SAND96-2934C
CONF-970464--3

MINIATURIZED ROBOTICALLY DEPLOYED SENSOR SYSTEMS FOR IN-SITU CHARACTERIZATION OF HAZARDOUS WASTE

G.J. Fischer
Sandia National Laboratories
P.O. Box 5800, MS-1003
Albuquerque, N.M. 87185
(505)844-3671

ABSTRACT

A series of "MiniLab" end effectors are currently being designed for robotic deployment in hazardous areas such as waste storage tanks at Idaho National Engineering Laboratories (INEL) and Oak Ridge National Laboratory (ORNL). These MiniLabs will be the first ever multichannel hazardous waste characterization end effectors deployed in underground high level waste storage tanks. They consist of a suite of chemical, radiological, and physical properties sensors integrated into a compact package mounted on the end of a robotic arm and/or vehicle. Most of the sensors are commercially available thus reducing the overall cost of design and maintenance. Sensor configurations can be customized depending on site/customer needs.

This paper will address issues regarding the cost of field sampling verses MiniLab in-situ measurements and a brief background of the Light Duty Utility Arm (LDUA) program. Topics receiving in depth attention will include package size parameters/constraints, design specifications, and investigations of currently available sensor technology. Sensors include radiological, gas, chemical, electrolytic, visual, temperature, and ranging. The effects of radiation on the life of the systems/sensors will also be discussed. Signal processing, control, display, and data acquisition methods will be described. The paper will conclude with an examination of possible applications for MiniLabs.

This work was supported by the United States Department of Energy under Contract DE-AC04-94AL 85000.
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy.

I. INTRODUCTION

Since the beginning of World War II and the subsequent arms race between the United States and what was formerly known as the Soviet Union, thousands of nuclear warheads were produced. A by-product from manufacturing these thousands of warheads has been highly toxic and radioactive hazardous waste. Typically, the higher level hazardous wastes were stored in Underground Storage Tanks (UST) located at various weapons production plants across the country. Characterizing the waste in the nation's underground radioactive and chemical storage tanks is the first step in the process of treating and disposing of it [1]. In 1990 the U S Department of Energy (DOE) Office of Science and Technology (OST) initiated the Light Duty Utility Arm (LDUA) program. A major portion of this program addresses stabilization and remediation of radioactive wastes accumulated in storage tanks. The priority of this program is verifying tank structural integrity and characterizing the high level mixed waste stored in the tanks.

The Light Duty Utility Arm (LDUA) is a seven degree-of-freedom robotic arm with a telescoping vertical mast. It is being developed to deploy the various MiniLab characterization and other end effectors into the UST's. In addition to the LDUA, the Houdini Robot, a remotely operated tracked vehicle capable of being inserted through the large vertical riser access ports into some of the storage tanks, will also be used as a deployment platform for end effectors in the OST programs.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DISCLAIMER

While the LDUA/OST program has been a driving force for the development of MiniLab end effectors, it is important to note that the MiniLabs may be deployed by any number of means. They can also be made as stand alone units or self-propelled.

In-situ characterization using robotics is a key solution to solving many of the technical problems encountered in waste sampling. Sampling by robotic methods:

* Leaves the hazardous waste samples in the tanks thus, reducing the secondary contamination to material and equipment.

* Reduce the expense and regulatory compliance associated with current core sampling extraction and analysis. Currently this process can take up to six months and cost up to $750,000 per sample, compared to a reusable in-situ MiniLab system costing around $300,000.

* Minimize human exposure to radioactive waste.

* Reduce the time and expense of site characterization by performing in-situ analyses in real time.

* Assesses the entire tank environment rather than just a small portion of the tank directly underneath the access risers as with core sampling.

II. MINILAB

Sandia has a long history in the development and deployment of instrumentation packages in hazardous environments such as the battle field and hazardous waste sites (see table 1). With the availability of today's real time computing power and vast array of commercially available sensors we can now develop systems that can be described as "chem. labs in a box." [2]

MiniLab's typically are cylindrically shaped packages of a given diameter and length. The entire cylindrical surface is smooth with no penetrations. This allows for easy cleaning and decontamination. A top plate or Tool Interface Plate (TIP) seals one end of the cylinder. The TIP includes an interface with quick connect power/utility connectors and a handle which is gripped by the deployment vehicle. A bottom plate seals the lower portion of the cylinder and serves as the main mounting platform for most of the on-board instrumentation. Viewing ports for the various instruments are machined directly into the bottom plate and are sealed with either clear fused quartz discs (for camera/lighting), .003 inch thick stainless wafers (for radiation monitors), or sliding gate valves (for infrared pyrometry). The materials used for the MiniLab housing components can be anything from plastic to stainless steel depending on the application and the use environment.

MiniLabs are specific to the site needs and constraints. However, many of the MiniLabs designed to date contain many similar components. Generally, they include a video and lighting system for tank viewing and inspection, an ultrasonic or laser range finder for position and standoff control, and on-board or external temperature sensors for monitoring the heat generated by the components or general atmospheric conditions.

Each MiniLab designed to date has had at least one obvious and unique feature which sets it apart from the others. The Hanford MiniLab incorporated a miniaturized penetrometer capable of measuring viscous properties of sludge type alkaline waste materials. The INEL MiniLab will have a chemical analysis probe which will be submerged directly into the acidic waste. The probe will be capable of measuring the pH and chloride levels, galvanic rates, polarization admittance instantaneous rate (PAIR) , and the waste specific gravity and particle size distribution. A drilling head used on the ORNL MiniLab is it's unique feature. A flat bottomed drill revolves around a stationary collimator which houses a Cadmium Zinc Telluride (CZT) radiation sensor. This sensor will provide discriminating information on radiation energy levels as a function of depth into the gunite wall or floor structure of the ORNL UST.

III. SENSOR TECHNOLOGY

Commercial sensor technology has progressed rapidly over the last few years. Most of the same measurements can now be made in a number of ways with many different types of transducers and sensors. For instance, distance can be measured using ultrasonic, laser, capacitive, or resistive methods. Selecting the best sensor match for the application is a consideration which is designed into each MiniLab.

Packaging of sensors can sometimes present some special challenges. For instance, the use of an infrared thermocouple in the tank environment, as with the INEL MiniLab, presents some special problems regarding the mechanical design. The use of a low temperature infrared device requires a window that can transmit very long wavelength infrared. Typically, windows of silicon or germanium are used on these thermocouples. Unfortunately, neither of these materials is sufficiently resistive to the nitric acid environment found in INEL's tanks. In fact, none of the common long wave infrared materials such as sodium chloride, silver chloride, and germanium oxide exhibit sufficient chemical resistance. Also, materials known to be chemically resistant to the nitric acid environment such as quartz or sapphire do not transmit enough infrared in the long wavelength region to be used here.

For this reason, a mechanical system for protecting the infrared thermocouple was devised. The system consists of a small gasketed door operated by a pneumatic cylinder and an internal chamber for the infrared thermocouple. The body of the thermocouple is sealed to the chamber so that the chamber itself is considered part of the external surfaces of MiniLab. The door is opened only when the thermocouple is being used and since the device is intended primarily for long range scanning of the waste the risk of contaminating the thermocouple is quite low.

Another important consideration in selecting commercial sensors is whether they work according to the manufacturer specifications, or at all. In designing a sensor system such as MiniLab, all commercial equipment is prequalified to insure that performance meets the sensing measurement goals.

IV. RADIATION HARDENING

Wherever possible, MiniLabs are designed to be inherently radiation and chemically tolerant. This is achieved by selecting materials which are resistant to the effects of radiation and harsh chemicals. For example; using stainless steel or anodized aluminum instead of low carbon steel for the outer housing and kalrez instead of viton o-rings for seals. Plastic materials such as teflon, which has a poor reaction to ionizing radiation, are avoided.

Radiation hardening key MiniLab components can be an expensive proposition. Typically a single radiation hardened microprocessor can cost in excess of $100,000 compared to a commercially available one costing a few hundred dollars. SNL's design approach has been to modularize key components such as on-board computers, video equipment, and lenses and package them in such a way that makes their replacement easy so that standard equipment can be used.

Total dose radiation dosimeters or RADFETs are included in the MiniLabs for use in determining when radiation susceptible components will need replacement. A RADFET, as described by the manufacturer, is an integrated dosimeter for ionizing radiation. Dose is determined by the measurement of a long-lived trapped charge, generated by photons and particles in a silicon dioxide layer grown on silicon. The total dose accumulation is measured primarily to monitor the absorbed dose by sensitive components.

V. SIGNAL PROCESSING

Signal processing can be achieved in a number of ways. Typically the end effector can acquire up to 14 channels of data simultaneously. All data, except video images, are transmitted digitally, allowing the induced noise and the connections to the MiniLab sensor head to be minimized. The digital control allows individual instruments to be turned on and off and different instrument ranges to be selected while the head is deployed. In addition, the communication protocol is converted to a standard (such as RS-232 or RS-485) to allow operation of the MiniLab from any properly configured serial port.

With the INEL MiniLab a single board computer (SBC) will be used to control and process MiniLab's sub-systems and functions. The embedded SBC which incorporates a micro processor is placed in an instrument enclosure, providing external system control and elimination of exposure to radiation. The SBC will support instruments located inside the MiniLab and in the instrument enclosure. The SBC will communicate with MiniLab to collect data and issue control signals. In addition, the SBC will communicate with INEL's data record system via an RS-485 connection, thus providing data acquisition and control for all instruments.

The ORNL MiniLab will be supplied and connected to a service umbilical which provides all input/output signal, power, and utility cables. The 200 foot umbilical connects directly to ORNL's existing VME computer. Signals are issued and collected through the VME.

VI. FUTURE MINILABS

Other future MiniLabs could be made to be self-propelled and completely autonomous. An autonomous vehicle would be capable of making its own decisions based on sensor inputs. For example, in tank leak detection for liquid waste the MiniLab would be able to sniff out where the leaks are occurring.

Tethered MiniLab vehicles could be used for data collection in piping or pressure vessels. For example, visual or ultrasonic inspection of welds could be performed throughout the length of the system. The MiniLab could be easily retrieved by simply reeling it back in.

Sandia National Laboratories is just beginning to conduct further research that will allow this type of system, including sensors and onboard computing, to be reduced to chip size. Imagine the applications for MiniLabs that can fit in a ball point pen.

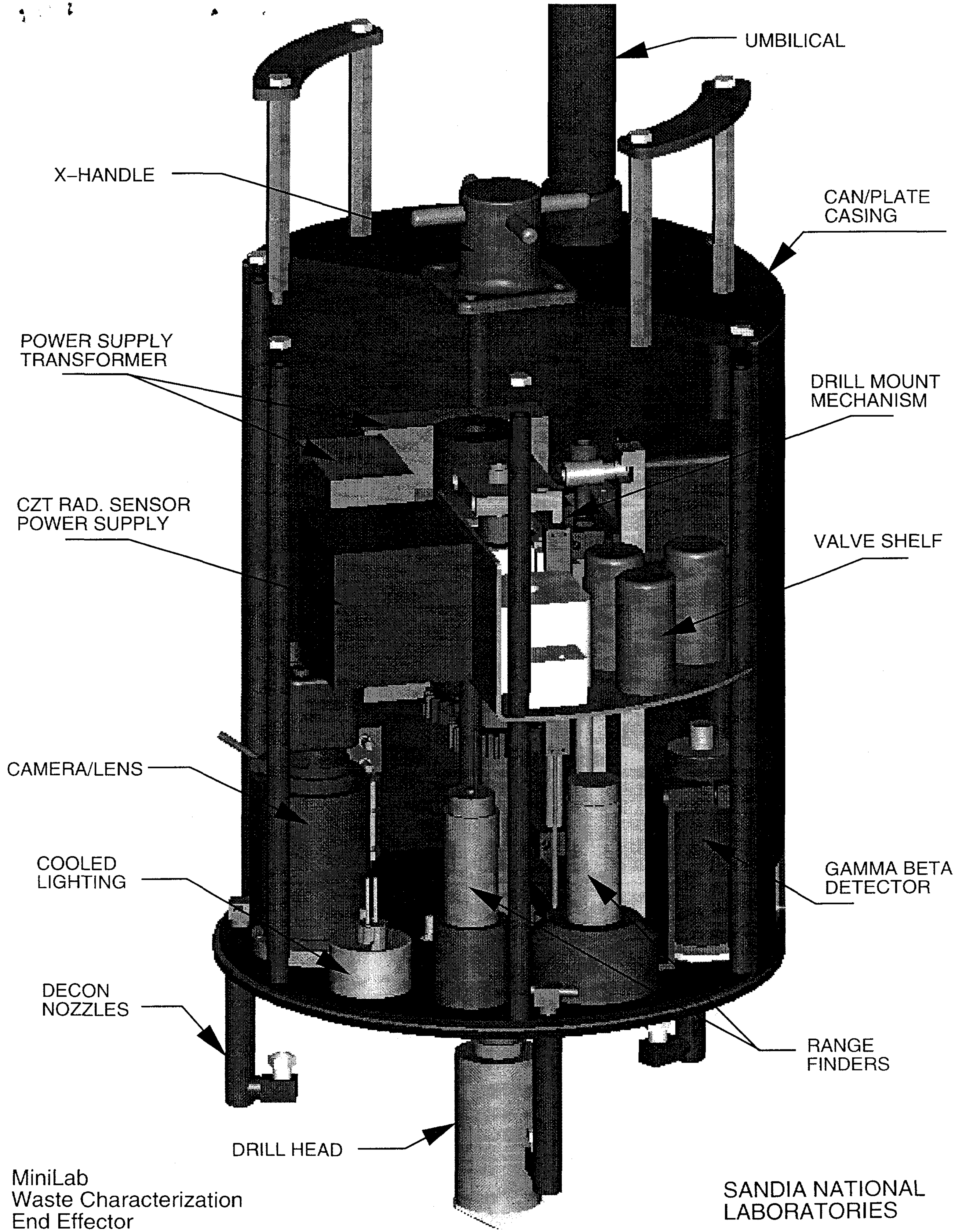
VII. REFERENCES

1. R.E.Gephart and R.E. Lundgren, "Hanford Tank Clean up: A Guide to Understanding the Technical Issues, second printing, July, 1996

2. B.R. Davies, "Remediating Hazardous Waste Robotically using a High-Level Control System and Real-Time Sensors," Proc. SPIE Int. Symp. on Optical Tools for Mftg. and Advanced Automation, Telemanipulated Technology Conference, Boston, MA, September, 1993.

YEAR BUILT	FOR WHOM	SENSORS
1991	Sandia Labs Internal	gas chromatography gamma spectrometer temperature pressure humidity oxygen hydrogen
1992	Westinghouse Hanford	hydrogen oxygen tip force viscosity pore pressure
1993	Idaho National Engineering Lab	metal detector dosimeter ultrasonic proximity ammonia gas sensor pyrometer fluxgate magnetometer
1994	Westinghouse Hanford	tip force pore pressure viscosity pH contact temperature IR pyrometer dosimeter gas specific sensor video camera & lighting conductivity
1994	Sandia Lab Internal	laser rangefinder metal detector
1995	Sandia Lab Internal	6-axis magnetometer IR pyrometer video camera
1995 (in progress)	Idaho National Engineering Lab	pH chloride concentration polarization admittance oxidation/reduction specific gravity video cameras & lighting infrared pyrometry ultrasound proximity total dose monitor
1996 (in progress)	Oak Ridge National Lab	dosimeter ultrasound proximity wall drilling hole depth measurement isotope identification total dose monitor video camera & lighting

TABLE 1



MiniLab
Waste Characterization
End Effector

SANDIA NATIONAL
LABORATORIES