

**A MOBILE MAPPING SYSTEM FOR HAZARDOUS FACILITIES\***

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**ABSTRACT**

The Mobile Mapping System (MMS) is a completely self-contained vehicle with omnidirectional capability and extremely good odometry, capable of operation up to 12 hours between battery charges. The platform itself is based on a dual differential drive system with a compliant linkage between the two drive systems. This compliant linkage allows for low-level controller errors to be absorbed by the system and their navigational effects to be compensated for, yielding an extremely accurate navigational capability. Vehicle design also allows for a considerable payload (250 lb) and a large surface area for auxillary equipment mounting (2 by 6 ft). The vehicle supports remote operation by reading commands and writing replies through its serial communications port. Use of a radio-ethernet and a radio-video channel allow for remote video and communications links to be maintained with the vehicle in many remote operation environments.

The MMS uses a structured light system to quickly acquire coarse range images of the environment and a coherent laser radar (CLR) to acquire finer resolution range images. The coherent laser radar can also be used to determine platform position and orientation to millimeter accuracies if targets of known. Sensor range image data as

well as video are off loaded to a remote computer for postprocessing, display, and archiving. Diagrams and images below include an image of the MMS vehicle before addition of sensors, diagram of vehicle with sensors, and computer system connections.

**I. INTRODUCTION**

Under the Department of Energy's (DOE's) Robotics Technology Development Program (RTDP), both Oak Ridge National Laboratory (ORNL) and Sandia National Laboratories (SNL) have been working for the past several years with commercial vendors and universities funded under the DOE University Robotics Program to define and build a mobile mapping system capable of large-scale three-dimensional mapping of unstructured environments.<sup>1</sup> Figure 1 shows the integrated Mobile Mapping System (MMS) that was built under this program. For the past two years, ORNL has taken the lead in program management and system integration, while SNL has focused on rapid world modeling technology and on building a portable structured light mapping sensor and supporting electronics. Other efforts that have been leveraged for this project include the invention and development of a dual differential drive electric vehicle by the University of Michigan and HelpMate Robotics, the development of a Coherent FM laser radar (CLR) by Coleman Research Corp., and the development of a visualization and modeling software package by Mechanical Technology Incorporated. The latter two were developed under a contract managed by DOE's Morgantown Energy Technology Center. Research into many aspects of both video and range image processing is being carried out by the Universities of Tennessee and Florida under the DOE University Robotics Program, and kernels of functionality are planned for integration into the overall project at a later date.

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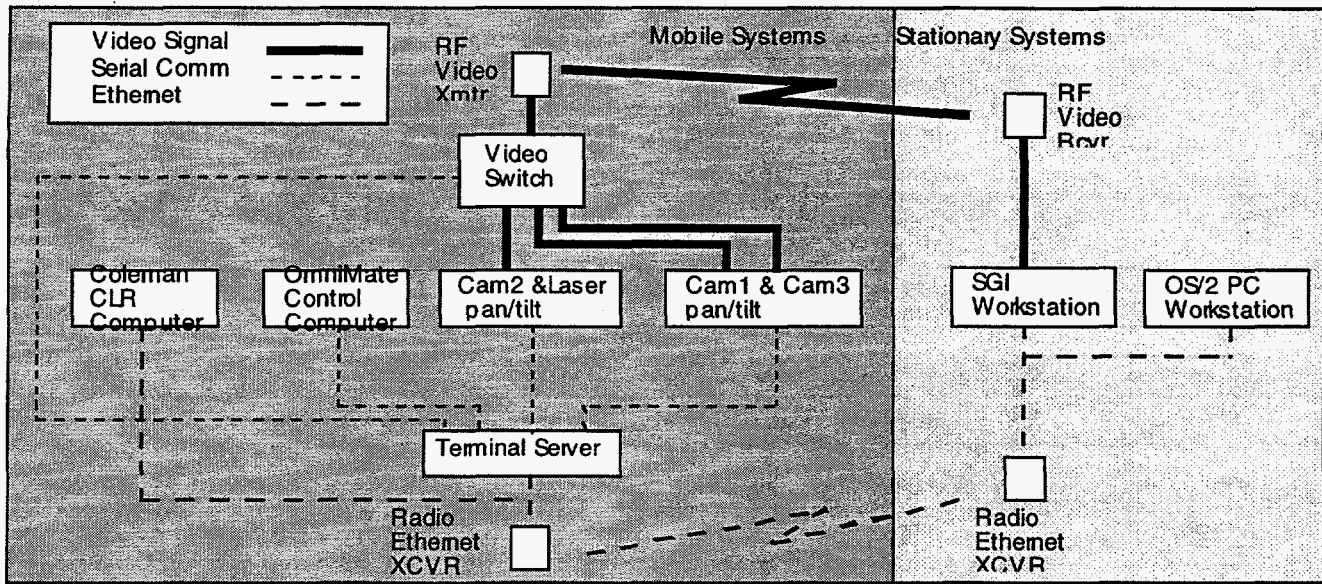


Figure 4. Mobile mapping computers

## B. Computing Systems

The computing resources used for this system are fairly common. Figure 4 shows the arrangement and interconnections of all systems used. On-board (mobile) computers include an IBM compatible 486 with 16 MB of memory and an internal hard disk to control the vehicle. Communications to the vehicle computer are performed through a serial protocol using a UNIX socket mechanism. The vehicle acts as a passive device, interpreting asynchronous commands and responding to status requests. Its local real-time control system is designed to be stable at all times, so no real-time communications with it are necessary. A separate, radio controlled, emergency power off switch is capable of interrupting vehicle wheel power remotely in an emergency situation. The vehicle also contains six perimeter contact switches that interrupt vehicle wheel power if bumped.

The Coleman CLR is controlled by an IBM compatible PC with 32 MB of memory and an internal hard disk running: OS/2, the Coleman radar control application, and a software package for remote operation of any OS/2 native application. The Coleman control computer is shock mounted with laser power supplies and optical switching equipment in a 19-in. equipment rack mounted on the vehicle platform (see Figure 1.). A remote, stationary PC, also running OS/2, is used to remotely control the CLR system for collection of high-density, high-precision range images and for system self location.

A stationary 100 MHz, Silicon Graphics Inc. (SGI) workstation with 64 Mb of memory and an internal hard disk provides the processing capability for the rapid world modeling task. It uses a built-in, real-time frame grabber

card to digitize the selected video source and display it to the user. It also performs image processing on video from one camera in support of the "structured light" ranging system. The SGI workstation runs all the data visualization and user interface software for driving the vehicle and operating the "structured light" ranging system.

## C. 3-D SENSORS

### 1. Coleman Coherent Laser Radar

The Coleman Research Corp. (CRC) laser radar is a prototype frequency modulated, continuous wave, CLR that was developed under a DOE-funded SBIR. The CLR sensor is a very high precision range measuring device with a wide field of view and a programmable scan pattern. It is capable of taking large data sets and can operate without operator intervention after being started.

In tests at ORNL, the system has been shown to be range accurate to about 10 micrometers. The current system has a 2 to 15 meter. range. Field of view is +/- 270° in azimuth, +/- 60° in elevation. It is completely programmable so that a scan of any area within its field of view at any angular resolution that is desired (up to 0.5 arc second) can be created. The system can also be programmed to take range measurements at a predefined set of azimuth and elevation angles.

### 2. Sandia Structured Light System

The second major MMS sensor is a Sandia-supplied 3-D range sensor based on structured lighting (SSL). This system consists of a fan beam laser light source mounted on one of the pan/tilt units and a camera detector mounted

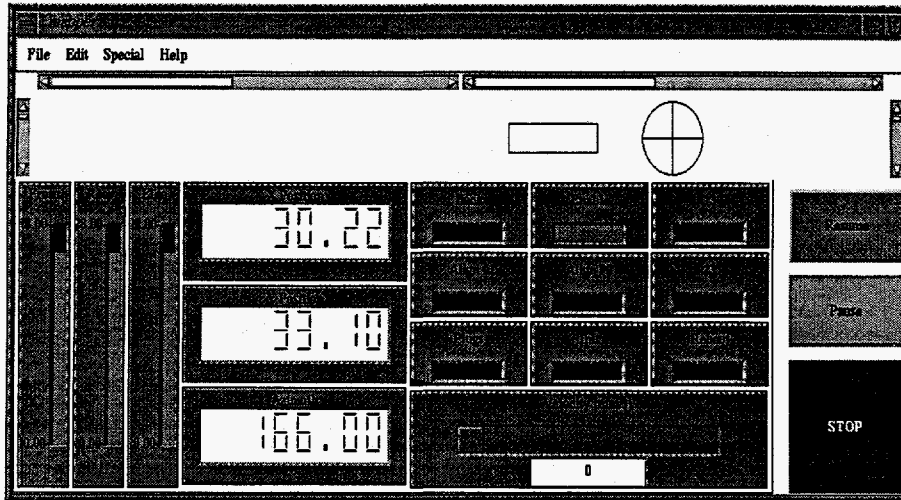


Figure 5. Mobile mapper driving GUI

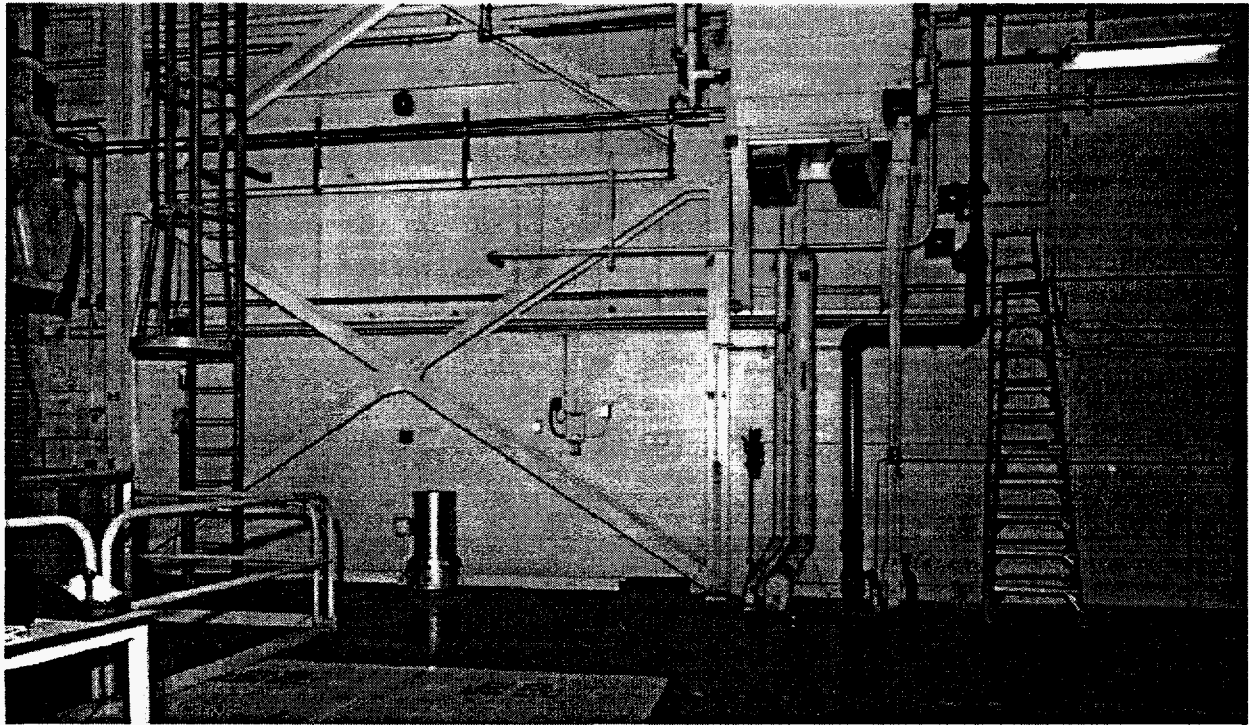
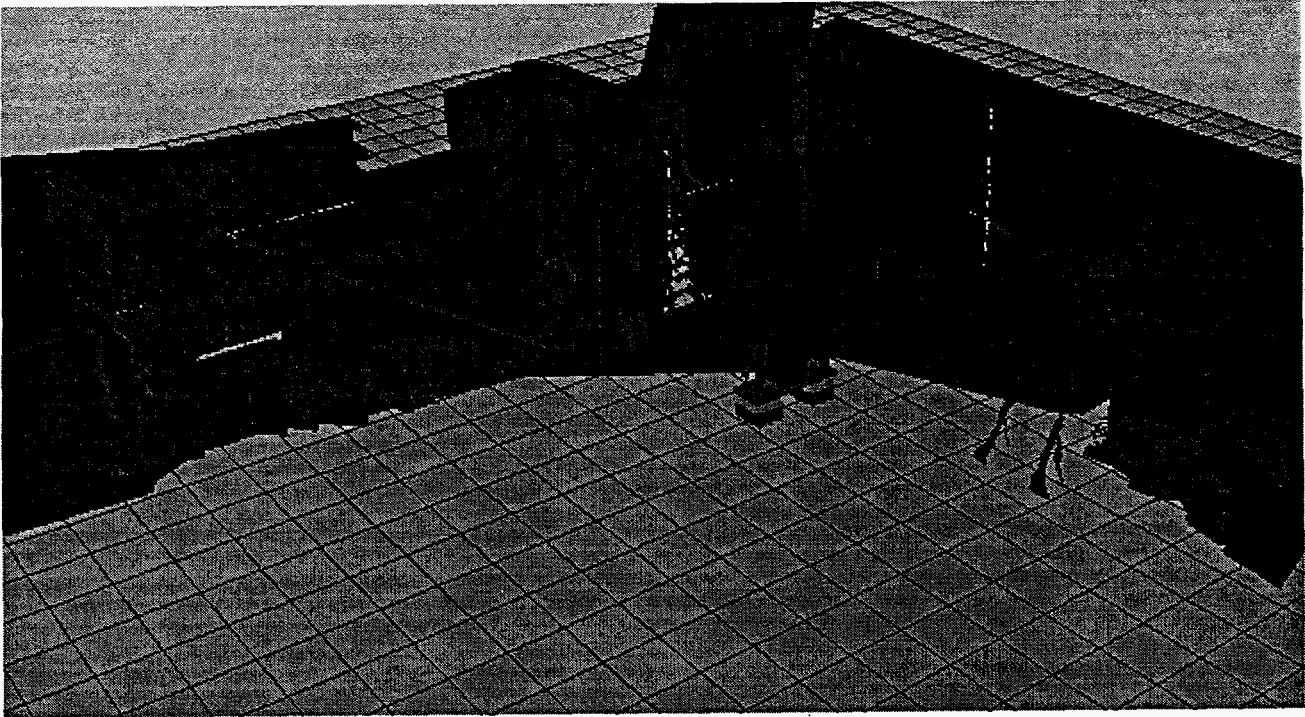


Figure 6. Photo of RTAF south wall



**Figure 8. Composite 3-D Map of RTAF**

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