MOBILE MUNITIONS ASSESSMENT SYSTEM FIELD CAPABILITIES

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Abstract

The United States has developed, stored, tested, and conducted disposal operations on various forms of chemical munitions for several decades. The remnants of these activities have resulted in the presence of suspect CWM at more than 200 sites in the United States, the District of Columbia, and the U.S. Virgin Islands. An advanced Mobile Munitions Assessment System (Phase II MMAS) has been designed, fabricated, assembled, and tested by the Idaho National Engineering and Environmental Laboratory under contract to the U. S. Army's Project Manager for Non-Stockpile Chemical Materiel for use in the assessment and characterization of "non-stockpile" chemical warfare materiel (CWM).

The Phase II MMAS meets the immediate need to augment response equipment currently used by the U.S. Army with a system that includes state-of-the-art assessment equipment and advanced sensors. The Phase II MMAS will be used for response to known storage and remediation sites. This system is designed to identify the munition type; evaluate the condition of the CWM; evaluate the environmental conditions in the vicinity of the CWM; determine if fuzes, bursters, or safety and arming devices are in place; identify the chemical fill; provide other data (e.g., meteorological data) necessary for assessing the risk associated with handling, transporting, and disposing of CWM; and record the data on a dedicated computer system.

The Phase II MMAS is capable of over-the-road travel and air transport to any site for conducting rigorous assessments of suspect CWM. The Phase II MMAS utilizes a specially-designed commercial motor home to provide a means to transport an interactive network of non-intrusive characterization and assessment equipment. The assessment equipment includes radiography systems, a gamma densitometer system, a Portable Isotopic Neutron Spectroscopy (PINS) system, a Secondary Ion Mass Spectroscopy (SIMS) system, air monitoring equipment (i.e., M-90s and a field ion spectroscopy system), and a phase determination system. Command and control equipment includes a data acquisition and handling system, two meteorological stations, video equipment, and multiple communication systems. The Phase II MMAS motor home also serves as an environmentally controlled on-site command post for the MMAS operators when deployed. The data developed by the MMAS will be used to help

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determine the appropriate methods and safeguards necessary to transport, store, and dispose of agent-filled munitions in a safe and environmentally acceptable manner.

Background

Beginning in World War I, the United States has produced a large quantity and variety of CWM to deter other countries from using chemical weapons of their own. Much of this CWM comprises what is called the national "chemical stockpile," which includes pre-mixed, or unitary, chemical warfare agents (e.g., nerve and blistering agents) in different types of munitions and in bulk quantities. Due to normal aging, the "chemical stockpile" presents a storage risk; hence, in the DOD Authorization Act of 1986, Congress directed the U.S. Army to destroy the chemical stockpile. The Army has developed a schedule for completing the destruction of the stockpile. This schedule complies not only with the direction from Congress, but also with an international treaty known as the Chemical Weapons Convention (CWC). The CWC, a revolutionary disarmament treaty, calls for the destruction of chemical weapons from the stockpiles of all nations.

In addition to the national "chemical stockpile," other CWM exists and is referred to as "non-stockpile chemical materiel" or NSCM. NSCM includes: 1) CWM that was previously disposed of by burial, 2) CWM recovered from firing ranges and former burial sites, 3) binary (i.e., two-part) chemical weapons, 4) former chemical weapon production facilities, and 5) miscellaneous CWM. The number of locations with NSCM is substantially greater than the number with "chemical stockpile" materiel; however, the quantities of NSCM are known to be much smaller than the quantity of stockpile materiel. On the other hand, NSCM is more diverse in its characteristics; for example, NSCM includes many more types of chemical weapons, different types of chemical warfare agents, and industrial chemicals and weapons in various conditions.

In October 1992, Congress directed the U.S. Army to submit a plan for destroying NSCM after the CWC treaty became effective. The United States and 164 other nations signed the CWC on January 13, 1993. The United States ratified the CWC on April 25, 1997, and it became active as of April 29, 1997. To achieve the destruction of chemical agents contained in the non-stockpile CWM, the Army proposes to select one or more strategies that (a) provide the highest level of protection for human health, safety, and the environment, and (b) enable the United States to comply with the requirements of the CWC.

A primary mission of the NSCMP is to respond to a variety of situations involving discovered, recovered, or buried CWM. The identification, recovery, storage, transport, and disposal of NSCM is anticipated to involve a varied array of chemical materiel, agents, munitions, operations, and locations. The NSCM is in a wide array of containers, configurations, and conditions. Safe and environmentally acceptable disposal methods of the materiel will require nondestructive techniques that allow evaluation and assessment of the chemical agents and containers in as safe a manner as possible. Since nondestructive evaluation (NDE) techniques can evaluate a container without compromising the structure of the container, the NSCMP is developing these techniques and technologies for evaluations to determine how valuable a tool they can be. One of these integrated evaluation and assessment systems is the MMAS currently being developed by the Idaho National Engineering and Environmental Laboratory (INEEL). The MMAS has been developed in two phases. The Phase I MMAS was designed, fabricated, and assembled in FY-96 and the first half of FY-97 and was turned over to the NSCMP in June 1997 following extensive acceptance testing. In order to "quickly develop" the Phase I MMAS, the INEEL used a "rapid prototyping" approach that has been successfully used at the INEEL in the past. This development method relies on the ingenuity and developmental skills of engineers and technicians to fabricate and assemble hardware without the use of detailed design drawings. In addition, close coordination and involvement of the end user is essential with this development approach. Final drawings are completed after assembly, testing and modifications are complete. This approach reduces the cost and schedule and improves the product because changes are easy to accomplish.

The Phase I MMAS is a goose neck trailer towed by a commercial four-wheel drive pickup truck. The trailer is loaded with an interactive network of non-intrusive characterization and assessment equipment, including: two radiography (X-ray) systems, a PINS system, chemical agent detection equipment (i.e., M-90s), a data acquisition and handling system, two meteorological stations, video equipment, communications equipment, and various support equipment. The Phase I MMAS has two onboard computers for data collection, processing, and storage. High speed modems provide a data link via phone lines, cellular phone service or satellite links to the main MMAS database. The data developed by the Phase I MMAS will be used to help determine the appropriate methods and safeguards necessary to transport, store, and dispose of the agent-filled munitions in a safe and environmentally acceptable manner. The total success of this program hinges on the performance of each of the subsystems that make up the Phase I MMAS.

The second MMAS system (hereafter referred to as Phase II) is a complete, state-of-the-art system capable of traveling to any site for conducting rigorous assessments of suspect CWM and will be turned over to the NSCMP in late FY-99 or early FY-2000. In addition to the assessment systems included in Phase I, the Phase II MMAS will incorporate a SIMS system, an advanced real-time radiography system, an enhanced air monitoring system, and, possibly, a phase determination system, a gamma densitometer system, a Raman spectrometer, and other advanced monitoring and NDE equipment.

Physical Description of the Phase II MMAS

Like the Phase I MMAS, the Phase II MMAS will be deployed to the various chemical warfare materiel discovery and remediation sites within and outside the continental United States. Once at the site, it will be used to identify the munitions type, evaluate the condition of the CWM, determine if fuzes, bursters, or safety and arming devices are in place, identify the chemical fill, and provide other data necessary for assessing the risk associated with handling, transporting and disposing of CWMs.

Phase II MMAS Vehicle

The Phase II MMAS vehicle is a 35-foot diesel-powered, commercially available motor home (see Figure 1). The motor home serves as a command and control platform and is capable of transporting and supporting various NDE subsystems and support equipment. The motor home is designed with air ride suspension to reduce the shock and vibration loads on the equipment it carries. It is designed to be transportable over land via roadways and by air onboard either a C-17 Globemaster III or a C-5A Galaxy military cargo plane. This "transportability" allows the system to be deployed to the various CWM sites.

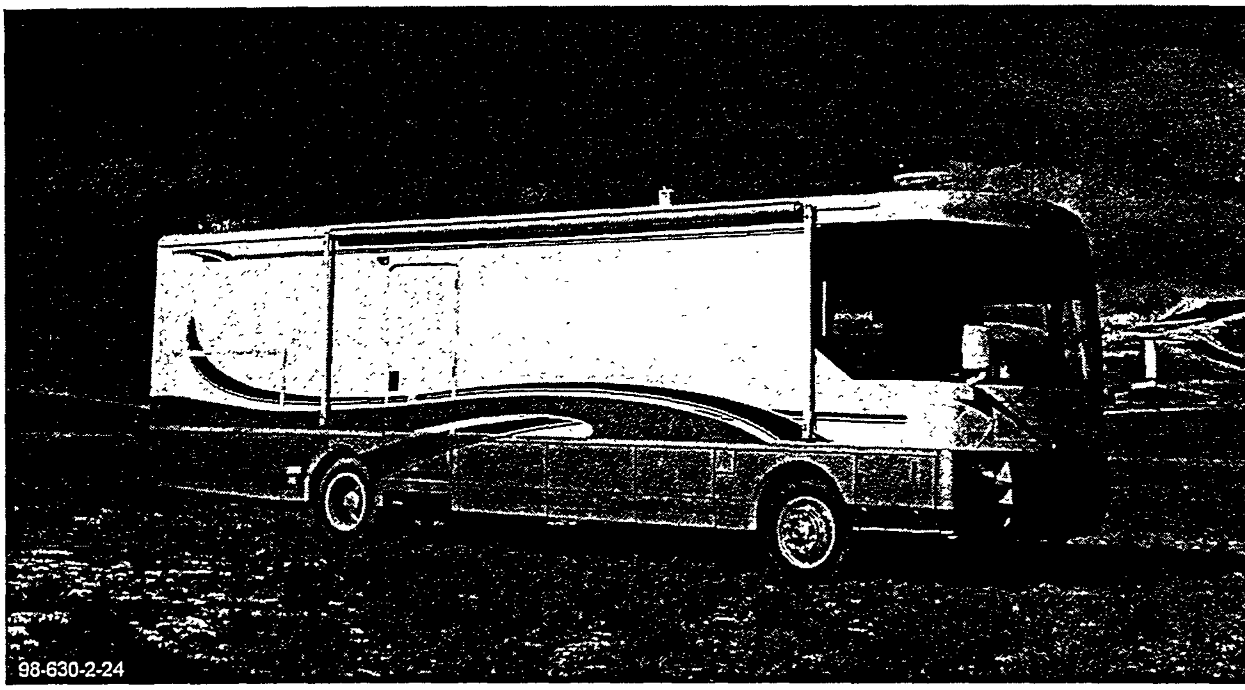

Figure 1. Photo of Phase II MMAS.

The basic layout of the Phase II MMAS motor home is shown in Figure 2. The back of the motor home and its "basement" areas are configured primarily for storage of the NDE equipment that is used in the field. The NDE equipment is stored in handling containers that can be easily unloaded from the motor home and moved close to the remediation site. The middle of the motor home houses the computer systems, communications, instrumentation, video equipment, workstations and all reference and training material.

The Phase II MMAS is designed to operate in a broad spectrum of climates. For cold weather operations, heat is provided via diesel-fired, hot water heater system to maintain the interior of the enclosure at nominally 70° F. In warm weather, the MMAS is air conditioned by a "basement"-mounted forced air system.

The motorhome includes an electric power supply and distribution system that provides the needed power for operations of all the NDE equipment and the enclosed operations area. The power supply and distribution system includes an Uninterruptible Power Supply (UPS) to

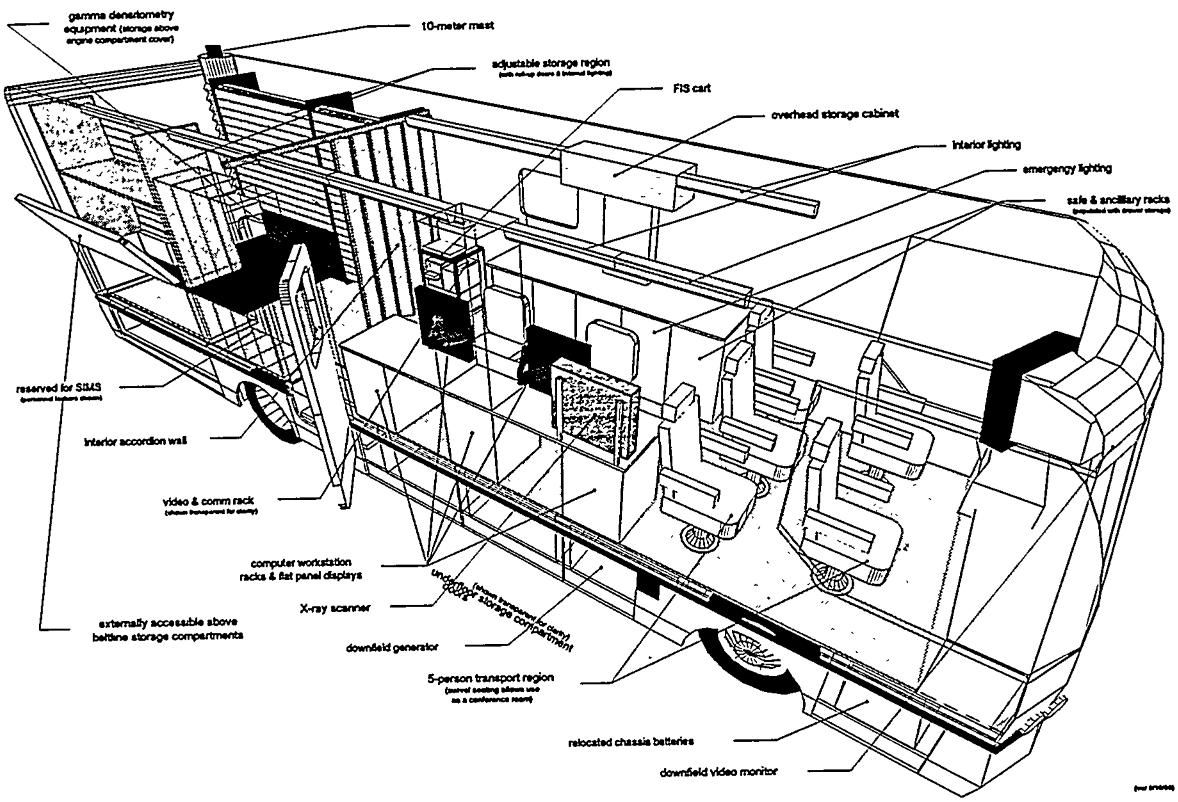

Figure 2. Phase II MMAS motorhome layout.

provide temporary backup power in the event of loss of primary power. The electrical power for the interior lights and all the active systems located in the motor home is provided by a 12.5-kW generator mounted on the motor home or by plugging into a facility outlet. A single power distribution control center is located within the motor home and is clearly labeled for ease of operations. Power outlets are distributed throughout the interior and exterior of the motor home. A 3.5-kW generator is used for power at the location of the item being inspected.

Command and Control Capabilities

The Phase II MMAS has extensive command and control capabilities including communications equipment, data management hardware and software, video systems, and meteorological monitoring capabilities.

Two cellular phones are installed in the motor home. Standard telephone jacks are installed near two operator stations and an external jack is provided to allow connection to a telephone landline. A satellite-based communications system is included and can be used to ensure communications are not compromised if the MMAS happens to be in a cellular phone black-out area within the United States. UHF and VHF hand-held radios are included to provide communications between the motorhome and personnel downrange at an assessment site. In addition to the hand-held radios, a wireless radio system is provided for use by TEU personnel who are downrange and dressed in personnel protective equipment (PPE). This wireless radio system includes six radio units, each with throat microphones and ear pieces. The signal from each wireless set is transmitted by RF to a "repeater" station located in the motor home and sent out to all other wireless sets. In addition, capabilities are provided to "patch" voice transmissions from the wireless sets through the two-way radio system.

The Phase II MMAS has an extensive personal computer (PC)-based data acquisition and handling system used primarily for system operations and temporary collection and storage of data of the NDE and other systems used within the MMAS. Two primary computer systems, with adequate random access memory (RAM), storage and processing speed, and a printer, are included with the system for redundancy and backup purposes. The equipment is compatible with the data acquisition hardware used with the NDE and other systems used in the MMAS. The data acquisition system is powered through the UPS to allow an orderly shutdown if there is a loss of electrical power. The MMAS also includes the capability to transmit data from the motor home to an "offsite" location for review and analysis. A laptop computer is included with the Phase II MMAS. Modems are installed in each of the three computers and each is capable of transferring data via a cellular phone as well as via regular analog, digital, or PBX telephone lines. Additionally, the satellite-based system can provide the capability to transmit data gathered by the MMAS at high speed (i.e., 60 kbps) from remote locations to subject area experts and decision makers. The laptop provides the ability to transfer data away from the motor home.

Data is collected by the various systems (PINS, SIMS, radiography, meteorology, etc.) utilizing their own data acquisition hardware and software. The data is then transferred to the MMAS DAS for storage, manipulation and transmitting to other locations. This transfer requires complete hardware and software compatibility. The Phase II MMAS data acquisition and handling system includes a library for known information about the munitions that the MMAS is expected to encounter. The Phase II MMAS DAS was develped to be compatible with the PMNSCM database, MARB97, to facilitate ease of transfer of data to and from this database.

Two simple, self-contained meteorological stations are included with the Phase II MMAS to obtain information on the current atmospheric conditions at the remediation site. The stations provide information on wind speed, wind direction, humidity and temperature. This information is needed for dispersion predictions that can be used to evaluate the threats posed by uncontrolled chemical releases during the munition recovery activity. Two deployable masts (2 meters and 10 meters in height) are included. The 2-m mast is a tripod that is deployed in the field away from the motor home and near the incident site. A RF signal transmits the meteorological data from the 2-m mast back to the MMAS motor home. The 10-m mast is a pneumatically operated telescoping mast that is integrated into the rear of the motor home for deployment directly above the MMAS. The 10-m mast is hard wired into the motor home for power and to transfer the meteorological data to the MMAS data system. Data from these two stations is fed into the U. S. Army's dispersion prediction code, D2PC, to determine various hazard zones.

A variety of video equipment is supplied with the Phase II MMAS. This equipment is used to document the field operations as they proceed. An auto-focus, "point-and-shoot" 35-mm camera, a digital camera, a Polaroid® camera and a portable Hi8 video camera along with video players, monitors and video matrix switch are included.

The Phase II MMAS includes safety equipment, such as fire extinguishers, first aid kits, chemical protective suits and man-portable breathing air tanks. A standard set of EOD equipment (e.g. shovels, rakes, hammers, wrenches, pails, and ropes) is included. In addition, equipment for the safe handling of materials associated with the operations of the NDE systems is included; e.g. rubber gloves, face shield and protective aprons.

Assessment Equipment

One of the primary functions of the Phase II MMAS is to transport a wide variety of NDE assessment systems. Presently the Phase II MMAS includes the following NDE systems:

1) Two commercially-available, field portable radiography (i.e. X-ray) systems that can provide detailed images of the munition; an ANDREX Smart-300 unit with a 300 kV X-ray generator (Figure 3) and an RTR-4 unit with a 150 kV pulsed X-ray generator (Figure 4). Each of these radiography systems includes an operator control unit. Multiple imaging systems are available. Standard transmissive and reflective Polaroid film is carried on the MMAS along with film cassettes and a portable Polaroid film processor. Multiple X-ray imagers include the 8 in. x 10 in. solid state camera imager which comes with the RTR-4 package. A larger 13 in. x 17 in. imager is also available. An advanced linear array, which is part of the digital radiography and computed tomography system, can be used with the ANDREX x-ray generator. Each imaging system has associated advantages and disadvantages which are considered by the operators in the field when selecting the type of imaging technique to be used. Complete assessment may require more than one imaging technique be used. A flatbed scanner/light table is installed in the motor home to digitize the radiograph and store the image in the Phase II data system and for viewing X-ray film.
2) An advanced radiography system, the digital radiography and computed tomography (DR/CT) system (Figure 5). This system measures the attenuation of X-rays through an object to determine the physical structure of the object in both two-dimensional sections and three-dimensional volumes. The detailed images provided by a DR/CT system can provide significantly more information about the munition firing train and the overall condition of the munition than traditional radiography systems.
3) PINS, a non-destructive analysis technique, which detects characteristic gamma rays from nuclei activated by neutrons. The PINS system is used to identify the elements within a munition, thereby disclosing the contents without drilling the casing or handling the chemicals inside. The PINS system (Figure 6) is comprised of five basic components; a gamma-ray spectrometer, a Nomad Plus® multichannel analyzer, a californium neutron

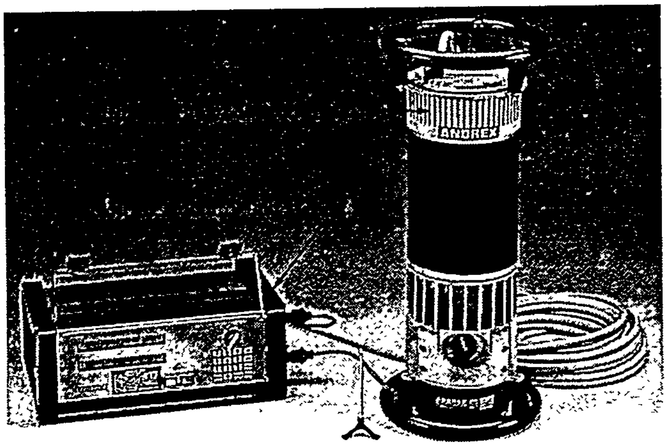

Figure 3. ANDREX Smart-300.

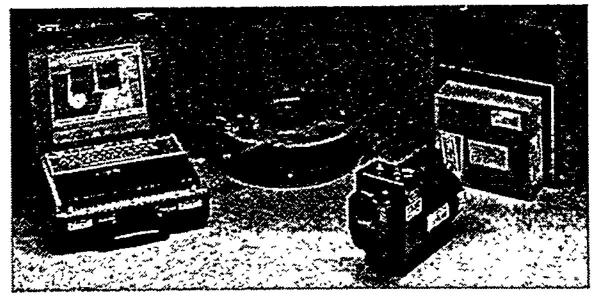

Figure 4. RTR-4 radiography system.

source (Cf-252) with shielding, interconnecting cables and a notebook (laptop) computer. Shielding of the neutron source is adequate to allow full time occupancy of the motor home. Efforts are underway to "miniaturize" the PINS to make it more transportable and user friendly.

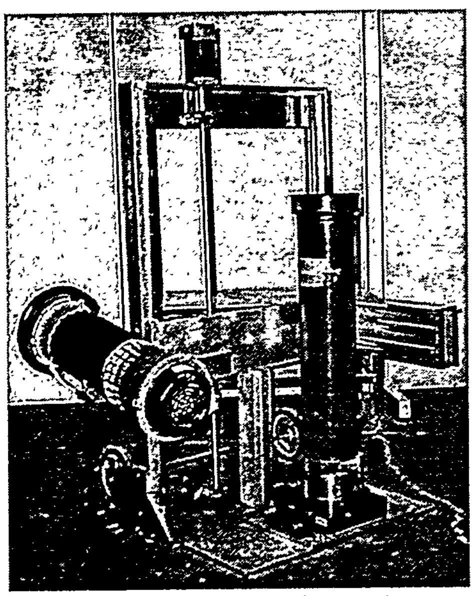

Figure 5. DR/CT radiography system.

Figure 6, PINS system.

4) SIMS, a surface analytical technique used for obtaining chemical fingerprints of surfaces. An ion-trap SIMS system (Figure 7) is used to detect the presence of chemical agent or non-volatiles on the munition surface or in the surrounding area (e.g., soil and overpack). All elements including hydrogen are detectable at part per million (ppm) levels (or lower) by SIMS. The method involves bombarding a solid sample with an energetic ion beam and monitoring sample atoms (i.e. secondary ions) that are ejected and analyzed via a mass

spectrometer. SIMS is extremely attractive for assessing suspect CWM for the following reasons:

- No sample preparation is required,
- No waste is generated,
- Analysis is rapid and simple,
- Capable of speciation, "fingerprinting",
- Amenable to almost any sample type, and
- Amenable to non-volatile organics and salts.

5) Gross-level air monitoring systems using ion mobility spectroscopy (IMS), a technique, which generates a spectrum of fragment ions, based on ion migration time. This migration time of the fragment ions is a function of their mass, size, and shape. Ion spectra of complex compounds contain one or more characteristic peaks that can be used for class- or compound-specific agent monitoring. Three Environics Oy M90 Chemical Warfare Agent Detectors (Figure 8) will provide the gross-level air monitoring capability. The M90s provide real-time displays that can be monitored by the operators working at the remediation site.

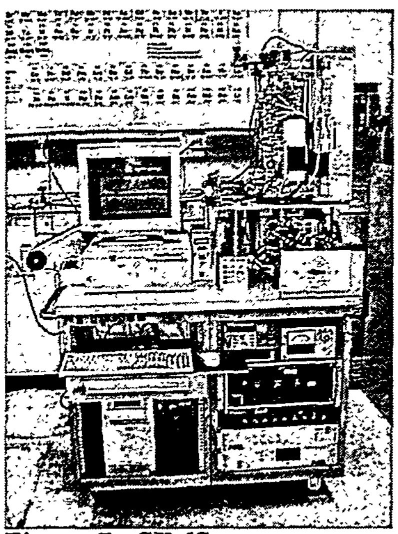
Figure 7. SIMS system.

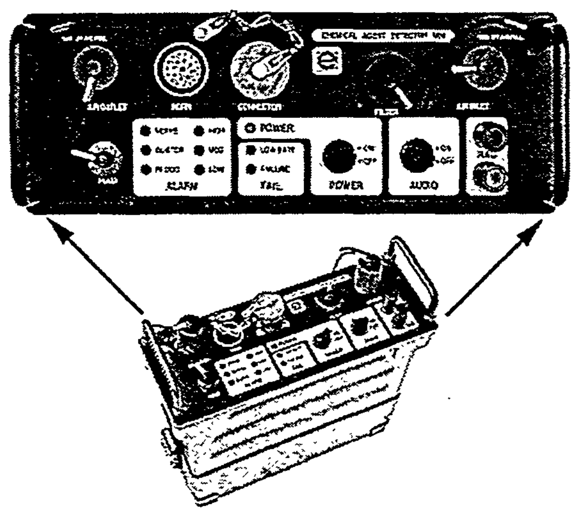

Figure 8. M90s.

6) Enhanced air monitoring capabilities are provided by a Field Ion Spectrometry (FIS) system (Figure 9). A variation of Ion Mobility Spectrometry, the FIS has shown the potential for increased sensitivity and resolution of CWA over conventional IMS systems (e.g. the M90s). The INEEL is adapting the FIS made by Mine Safety Appliances Co. to a field portable sampling and analysis station. The system is capable of multi-agent identification and analysis response time is immediate (< 5 s for a single agent; < 60 s for multiple agents) System recovery for subsequent sampling is also quite fast (< 10 s).

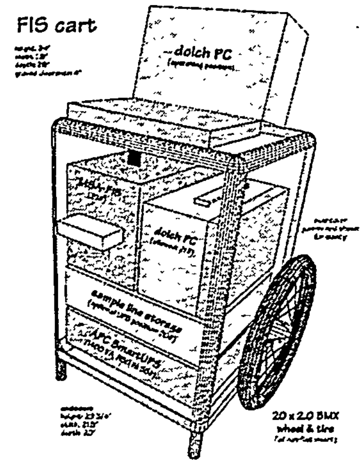

Figure 9. FIS.

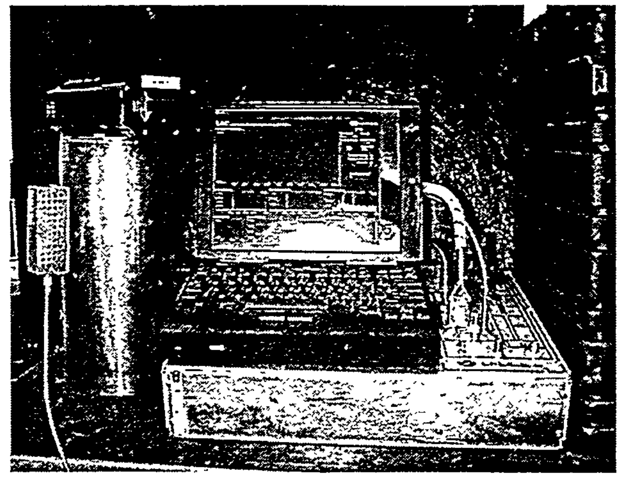

Figure 10. Phase Determination System.

Future Assessment Systems

Several advanced detection and monitoring systems are presently being developed at the INEEL for possible future inclusion in the Phase II MMAS. These "advanced" systems include the following:

1) Phase Determination System, a nonintrusive technique capable of detecting subtle changes in a container's vibration characteristics caused by differences in the physical properties of the fill material. The INEEL has developed a Phase Determination System (Figure 10) that integrates two NDE acoustic measuring technologies into a single system for the characterization of a munition's fill. One system is a contacting method that obtains resonance spectrums of an object by continuously exciting the object over a wide frequency range using a sine sweep technique. The contact method is known as the Digital Synthesizer and Analyzer (DSA) and it uses two piezoelectric transducers, one to excite the object and the other to measure the object's response. The other acoustic system is a noncontacting system that uses a broad band (white-noise) referred to as Laser Acoustic Characterization (LAC) system. This sensor uses sound from a conventional speaker to excite the object and a low-powered infrared laser diode to measure the response, i.e., surface vibrations. Both systems use statistical techniques for classification. By collecting and displaying spectrums of the munition during the excitation and non-excitation periods, a determination can be made whether the munition is empty or filled with a liquid or a solid.
2) Raman Spectroscopy, the measurement of the wavelength and intensity of inelastically scattered light from molecules. Raman scattered light occurs at wavelengths that are shifted from the incident light by the energies of molecular vibrations. A major advantage of Raman spectroscopy over other spectroscopic techniques is the ability to look through glass at aqueous environments to obtain multicomponent qualitative and quantitative analyses. The INEEL is packaging a commercial Raman spectrometer into a "field-portable" system (Figure 11). This system will be used to assess unknown

material contained in glass vials, bottles, jars, etc. (e.g. suspected Chemical Agent Identification Sets - CAIS). Sample preparation is minimal.

3) Gamma densitometry (GD), a method using the measurement of the attenuation of X-rays or gamma rays through an object to estimate the material density or X-ray linear attenuation coefficient of the object. Given a sufficient difference in the density or linear attenuation coefficient of each chemical fill material, the material may be uniquely identified. The GD technique requires that several assumptions be made; 1) uniform cylinder walls, 2) homogeneity of material, and 3) void space availability. All of these problems may be overcome if the spatial distribution of material and casing are well defined. A field portable system (Figure 12) that applies this technique has been developed and tested at the INEEL. The system creates a narrow line of radiation by highly collimating a gamma ray source and placing an additional collimator in front of a high-purity germanium detector. The object (i.e., munition) is then passed through the beam of radiation and a series of transmission measurements are obtained.

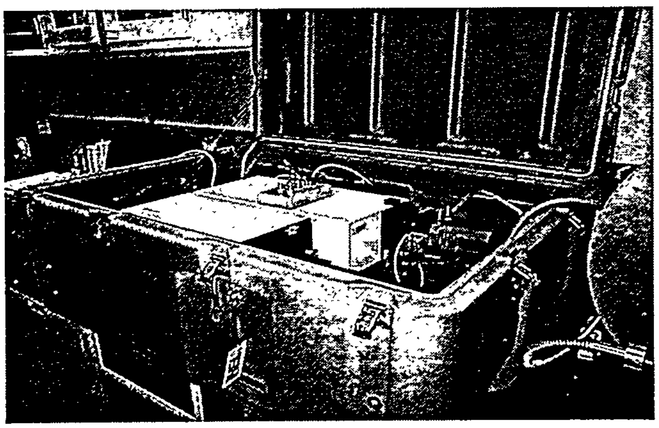
Figure 11. Raman spectroscopy.

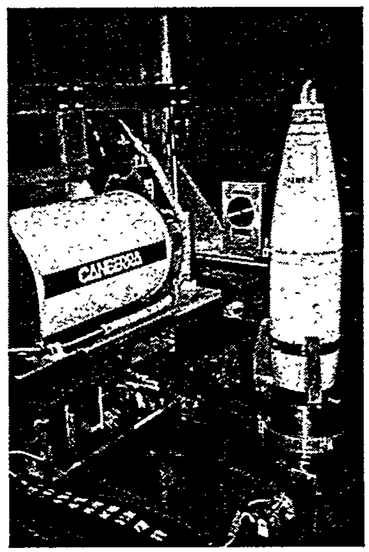

Figure 12. Gamma densitometry.

Testing Program

Even though the INEEL used a "rapid prototyping" approach to develop the Phase II MMAS, the process began with the development of the design criteria and ends with design verification. This design verification process is necessary to ensure that systems, structures and components fulfill the functional and operational requirements and customer expectations. Design verification methods include, but are not limited to:

1) Technical reviews,
2) Peer reviews,
3) Alternate calculations, and
4) Qualification testing.

The design verification process may be used to identify opportunities for improvements in the efficiency, productivity, safety, reliability, or cost of the designed system, structure, or component. To provide this design verification, it is necessary to completely define the overall testing objectives, conditions and requirements to assure that all systems perform as required.

The Phase II MMAS testing activity served two purposes:

1) Final, integrated system testing and
2) System acceptance testing.

The logic and schedule for the development of the Phase II MMAS is divided into two distinct stages. In the first stage, the mobile platform (i.e., the MMAS motorhome) is equipped with its primary interface and support equipment (e.g., communications, computers, video, and meteorological instruments) and all currently used assessment systems (e.g., PINS, film-based and near-real time digital radiography, and gross-level air monitoring systems). Currently used assessment equipment and commercially-available equipment will NOT be tested nor qualified as part of the Phase II MMAS testing activity. However, the interfaces between the assessment equipment, the commercially-available equipment and the Phase II MMAS will be evaluated. For the rapid-prototyping design approach to be successful, the scope of the verification process must encompass not only the overall system but also the individual components, subsystems and systems that make up the overall system. Therefore, the Phase II MMAS testing was conducted in three stages; component/subsystem-level testing, system-level testing, and field testing. Component/subsystem-level testing was conducted during the fabrication and assembly of the MMAS as the components are received. System-level testing was performed at various stages of assembly to verify overall system operation; e.g. heating, ventilation and air conditioning (HVAC) system testing, road tests, and deployment tests. MMAS field tests were performed to verify the operations of the various MMAS subsystems and systems as they relate to one another and the users. These field tests provided an evaluation of the operational procedures and their interaction with the MMAS.

During the second developmental stage, the state-of-the-art, enhanced assessment systems (e.g., SIMS, FIS, and the DR/CT system) will be incorporated into the Phase II MMAS platform. Prior to these "new" assessment systems being fielded by the U. S. Army, each will require a certain level of qualification and acceptance testing. The individual developers of the equipment will perform a significant portion of the qualification testing before it is installed in the Phase II MMAS. After the assessment system is installed in the motorhome, each "new" assessment system will undergo field testing to verify acceptable performance following transport and field setup. These field tests will check overall interfaces (both physical and procedural) along with the ruggedness of each new MMAS assessment system.

Finally, a final, integrated system test of the Phase II MMAS with its new assessment systems will be performed in the field under near-real assessment conditions to demonstrate proper and adequate performance.

Assessment Flow Chart

When the operators of the Phase II MMAS arrive at an assessment site, the Phase II MMAS is located away from the actual incident site. Only the assessment equipment is co-located with the discovered item. Figure 13 depicts the assessment data flow and how each NDE system interacts with the Phase II MMAS.

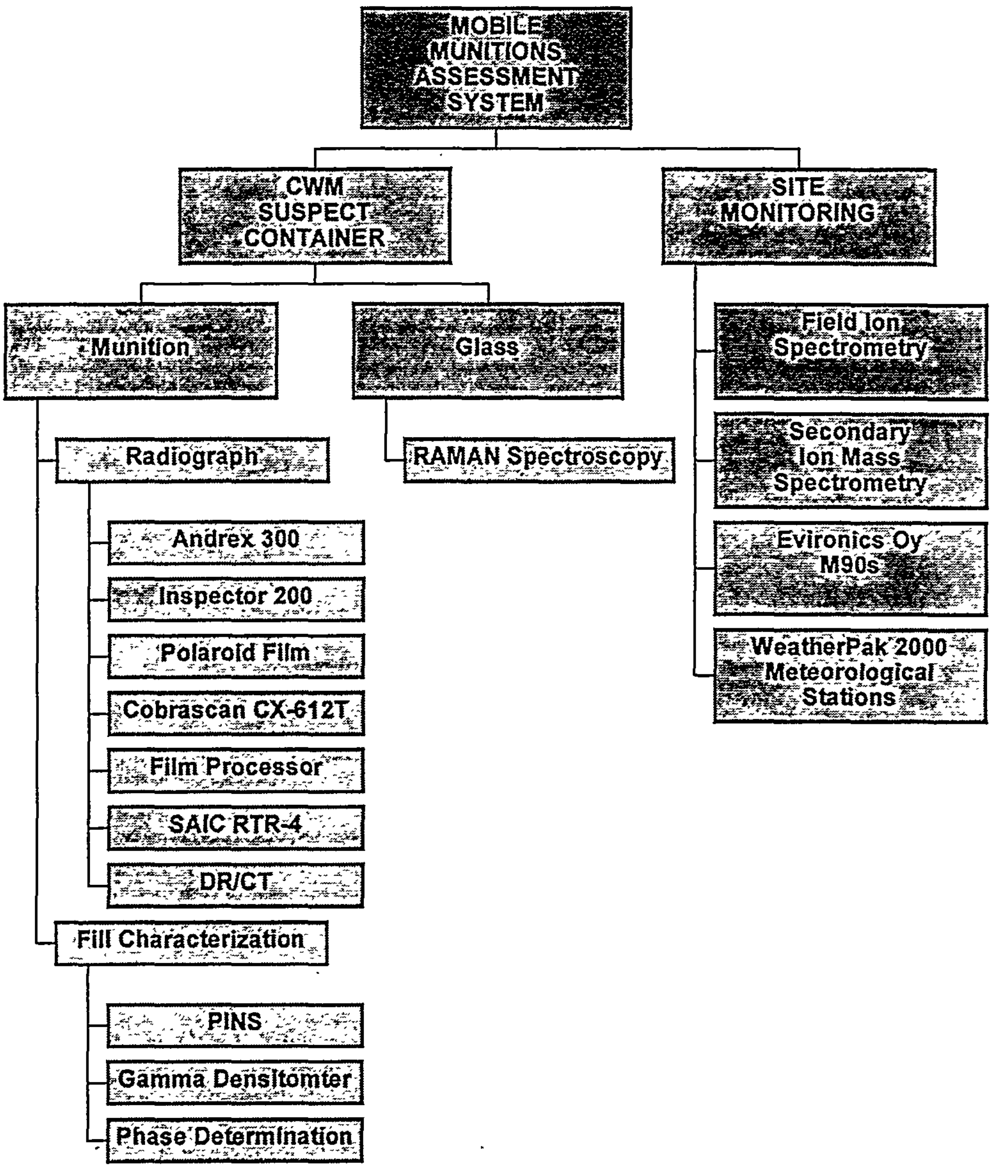

Figure 13. Assessment activity flow chart.

Summary

The Phase II MMAS has been designed, fabricated, assembled, and tested by the Idaho National Engineering and Environmental Laboratory under contract to the U. S. Army's

Project Manager for Non-Stockpile Chemical Materiel for use in the assessment and characterization of "non-stockpile" chemical warfare materiel (CWM). The Phase II MMAS and the previously deployed Phase I MMAS meets an immediate need to augment response equipment currently used by the U.S. Army with a system that includes state-of-the-art assessment equipment and advanced sensors. The Phase II MMAS will be used for response to known storage and remediation sites. This system is designed to identify the munition type; identify the chemical fill; evaluate the condition of the CWM; evaluate the environmental conditions in the vicinity of the CWM; determine if fuzes, bursters, or safety and arming devices are in place; provide other data (e.g., meteorological data) necessary for assessing the risk associated with handling, transporting, and disposing of CWM; and record the data on a dedicated computer system.