New Technology Gives Bombs Squads the Upper Hand in the Fight Against Radiological or Nuclear Terrorism

by John Smalling

Experts in the US Department of Homeland Security have determined that a possible threat exists for the detonation of Radiological Dispersion Device (RDD) and/or an Improvised Nuclear Device (IND) on US soil. Various US government agencies are currently procuring radiation monitoring systems to attempt to guard our homeland at locations such as border crossings, seaports, airports and post offices[1]. These are common, commercially available radiation monitors capable of alarming if radioactive materials are present. Also, many law enforcement agencies are now providing officers with Radiation Pagers to detect potential terrorists devices[2]. However, numerous materials present in legitimate commerce, such as kitty litter, ceramic tiles, fertilizer, and smoke alarms, may be slightly radioactive and can set off these radiation pagers or vehicle monitors. When an alarm is triggered, appropriate law enforcement or other response personnel must be able to quickly ascertain if the alarm was caused by a legitimate commercial radioactive source, a naturally-occurring radioactive material (NORM), or a potential terrorist weapon. To counter the threat of either a RDD (commonly referred to as a dirty bomb), an IND, or a small tactical nuclear device such as the Russian suitcase nuclear device, it is necessary to do a spectroscopic analysis of the suspicious package, container, or vehicle that caused the alarm.

This paper provides general information about the technologies that can be used to ascertain if a suspicious package or suspicious vehicle contains an innocent radioactive source or a possible terrorist weapon. Possible terrorist weapons include a RDD, an IND (a terrorist homemade nuclear device), or a State Nuclear Device (such as a Soviet manufactured suitcase nuclear weapon). Should a suspicious package or container emit radiation, the technologies herein described are available to accurately determine if the suspect item might be a potential radiological or nuclear device. This information can prove to be invaluable in disarming the device or controlling the spread of contamination in the case of a Radiological Dispersion Device.

The need for a portable radioactive identification detector by local law enforcement

Following the September 11 terrorist attack on our nation, the threat of a potential for a radiological or nuclear terrorist attack became more apparent. This was confirmed when searches of Al-Qaida homes in Afghanistan revealed drawings and diagrams of how to make a Radioactive Dirty Device [4, 6]. In fact, the US has already arrested one suspect in Chicago in connection with a dirty bomb plot[10]. Radioactive sources that could be used to manufacture a RDD, or dirty bomb, are readily available throughout the world. There are very large radioactive sources that are used in industrial applications or medical applications and could have Curie quantities of radioactivity. Many radioactive sources have been reported missing or stolen. Over 800 radioactive sources have been lost or stolen in the past 5 years in the U. S. alone[5]. Unlike an Improvised Nuclear Device, a RDD would not cause widespread death, but it could cause widespread panic and leave a large area uninhabitable for months[4].

There have been numerous documented instances of terrorists' attempts to gain possession of the Special Nuclear Material (SNM) that could be used to build a crude nuclear weapon[6,7]. In August, 1994 in the Munich, Germany airport, a terrorist was caught smuggling almost 400 grams of weapons grade plutonium (WG Pu)[9]. The National Resources Defense Council has stated that as little as 1000 grams of WG Pu could be used to build a high technology tactical nuclear device[6]. For comparison purposes, 1000 g of plutonium is approximately 50 cc or about one-seventh the volume of a soft drink can[13]. It is unfortunate that over the years many facilities outside the US have not had adequate monitoring controls deployed, and there have been numerous instances where highly enriched uranium and WG Pu, either of which could be used to make a crude nuclear device, have been diverted[7].

US Congressman Curt Weldon (R-PA) is one of the leading congressional experts on nuclear terrorism threat[3]. Congressman Weldon frequently speaks at First Responder conferences (Fire, HazMat, etc.), where he warns about the possibility of terrorists obtaining one of the missing Russian suitcase nuclear devices. According to Congressman Weldon, approximately 86 Russian suitcase nuclear devices are now missing and no one knows where these devices may be.

Terrorist use of a RDD is considered far more likely than the use of a nuclear device[4]. These radiological weapons are a combination of conventional explosives (or other dispersal means) and radioactive material. Such radiological weapons appeal to terrorists because they require very little knowledge to build and deploy compared to a nuclear device. Also, the radioactive materials used widely in medicine, agriculture, industry and research are more readily available and easier to obtain than weapons grade uranium or plutonium, although there have been numerous documented cases of SNM smuggling. SNM is a fissionable material such as Uranium-235 or WG Pu that can be used to make a nuclear device.

Potential targets for a radiological/nuclear attack include highly dense urban areas, financial centers, important transportation and communication centers such as airports, train stations and subways, state or government centers such as embassies, large

continued on page 50

tourist attractions such as amusement parks, large sporting events, and commercial shopping centers. In order to reduce the threat of a device entering our country, radiation monitors are being placed at key choke points. However, these monitors alarm quite often from small amounts of naturally occurring radiation or legitimate radioactive sources used in medical or industrial applications. Various problems are associated with the explosion of a dirty bomb. While the greatest hazard would likely be from the effects of the conventional explosives, few, if any, deaths would actually be expected from acute radiological exposure. However, widespread contamination can have a significant psychological and financial impact. According to a study from the Center for Technology and National Security Policy at the National Defense University, "if such a [dirty bomb] — known formally as a radiological dispersion device — were set off in the heart of Washington or New York City, the economic effects might reach *$40 billion* from the loss of economic activity."

An effective way to reduce these potentially devastating consequences is to use the layered approach advocated by the Department of Homeland Security. Numerous low cost radiation monitors have been distributed throughout the US, including radiation pagers carried by US Customs Agents and some state and local law enforcement officers. These devices will be almost useless unless equipment is available in a timely fashion to identify a potential terrorist weapon and distinguish it from a natural or commercial radiological source, before it is detonated. In some instances, federal resources may not be able to respond in a timely fashion to investigate a "suspicious package" and the ability of local law enforcement or bomb squads to diagnose the situation could make the difference in loss of life and significant property damage.

In an ideal world, a local bomb squad or EOD team should be able to quickly determine if a suspicious container or vehicle that has triggered a radiation alarm might contain a terrorist weapon. With the availability of field portable High Purity Germanium (HPGe) detectors[14,15], this goal is now achievable. Fortunately, radioactive materials have a natural signature and constantly emit gamma rays, X-rays, alpha particles, beta particles, or neutrons. The gamma ray signatures are like "fingerprints" and there are numerous detectors that can identify these fingerprints.

However, there are many naturally-occurring radioactive materials and other legitimate radioactive shipments that could trigger an alarm and this presents a problem. These materials are, in fact, quite common. For example, any person who has recently undergone a nuclear medical procedure (such as a heart stress test which uses radioactive Thallium-201), has been injected with a small amount of a radioisotope that emits gamma radiation. These people can set off radiation monitors for several weeks after they have undergone a procedure. There are literally thousands of such medical procedures performed every day in the United States alone. Many building materials and common products such as fertilizers contain naturally occurring radioactive materials. There are also thousands of radioisotopes used daily for legitimate industrial, medical, and other research purposes and these sources are frequently shipped via commercial carriers. If vehicles, packages, or people were stopped every time an increased radiation level was detected, commerce would be halted and the resulting negative economic impact would be huge. For example, the Port Authority of New York estimated that if a single terminal were to be closed for 1 hour while a false positive signature is investigated more thoroughly, the cost to the city would be $500,000.

Fortunately, as mentioned above, almost all radioactive materials emit unique gamma energies that are very similar to fingerprints. These emissions can be used to determine exactly what type of radioactive material is present, segregate the material into easy-to-understand categories, such as "Medical" or "Nuclear" and provide additional technical details if needed. Simple procedures can be put in place to locate where a radioactive source is located and to determine if it is a distributed source, such as a load of bananas, which contain radioactive potassium, or a load of fertilizer, which contains radioactive thorium (a naturally occurring decay product of uranium). However, if a non-distributed, or "point source" is located in a suspicious vehicle or shipping container, it would be necessary to identify the nature of this type of radioactive source, as this could be indicative of a terrorist weapon.

Types of Radiation Detectors Available to Locate and Identify Potential Radiological terrorist devices

Radiation detectors fall into two categories: gross counters and energy sensitive. Gross counters count each event (gamma or neutron) emission the same, regardless of energy. Gross counters, such as Radiation Vehicle Portal Monitors and Radiation Pagers, are being deployed throughout the US at border crossings, seaports, airports and with law enforcement personnel. These gross counters are useful for screening people, packages, luggage, cargo and vehicles for the presence of gamma or neutron radiation. However, due to the prevalence of naturally occurring radioactivity, these gross monitors are "alarming" quite often. These alarms are caused by some type of radioactive source, but they are typically legitimate radioactive sources. These false alarms are frequently referred to as nuisance alarms.

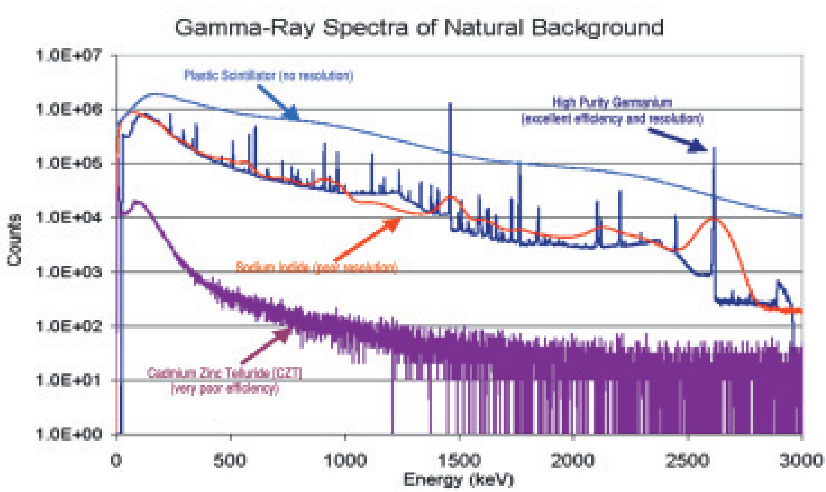

Figure 2. Comparison of Different Detectors Presented at 2003 Institute of Nuclear Material Managers by Dr. Ron Keyser

One of the more commonly used gross counters is the radiation pager deployed to US Customs Agents and to many state or local law enforcement agencies. These pagers are acknowledged to be inadequate in making an appropriate identification of suspect materials (GAO-03-279T, November 2002).

Figure 2 shows a comparison of natural background radiation as collected by four different types of detectors. Plastic scintillator detectors have no ability to resolve gamma peaks, sodium iodide and cadmium zinc telluride detectors have very limited ability to resolve the gamma lines. Only high purity germanium detectors can consistently and accurately identify the radioactive material that caused an alarm.

Some analysis has been attempted with low-resolution energy sensitive detectors such as sodium iodide (NaI) detectors, but these types of detectors have difficulty properly identifying the radioactive contents. Radiation Identifiers based on sodium iodide detectors provide only a rough approximation of the energies emitted (analogous to a smudged fingerprint) and very often will misinterpret or incorrectly analyze the radioactive materials. Such detectors would not identify the presence of Special Nuclear Material that has been hidden inside one of the thousands of legal radioactive shipments occurring every day. During recent testing, none of the low resolution systems were capable of satisfying even the minimum requirements of identifying shielded radioactive materials (Illicit Trafficking Radiation Detection Assessment Program, 2001). While these instruments may prove useful as a second layer in the Department of Homeland Security's layered approach, they are not the proper instruments to be deployed by bomb squads. Other systems have attempted to use cadmium zinc telluride (CZT) detectors to identify radiological materials. These "medium resolution" detectors are very small (typically 15mm x 15mm x 7mm) and they are therefore very inefficient. Count times using a CZT based detector would be orders of magnitude longer than an HPGe detector. Time is of the essence in performing analysis of an unidentified radioactive source. It is simply not feasible to perform a measurement that may last an hour or longer and still be unable to yield a definitive answer.

The only type of detector that can positively determine gamma energies and identify the specific radioactive material is high purity germanium (HPGe) due to the fact that it exhibits better efficiency and has superior resolution. This fact was attested to by a senior administrator at Lawrence Livermore National Laboratory (ABC News, July 21, 2002). A comparison of three "fingerprints" of the same material using a low resolution NaI detector (Blue), a medium resolution detector CZT (Black), and a high resolution HPGe detector (Red) is shown in Figure 3.

The "peaks" in these graphs represent the unique fingerprints of the two radioactive materials in the sample (iodine and plutonium in this case). The advantage of the high resolution of HPGe detectors (red graph) is evidenced by the peaks that are much narrower and appear as sharp spikes in the figure. The broader peaks in the blue and black graphs make positive distinction of the radioactive materials difficult if not impossible.

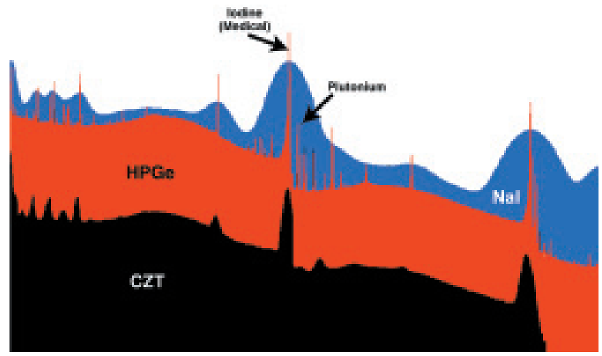

Figure 3. Radioactive Material Fingerprints. Same Material Viewed with Three Types of Technology.

When taken in the context of fingerprints, the HPGe detector provides a complete fingerprint…as if you had crisp clear prints of four fingers and a thumb at the crime scene. A sodium iodide detector would give a result comparable to finding one smudged thumbprint that was barely legible.

Figure 4 shows a close up of a particularly interesting region. The characteristic peaks (or fingerprints) from iodine and plutonium overlap one another. In the blue and black graphs, these appear as one peak, whereas in the red graph the peaks are clearly distinguishable. The low and medium resolution systems (blue and black graphs respectively) are unable to find the special nuclear material (plutonium) shipped in a package that also contained a legal shipment of a medical isotope (iodine). The Special Nuclear Material is clearly detected in the high resolution system (red graph).

If HPGe detectors are the only type of detectors that accurately identify radioactive materials in a short period of time, why have they not been deployed in the fight against terrorism? The germanium crystals have historically been costly because of the special manufacturing process and strict quality requirements. These detectors must be operated at very low cryogenic temperatures and they traditionally required liquid nitrogen (LN) as the cooling agent. The handling and logistical problems associated with keeping germanium detectors filled with LN would be very problematic for most bomb squads.

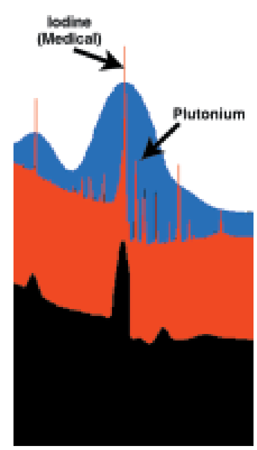

Figure 4. Close up of critical region where plutonium and iodine peaks overlap.

Until very recently, all portable HPGe detectors used LN as a coolant to obtain optimal energy resolution. LN presents both safety and maintenance problems in field use. During the last few years, line powered, mechanical coolers have been widely used in lieu of LN, but these mechanical coolers were not field portable. Recently, battery-operated, mechanical coolers have been introduced to handheld HPGe detectors (Lawrence Livermore National Laboratory News Release NR-02-03-06). The introduction of reliable portable mechanical coolers to HPGe detectors removes the major impediment to their deployment in field applications. Scientists at Lawrence Livermore National Lab used their expertise to develop software for the system that gives the power and sophistication of the laboratory instrument in a "push-a-button-get-an-answer" device that law enforcement officers can easily deploy.

Figure 5. Detective-EX
Portable HPGe Detector
(http://www.ortec-online.com/psis.htm)

A portable High Purity Germanium detector offers the HazMat Team or Bomb Squad an instrument that can quickly and accurately identify the radioactive contents of a suspicious package, vehicle, or cargo container that has triggered a radiation alarm. This quick and accurate identification can be used to take appropriate actions if the device was identified as a potential terrorist weapon. For example, once a RDD has been identified, it could be rendered safe by placing the RDD in a Mobile Explosion Containment Vessel or by disarming the explosive mechanism. If a containment vessel were used, the spread of radioactive contamination would be limited to the containment vessel itself, preventing a very costly cleanup of radiation spread over several city blocks.

In summary, the only commercially available technology that can accurately identify radioactive sources and determine if they exhibit a threat to our homeland are High Purity Germanium Detectors. The obstacle of having to use liquid nitrogen to cool these detectors has now been overcome. These detectors (Figure 5) are now available and are being deployed to truly give bomb squads and the EOD community the upper hand in dealing with radiological and nuclear terrorism. Various Homeland Security federal grant programs are available to provide funds for this type of equipment.

References

(1) http://www.marineexchangesea.com/CBP-TIN-04-04RPMFAQs.doc
(2) http://abcnews.go.com/sections/us/WorldNewsTonight/dirty_bomb_040107.html
(3) http://abcnews.go.com/sections/primetime/2020/ross011108.html
(4) http://www.cdi.org/terrorism/dirty-bomb.cfm
(5) http://www.aclj.org/news/homelandsecurity/020610_accessible.asp
(6) http://www.nrdc.org/nuclear/fissionw/fissionweapons.pdf
(7) http://www.nti.org/e_research/cnwm/interdicting/index.asp
(8) http://www.nti.org/e_research/cnwm/threat/demand.asp
(9) http://www.cia.gov/cia/public_affairs/speeches/1996/go_appendixa_032796.html
(10) http://abcnews.go.com/sections/us/DailyNews/chicagosuspect020610.html
(11) http://www.llnl.gov/llnl/06news/NewsReleases/2002/NR-02-03-06.html
(12) http://www.tmc.edu/thi/dinuc.html
(13) http://www.bits.de/NRANEU/NonProliferation/docs/smuggling_threat_williams.htm
(14) http://www.ortec-online.com/news-release/nr_detrelease.htm
(15) http://www.ortec-online.com/pdf/detective.pdf