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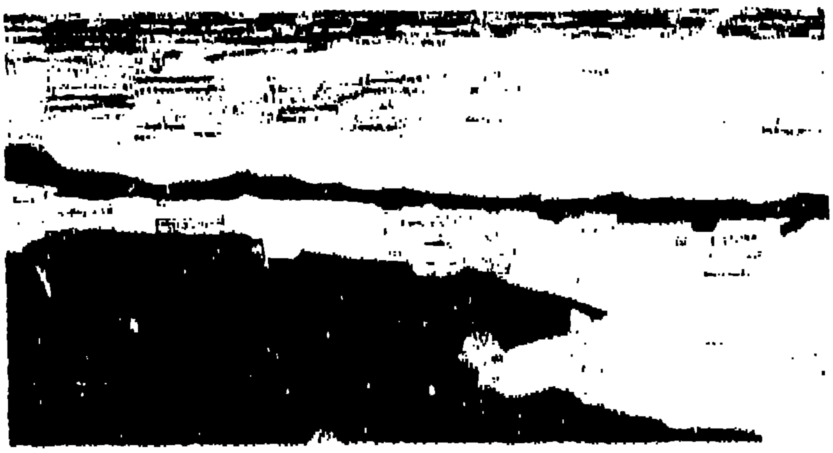

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IN-FIELD ANALYSIS AND ASSESSMENT OF NUCLEAR MATERIAL

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ABSTRACT

Los Alamos National Laboratory has actively developed and implemented a number of instruments to monitor, detect, and analyze nuclear materials in the field. Many of these technologies, developed under existing US Department of Energy programs, can also be used to effectively interdict nuclear materials smuggled across or within national borders. In particular, two instruments are suitable for immediate implementation: the NAVI-2, a hand-held gamma ray and neutron system for the detection and rapid identification of radioactive materials, and the portable mass spectrometer for the rapid analysis of minute quantities of radioactive materials. Both instruments provide not only critical information about the characteristics of the nuclear material for law enforcement agencies and national authorities but also supply health and safety information for personnel handling the suspect materials.

1. INTRODUCTION

Illicit trafficking in nuclear materials poses a threat to global proliferation as well as a potential danger to public health and safety. The potential for a terrorist group or rogue state to obtain nuclear weapons materials is considered one of the most serious threats to international security.[1] According to suspects recently apprehended in nuclear smuggling activities, tens of millions of dollars have been offered for nuclear material to build a bomb. The past five years have witnessed a sharp increase in the number of smuggling incidents involving nuclear materials. In Germany the number of incidents increased from 41 in 1991 to about 250 per year for each of the past two years.[2] Within the Russian Federation there were 56 incidents in 1994 involving the illegal transport of radioactive materials.[3] Although most of the materials seized in these incidents have been non weapons-related materials such as natural and depleted uranium and radioactive industrial and medical sources, there were several seizures of weapons related nuclear materials in Europe involving plutonium and highly enriched uranium in 1994.

Public attention to nuclear smuggling has focused mostly on the detection and prevention of the trafficking of nuclear materials useful for the production of a nuclear bomb. Although generally ignored, radiological sabotage poses an equally significant threat. A well-placed radioactive dispersal device could contaminate a large area in the financial or governmental districts of a country. To address the general threat of illegal trafficking in nuclear materials, the potential uses of the material in both a nuclear weapon and in a dispersal device must be considered. Fortunately, the technologies used to monitor, detect, analyze, and assess the illegal movement of nuclear materials are similar for both scenarios.

II. RATIONALE

In our discussion of methods to counter nuclear smuggling, we discern three distinct areas in which technology can make a difference: (1) containment of the material at its source or point of origin; (2) detection, analysis, and assessment while the material is in transit; and, (3) analysis of seized material to determine the pathway and source where legitimate control was lost.

The first area is currently being addressed by the international community and, in particular, by the Russian Federation and the US. Cooperative agreements have been established between technical institutes and laboratories in Russia and the US to improve the materials control, protection, and accountability of nuclear materials in both countries and considerable progress has been achieved in a short time. As of Spring 1996, portal monitors for special nuclear material have been installed at six Russian facilities. Even with rapid improvements in physical protection and control of nuclear materials, the threat of nuclear smuggling will continue for the foreseeable future.

The second area, detection, analysis, and assessment during material transit, is the most technically challenging and also provides the best opportunity to interdict nuclear material and keep it from falling into the hands of terrorists or rogue states. The remainder of the paper will address this problem and review currently available instrumentation and technologies that can be brought to bear on this difficult problem.

The third area, forensics, involves the detailed analysis of the nuclear materials following seizure by a law-enforcement agency. Many different analytical techniques can be used to derive information about the original source of the materials from isotopic distributions and trace elements in the nuclear materials. Pollen and DNA signatures can also help identify pathways the material has traveled as well as provide information about the possible location where legitimate control of the nuclear material was lost.

Sophisticated analytical laboratories in Europe and the US perform these detailed analyses but only after the fact and are useful in closing off future shipments of nuclear materials. Laboratory forensics analysis is an excellent tool for obtaining the maximum amount of information from the sample of suspect material and its packaging, but it is too time-consuming to serve as a real-time tool for law-enforcement agencies. Consequently, additional technologies are required to address the problem in real time in the field.

III. IN-FIELD ANALYSIS AND ASSESSMENT

Real time detection, analysis, and assessment of smuggled nuclear materials provide many technical challenges. Instrumentation must be able to rapidly interrogate individuals, vehicles (automobiles, trucks, and railway cars), and cargo (airplanes, ships) to determine the presence of nuclear or radioactive materials. False-alarm rates must be very low if these instruments are used routinely by law enforcement or customs officials. At the present time we do not have the perfect instruments for accomplishing these goals, but there are many current technologies that can readily be applied to the detection of suspect nuclear materials.

A. Portal Monitors

Los Alamos National Laboratory has developed both pedestrian and vehicle portal monitoring systems for deployment at choke points through which nuclear material may be transported. These instruments have a high level of sensitivity, capable of detecting the movement of less than 10 g of highly-enriched uranium (HEU) through the pedestrian portal monitoring system and 40 g of HEU through the most sensitive vehicle monitoring system. The actual detection thresholds will depend on the type of material, its configuration, and the method of shielding employed. Quoted sensitivities are with the least favorable metallic source shape, namely, an unshielded sphere, passing through the detector at the least sensitive position with a 50% probability of detection at the 95% confidence level in a 25 μR/h background. Sensitivities improve considerably if the source is in the shape of a disk.

1. Pedestrian Monitors. Pedestrian portal monitors can be deployed at airports, train and bus stations, or any location through which a mass of people will be required to pass. Commercially-produced pedestrian portal monitors are in routine use in US nuclear facilities and similar systems have been placed in several Russian facilities for testing and evaluation. We are currently working with Russian and European customs authorities to improve the performance and applicability of these technologies.

At normal walking speeds and a sampling time of 0.5 s, the sensitivity of the pedestrian portal monitor, as defined above, is 0.3 g of plutonium and 10 g of HEU.

2. Vehicle Monitors. Vehicle radiation monitors examine cars and trucks in either the drive through or wait in modes. The detection sensitivity of these systems will again depend upon the source-shielding configurations and the time available for the measurement. High-volume checkpoints require drive-through monitors to minimize delays with a resulting reduction in sensitivity, while wait-in monitors are required for maximum sensitivity.

At normal drive-through speeds of 8 km/h and a sampling time of 1 s, 10 g of metallic plutonium and 1000 g of HEU will be detected for the least-favorable metallic source shape[1]. For low traffic volumes, the wait-in vehicle monitor sensitivity for a 1 minute sampling is increased to 0.3 g of weapons-grade plutonium and 10 g of HEU[1].

B. Hand-Held Monitors

If either of the above systems sense the presence of radioactive materials, an alarm (silent or audible) notifies the personnel manning the portal. In that case, a battery powered, hand held monitoring unit can be used to locate the source of radiation and determine its characteristics, such as the NAVI-2[6] (shown in Figure 1). In this instrument, the gamma-ray detector is a ruggedized, collimated NaI(Tl) crystal which combines good detection efficiency with moderate energy resolution. Multichannel analysis of the pulse height distribution of the gamma-ray spectrum is used to identify energy windows for each type of nuclear material. Neutrons are simultaneously monitored by two 20 atmosphere ^{3}He proportional counters moderated by polyethylene.

This easy to operate system can be used to rapidly detect the exact location of nuclear material on an individual or inside a vehicle. It can also automatically identify the type of nuclear material by distinguishing between depleted uranium, enriched uranium, plutonium, and a simulated source. This rapid assessment capability is critical for personnel protection and to minimize possible contamination.

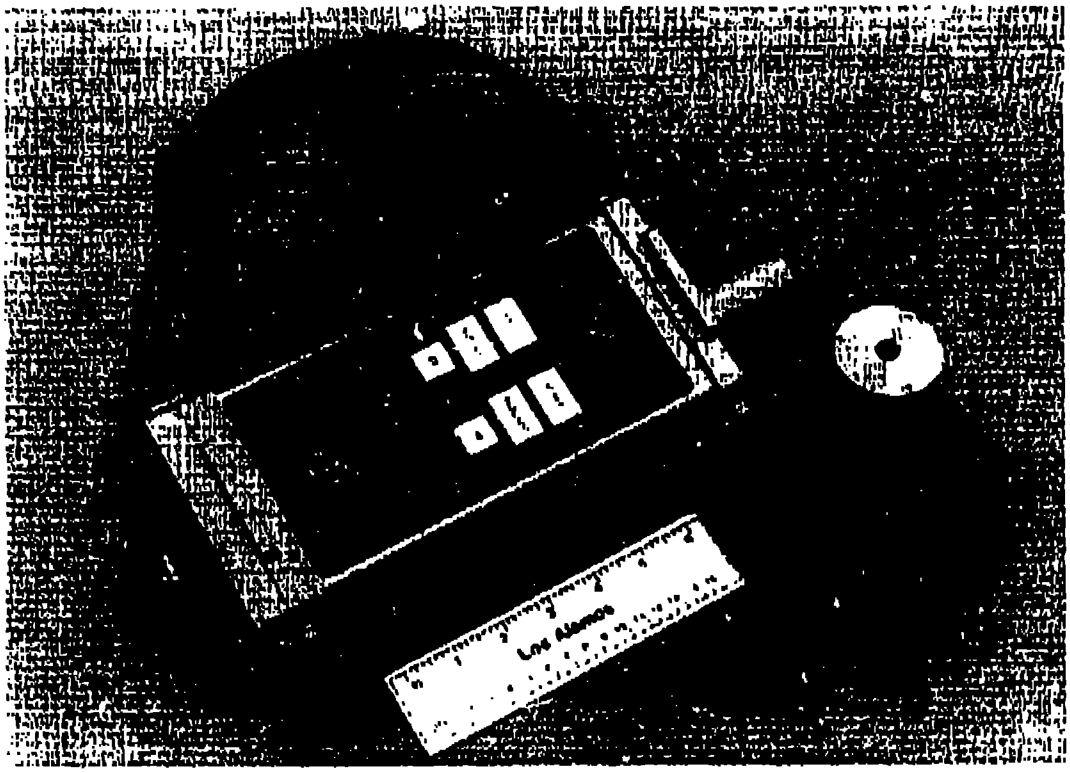

Figure 1. NAVI-2 handheld gamma-ray spectrometer and neutron detector.

C. Mass Spectrometry

Once suspect nuclear material is detected, the first priority is to place the material into a stabilized configuration. This may range from the simple expedient of a plastic bag, for a small quantity of plutonium, to a shielded container for a highly-radioactive source. It is important to maintain the integrity of the material and its packaging because both can provide information about the source of the material as well as the pathway along which the material has traveled. Once the material has been placed into a safe-handling configuration, then more detailed in-field assessment analyses can be performed on the sample, ranging from sophisticated gamma-ray spectrometry to mass spectrometric analysis, depending upon the chemical and physical form of the material.

Los Alamos has developed a robust, easy-to-use method for the rapid determination of the isotopic signature of a wide variety of uranium compounds. Small samples of materials confiscated from nuclear smuggling or collected during in-field inspections of nuclear facilities can be rapidly analyzed. These samples can either be pure compounds or mixtures of uranium compounds with other non-nuclear materials. Less than 10 mg of sample is required for the precise mass spectrometric determination of the isotopic signature of uranium. This ruggedized, transportable mass spectrometer shown in Figure 2, provides a unique in-field analytical capability.

In some situations, the law-enforcement agency may not want to immediately seize the material but would prefer to monitor the movement of materials to determine its source or final. These instruments and similar instruments can also be used to meet this requirement. Unattended systems have been developed which can be deployed to monitor the movement of nuclear materials.

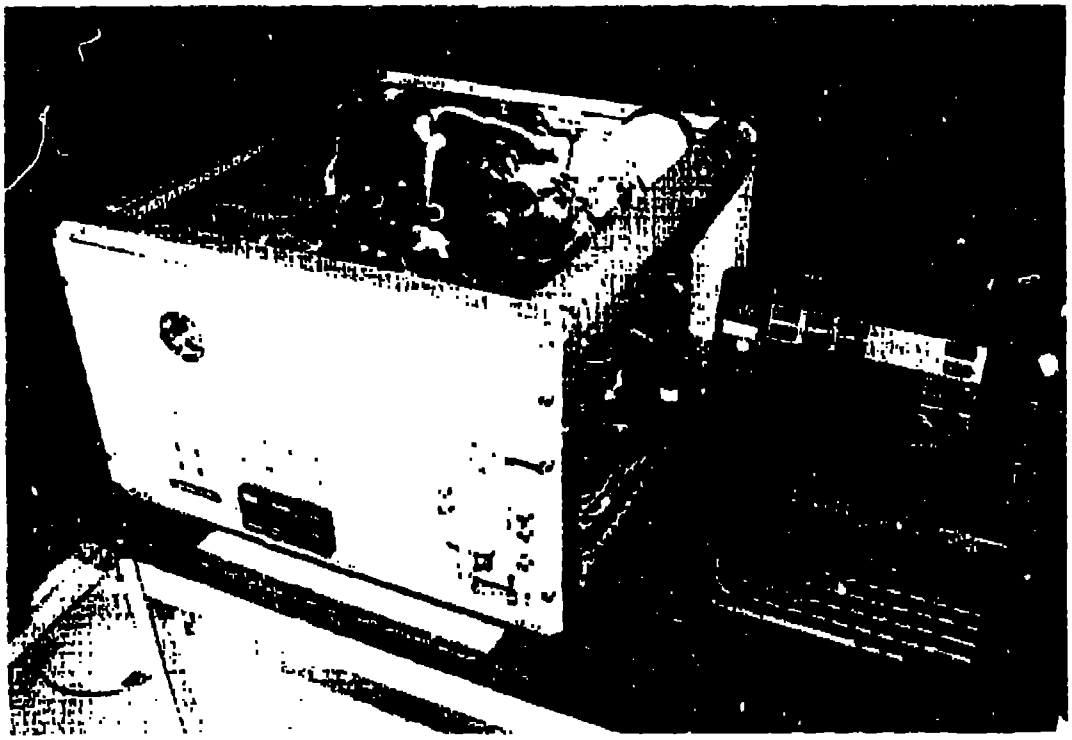

Figure 2. Transportablemass spectrometric system for isotopic analysis of uranium.

IV. CONCLUSIONS

The three instruments (portal and hand-held radiation detectors and the mass spectrometer) discussed above are part of a suite of instrumentation developed within US Department of Energy programs that can be directly applied to the problem of countering nuclear smuggling. Specific applications will require enhancements or modifications to the existinginstruments but we have a solid base from which to begin addressing this serious threat

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