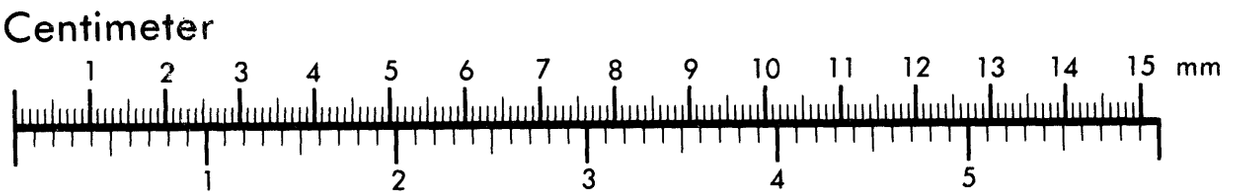

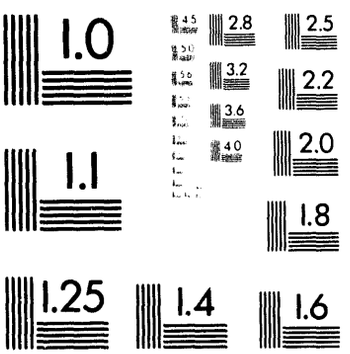

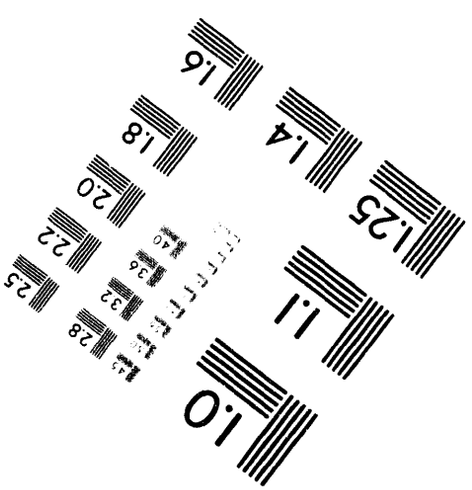

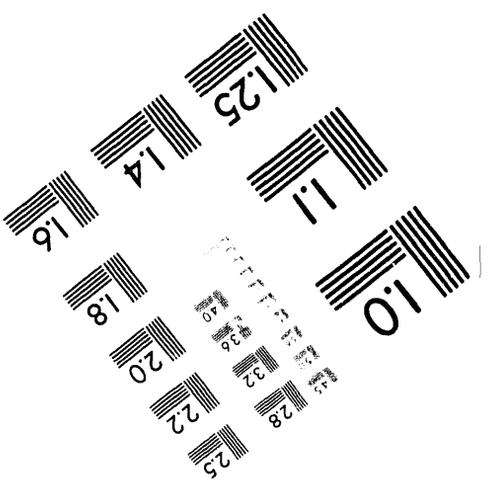

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AN AUTONOMOUS MOBILE ROBOT TO PERFORM WASTE DRUM INSPECTIONS (U)

by

K. D. Peterson

Westinghouse Savannah River Company
Savannah River Site
Aiken, South Carolina 29808

C. R. Ward

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DISCLAIMER

AN AUTONOMOUS MOBILE ROBOT TO PERFORM WASTE DRUM INSPECTIONS

Kurt D. Peterson and Clyde R. Ward
WESTINGHOUSE SAVANNAH RIVER COMPANY
EQUIPMENT & MATERIALS TECHNOLOGY DEPARTMENT
BUILDING 773-A
AIKEN, SC USA 29808
803-725-1180

ABSTRACT

A mobile robot is being developed by the Savannah River Technology Center (SRTC) Robotics Group of Westinghouse Savannah River Company (WSRC) to perform mandated inspections of waste drums stored in warehouse facilities. The system will reduce personnel exposure and create accurate, high quality documentation to ensure regulatory compliance. Development work is being coordinated among several DOE, academic and commercial entities in accordance with DOE's technology transfer initiative. The prototype system was demonstrated in November of 1993. A system is now being developed for field trials at the Fernald site.

BACKGROUND

There are currently thousands of drums of radioactive, hazardous, and mixed waste stored at several Department of Energy (DOE) sites throughout the United States. These drums are being stored in warehouse-like facilities on an interim basis, pending final disposition. Recent emphasis on anticipated decommissioning of facilities indicates that many more drums of waste will be generated, requiring additional storage. Federal and State regulations dictate that hazardous waste covered by the Resource Conservation and Recovery Act (RCRA) be inspected periodically for container degradation and to verify inventories. All known DOE waste storage facilities are currently being inspected manually. A system to perform robotic inspection of waste drums is being developed by the SRTC Robotics Group of Westinghouse Savannah River Company (WSRC) to reduce personnel exposure to potential hazards, to increase cost effectiveness, and to create high quality archives which will ensure regulatory compliance and enhance waste management operations. The robot system's name is Stored Waste Autonomous Mobile Inspector (SWAMI).

The DOE Office of Technology Development (OTD) is directing this effort through the Robotics Technology Development Program (RTDP) and through Morgantown Energy Technical Center (METC). In accordance with DOE's technology transfer initiative, development work is being coordinated among several DOE, academic and commercial entities. In addition to WSRC, participants include: South Carolina Universities Research and Education Foundation (SCUREF); Education, Research and Development Association (ERDA) of Georgia Universities; Martin Marietta Astronautics Division, through a Program Research and Development Announcement (PRDA); and Fernald Environmental Restoration Management Corporation (FERMCO).

OBJECTIVES AND BENEFITS

Program objectives fall into several categories: reducing personnel hazards, increasing cost effectiveness, improving inspection data quality, and providing additional information to enhance waste management operations. Manual inspection of waste drums requires personnel to be in close proximity to waste material for long periods of time, with a potential for exposure to hazardous or radioactive materials. Inspection personnel are also exposed to facility hazards, such as forklift traffic. By performing these inspections robotically, chronic exposure to these hazards is eliminated. Significant cost savings can also be realized by reducing the personnel time required for inspections. Since facilities of this type are also capable of storing thousands of waste drums at a time, manual inspection is extremely tedious, and significant variance of inspection quality can be expected. Robotic inspection of waste containers will not exhibit the degradation of quality associated with human performance in highly repetitive tasks. Drums may be stacked up to four levels high, and SWAMI will inspect top level drums as competently as first level drums, a feat not easily achieved by manual inspections. High quality, consistent inspection data will contribute directly to prevention of waste containment failures.

SWAMI will also provide additional information not currently available with manual inspections. During the inspection, SWAMI will record images of each drum and data associated with it, including the drum's location, bar code number, and a time stamp. This information can be provided to the site's waste management database. Archive images can be retained to note trending or support documentation requirements. SWAMI will also conduct a rigorous survey of the facility floor for potential radioactive contamination. Detection of radioactive contamination will prevent it from being tracked throughout the facility, as might occur during a manual inspection.

PROGRAM

The project has been divided into four phases: prototype development & demonstration, system development, system demonstration & testing at Fernald, and transfer of technology to industry. Prototype development was initiated in 1992, and culminated in a series of demonstrations during the RTDP Robotics for Mixed Waste Operations Demonstration at Savannah River Site in November of 1993 (See Figure 1.). A second vehicle is currently being developed which will incorporate lessons learned during prototype development, include several features not found on the prototype, and address Fernald-specific requirements. SWAMI II is currently scheduled to begin approximately 17 weeks of field demonstrations and testing at Fernald in April, 1995. Following the demonstration, an offering of SWAMI II technology will be made to industry through the Savannah River Site (SRS) Technology Transfer Department.

Since technology transfer to industry is a fundamental program objective, developing a system which performs its function in a cost effective manner is of major import. Development strategy is to utilize known commercial technologies, then apply and integrate them in an innovative way. Vehicle subsystems are being developed independently, and then integrated on the vehicle platform. This modularization of subsystems is also reflected in the system software.

PROJECT CONSTRAINTS

Although the parameters used for developing the vehicle are a composite of the general features of existing and planned storage facilities at the target sites, SWAMI II will initially be deployed at the Fernald Site for testing and demonstrations. As a result, Fernald waste storage specifications are predominately being used to configure SWAMI II. Waste storage facilities at Fernald are a combination of previously existing process facilities and dedicated storage facilities. Although other containers are present in relatively small numbers, SWAMI II will be targeted to inspect 55 and 85 gallon drums. These containers are stacked on pallets up to 4 levels high. Each drum is bar coded with a unique number for identification. Bar code label placement is relatively uniform. Aisles are a minimum of 36 inches wide, many of which do not allow vehicle access from both ends, requiring SWAMI II to back out of aisles. The storage facilities typically do not have

temperature control. Several storage facilities have a drum capacity of approximately 12,000 drums.

Figure 1. SWAMI Demonstration at Savannah River Site

PROTOTYPE DESCRIPTION

The base vehicle is a modified Transitions Research Corporation (TRC) Helpmate®. Several modifications, such as pallet sensing ultrasound transducers were added by TRC. The vehicle is equipped with several systems to perform navigation, collision avoidance and collision recovery. Basic navigation is performed by dead reckoning. An ultrasonic array faces forward and to each side of the vehicle. These sensors are used to register physical features and update navigation. Collision avoidance is also accomplished using these sensors. A forward-looking structured light system provides additional collision avoidance capability. Should a collision occur, pressure sensitive strips located around the vehicle's periphery and compliant bumpers with deflection sensors are used to aid in recovery. Emergency stop switches are also provided. The vehicle's 28 inch overall width allows it to successfully navigate within 36 inch wide aisles.

The prototype subsystems consist of two general groups: vehicle control and sensor subsystems. There are three vehicle control subsystems: the operator interface computer, the onboard control computer, and the TRC vehicle computer. There are 4 sensor subsystems: the radiation monitor, the bar code readers, the video assembly and the position determination system.

The operator interface computer uses two programs to interact with SWAMI: the SWAMI Operator Interface and RADMAP. Both were developed by SRTC. The SWAMI Operator Interface provides remote vehicle controls, an inspection interface, and a configuration interface. RADMAP provides a facility map on the operator screen with the vehicle's current position and status indicated with an icon. Radiation data can also be plotted as it is received from SWAMI or at a later time. Other information can also be displayed, such as alarms. RADMAP has been submitted for copyright by SRTC and will be available for technology transfer.

The onboard control computer consists of 3 microcomputers on a half-height VME backplane, and other peripherals. It communicates with the operator interface computer over a spread spectrum radio ethernet, and with onboard subsystems through serial ports. The onboard computer software was developed by the University of South Carolina through a SCUREF contract. SWAMI is the first commercial mobile robot to utilize GENISAS software from the GISC library created by the OTD Robotics Program.

The image capture/compression/storage system uses fixed mount CCD video cameras and light strobes for each drum level and aisle side. The strobes are used to provide consistent lighting levels while minimizing power consumption. A PC-DOS (486/33 Mhz) computer performs the actual image collection functions. At a command from the onboard control computer, the system captures the digital images, compresses them and attaches other data to the compressed file, including bar code number, drum location and a time stamp. The entire file is then stored to an onboard optical disk. Image capture and compression are performed on commercially available PC-DOS boards.

Fixed mount rastering bar code scanners are used to read the unique bar code number on each drum. A separate scanner is used for each drum level and aisle side. The scanners use a 670 nm visible laser diode light source, which is eye-safe. In addition to scanning side-to-side, a raster feature indexes the scanner through a vertical arc, creating a "scan window". This window allows the scanner to read bar codes whose location and orientation are not precisely controlled. The simple raster feature avoids the complexity, expense, weight and power requirements of omnidirectional units. The scanners communicate with the onboard control computer through a single RS-485 multidrop port.

The radiation subsystem is used to monitor the floor for potential alpha and beta-gamma radioactive contamination as SWAMI performs its inspection. The system uses gas proportional detectors which are in front of the vehicle to locate contamination before the vehicle passes over it. Onboard P-10 gas cylinders are required to continuously purge the detectors. The system is the same as that used on SIMON, another SRTC mobile robot. SIMON has demonstrated that robotic surveys are superior to manual surveys in detecting low levels of radioactive contamination. Data from the radiation subsystem is sent to the operator interface computer in real time over the radio ethernet and displayed on RADMAP as SWAMI performs the inspection.

Due to the large area SWAMI must navigate within, accumulated errors in the base vehicle's dead reckoning navigation system will become significant. The position determination subsystem is used to update the vehicle's dead reckoned position and maintain the vehicle's odometry within acceptable accuracy. Accuracy is required not only for vehicle navigation, but also so that drum images are taken in the proper vehicle position. The system uses a 360 degree scanning laser to read bar coded retroreflective fiducials placed on the facility walls. This information is then used to refine the Helpmate's dead reckoned position.

ADDITIONAL SYSTEM DEVELOPMENT

The SWAMI II system to be tested at Fernald will differ in several aspects from the prototype already demonstrated. Some changes are due to Fernald's specific requirements, while others are simply enhancements that have not yet been implemented.

A significant enhancement for SWAMI II will be offboard analysis of drum images to detect corroded drums. This system is being developed by Martin Marietta Astronautics Division, and will relieve the operator of the drudgery of reviewing all of the drum images collected. The system will present the operator only with those drum images which display a potentially unacceptable corrosion condition. Images will be stored in a mass storage medium to allow viewing of historical images if trending is desired. The image capture system will be modified to provide the resolution required for automatic image analysis.

Scintillation type radiation detectors are being considered for SWAMI II. These detectors do not require P-10 gas, so onboard space requirements are reduced. Lengthy purge times and gas management equipment is also eliminated.

Additional onboard subsystems will include a laser scanning system to detect dented drums, a drum locating system and drum presence detectors. SWAMI currently relies solely on a facility mapping of drum locations to obtain drum images, etc. A drum locating system will be implemented on the bottom level of drums to better determine the actual location of each drum. Drum presence detectors will be used for all drum positions to eliminate false error indications based on bar code noreads.

Since many of Fernald's aisles do not allow vehicle access from both ends, the base vehicle will be modified to allow autonomous backing with sensors to prevent collisions. Additional software modifications will be made to accommodate inspection mission requirements.

SUMMARY

The SWAMI system will provide a safe, cost-effective method to perform mandated inspections of waste drums and obtain superior data for facility and waste management. Because it does not rely on extensive facility modifications, SWAMI will be able to be deployed in a specific facility with a minimum investment of time and capital. By culling out those drums whose condition is acceptable, facility personnel can allocate more time to investigation and disposition of suspect drums.

ACKNOWLEDGMENTS

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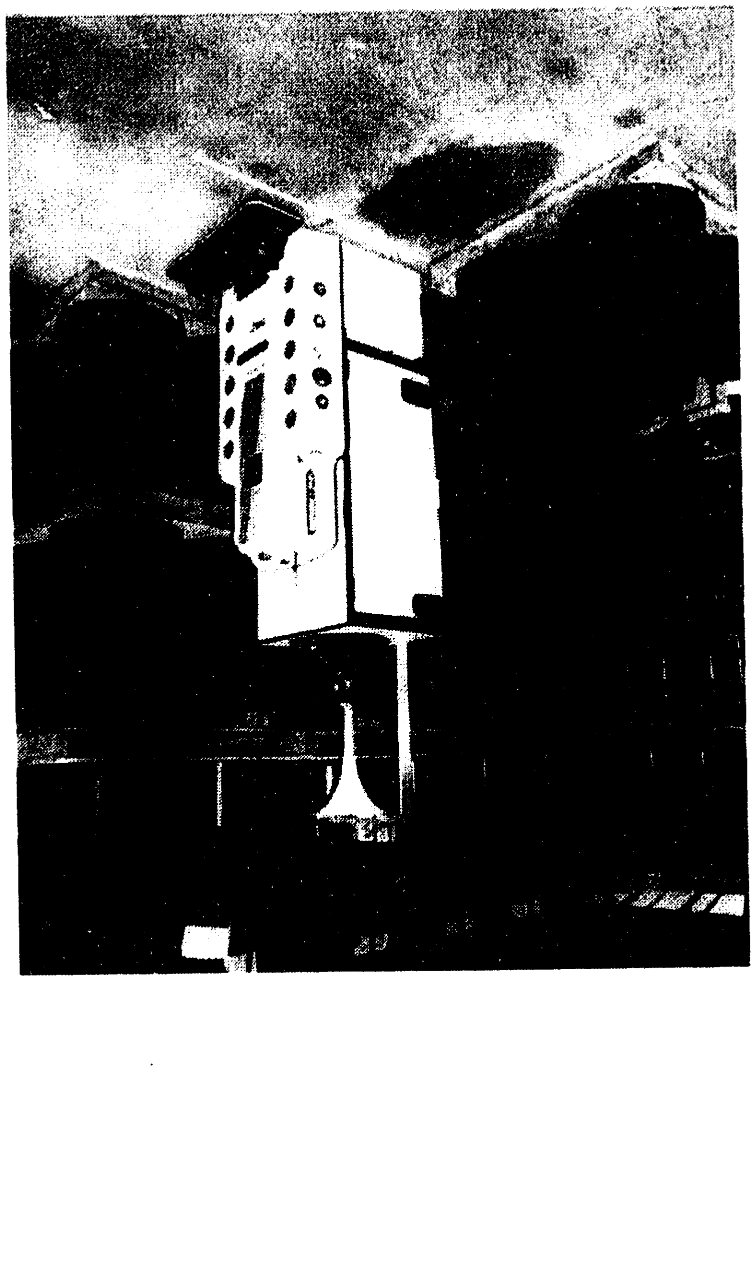

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