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Revolution in Nuclear Detection Affairs

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Abstract. The detection of nuclear or radioactive materials for homeland or national security purposes is inherently difficult. This is one reason detection efforts must be seen as just one part of an overall nuclear defense strategy which includes, inter alia, material security, detection, interdiction, consequence management and recovery. Nevertheless, one could argue that there has been a revolution in detection affairs in the past several decades as the innovative application of new technology has changed the character and conduct of detection operations. This revolution will likely be most effectively reinforced in the coming decades with the networking of detectors and innovative application of anomaly detection algorithms.

It is very difficult to detect threat material using radiation detectors. Radiation that is emitted from threat material is often attenuated substantially before it reaches a detector. As importantly, natural and other background radiation substantially affects detection. As shown in Figure 1, variations in background radiation are very large. Significant signals from threat materials quickly fall into the noise of background radiation. As seen in Figure 3, a signal from a 150 mCi Cs-137 source, 150 feet from the source, is visible, but at 300 feet from the source, the signal becomes very difficult to distinguish from background radiation.

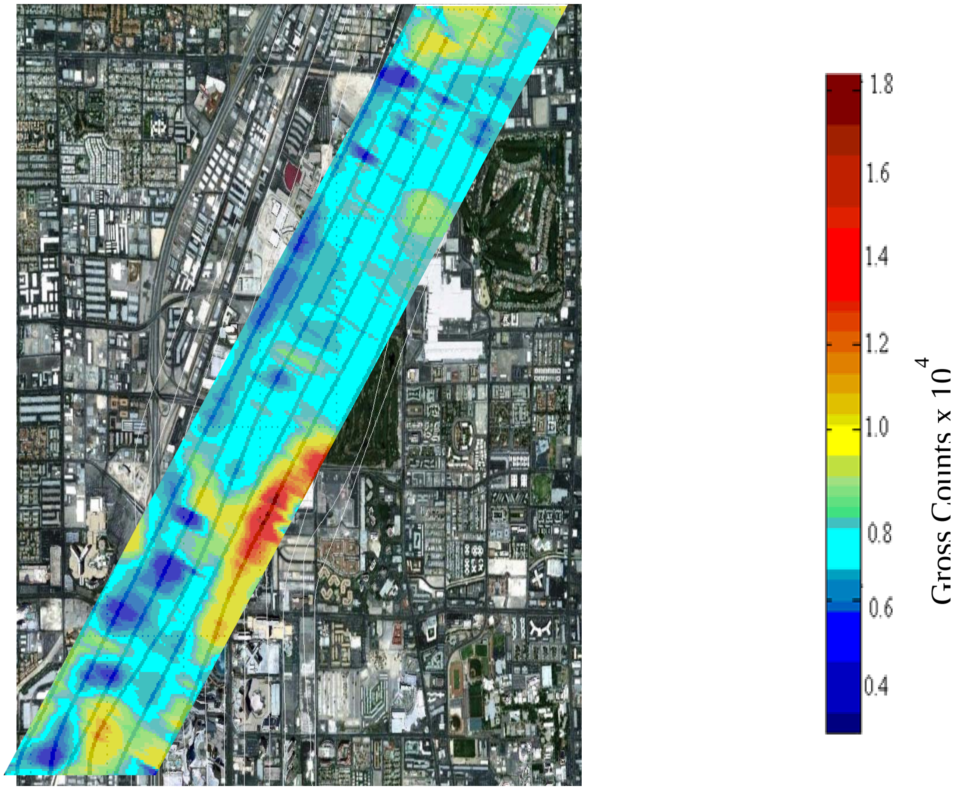

FIGURE 1. Urban variations in radiation background with hotspots.

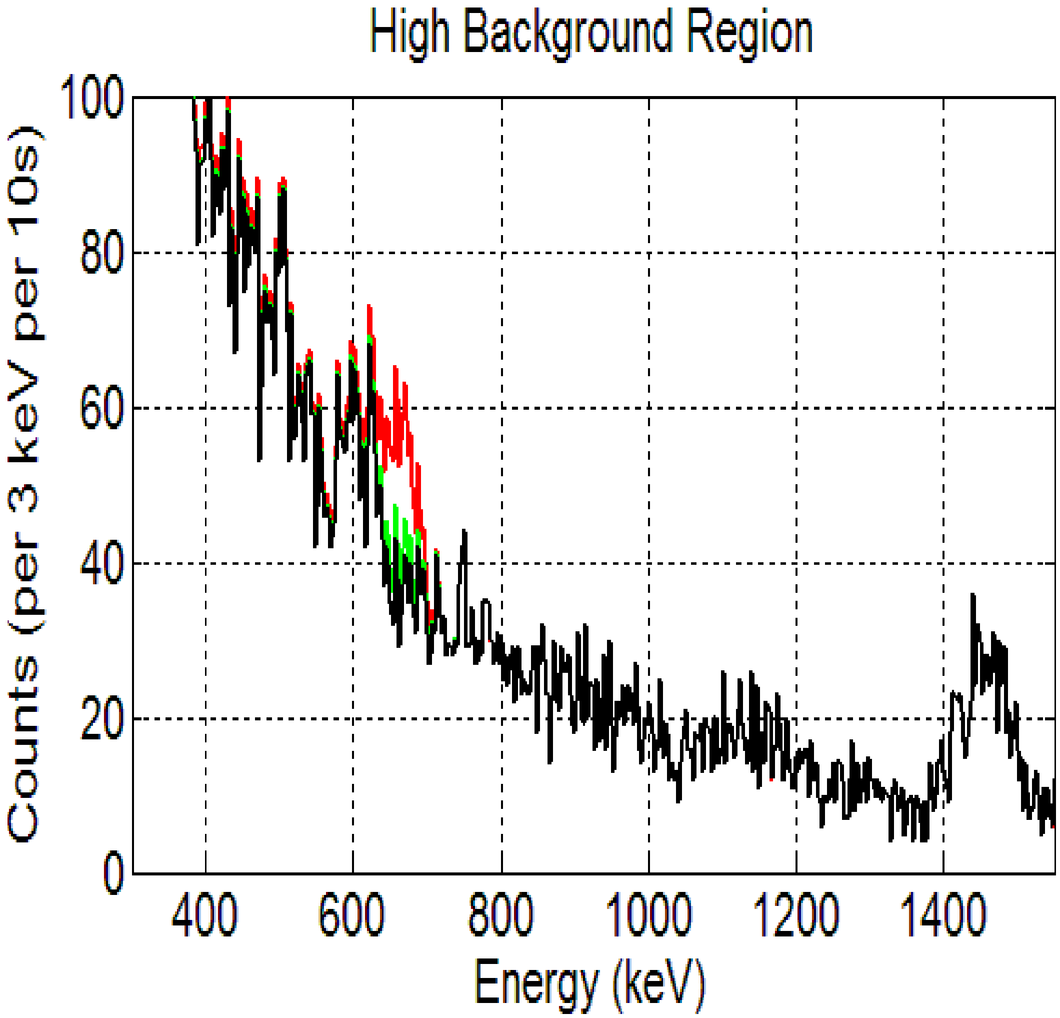

FIGURE 2. Background signal to noise ratio can greatly impact a system false alarm rate and minimum detectable source activity. **Black** (natural background radiation), **Green** (1 mCi Cesium-137 source at 300 ft from the detector) and **Red** (1 mCi Cesium-137 source 150 ft from the detector).

There are a limited number of technical ways for dealing with these challenges. One is to use larger detectors and thus detect a greater amount of radiation, thereby utilizing a larger sample size. Another is to try to reduce the background signal, with, for example, very high resolution detectors that can distinguish radiation from other sources by their energy signal, or approaches such as Compton imaging or coded aperture imaging that, in essence, limit background radiation to a smaller area. It is also possible to make the source "brighter," by forcing it to emit more radiation by activating the source, for example, with neutrons to make fissions.

RMA's

It is sometimes instructive to look at nuclear security efforts as one would military strategy. One useful approach used by military strategists is to look both historically and prospectively at what are called Revolutions in Military Affairs (RMA's). An RMA is defined by the Office of Net Assessments of the Department of Defense as

> *a major change in the nature of warfare brought about by the innovative application of new technologies which, combined with dramatic changes in military doctrine and operational and organizational concepts, fundamentally alters the character and conduct of military operations.*

It is important to note that an RMA is not driven by technology, but rather by the innovative application of technology. Several RMA's are illustrated in the briefing: the development of the longbow during the 100 Years War; the gunpowder revolution; Napoleon's application of industrialization in *levée en masse*; Hitler's application of technology in his Blitzkrieg strategy; and the more recent application of nuclear weapons.

As Director of the Domestic Nuclear Detection Office of the Department of Homeland Security, I sought first to answer the question of whether there had been an analogous "Revolution in Detection Affairs," and second how we could support this revolution and move it forward in a way that supported our objectives. In the decades since the early detectors, there had certainly been many important technical improvements, but it was unclear whether any could be considered a revolution in the context of altering the "character and conduct" of detection operations.

After examining many of the impressive developments in detection technology, the change that could most closely be considered a revolution is the fairly recent capability and deployment of mobile detectors that can be used by large numbers of non-specialists, including police, border agents, etc. This is illustrated in figure 3. It wasn't very long ago that identification of threat materials (radioactive and nuclear) could only be identified by specialists in a laboratory.

FIGURE 3. Radiation detection from the laboratory to the field

As shown in figures 4,5, and 6, this change has been affected by the adoption of advances in micro-electonics and advanced algorithms. We have seen computer memories expand beyond the Apple-II of 16 kilobytes in 1978 to the flash drives of 32 gigabytes of today. A rack of gamma–ray electronic detection equipment has shrunk to the hand-held detector of today.

Revolution in technology & gamma spectroscopy

“Electronics” for a 1964 gamma ray spectrometer

26,000 bytes in 1964

And an even more capable version today

Revolution in technology & gamma spectroscopy

“Output” device for 1964 gamma ray spectrometer

And an even more capable version today

Revolution in technology & gamma spectroscopy

26,000 bytes in 1964

32,000,000,000 bytes today

FIGURES 4,5, and 6 show the improvements in electronics that have facilitated the revolution in detection.

This change in detector technolgoy allowed specialists to transfer to non-specialists a large number of effective devices and facilitated a new strategy that one might call a surge strategy, which allows detection and identification of threat materials in a way that wasn't possible two decades ago. <u>The fundamental challenges that face those trying to find threatening materials remain, but the "character and conduct" of operations using the new technology allows a fundamental change in the nature of detection strategy.</u> The relationship between offence and defense has changed and thus one may consider this a revolution in detection affairs analogous to a revolution in military affairs described above.

As examples, as of 2012, within DHS, Customs and Border Protection had deployed nearly 1500 radiation portal monitors, and 1631 radiation identification devices (RIIDS). The US Coast Guard had deployed nearly a thousand RIIDS and 240 wide are search backpacks as well as a number of other advanced radiation detectors. Even the Transportation Security Agency had deployed 75 RIIDs and 50 backpacks with its VIPR teams. State and local authorities also have deployed substantial radiation detection capabilities. For example, New York City has nearly 6000 pieces of radiation detection equipment and DNDO makes available to State and local authorities Mobile Detection Deployment Units with detection and search capabilities.

This leads to the question of what technological innovations are most likely to reinforce this revolution. There are a few basic categories: 1) new materials with better resolution and other capabilities; 2) detectors with the ability to locate and track materials using techniques such as coded aperture imaging; and 3) the ability to connect and intelligently network the tens of thousands of detectors that are now or can be deployed.

Just as the first revolution piggy-backed on improvements outside of the detection world (micro-electronics), it is likely that the supporting revolution will be based on developments that are also occurring outside of detection. The most dramatic technical innovation that appears to be developing outside of radiation detection is in the area of networking, from cell phones, to the internet, to social networking. The presentation concludes with computer simulation to illustrate how intelligent networking can substantially improve detection (figure 7). The computer simulation uses the data from the ensemble of detectors to sample the Fourier transform of the radiation field. Then the possible location of a source is determined from the inverse transform. This is a way to try to identify the presence or location of a source while avoiding the problem of false alarms in individual detectors. There are two screens displayed in this simulation. The first shows the location of individual detectors and also, from time to time, the injection of a source into the picture. The other panel shows how the inverse Fourier transform responds when a source is present or not. This simulation was developed by Dr. Thomas Albert, DNDO. The simulation demonstrates that it is possible to detect threat material with intelligent networks that couldn't be detected with individual detectors. It is reasonable to assume that with even more complex anomaly detection and network algorithms, capabilities will be further enhanced.

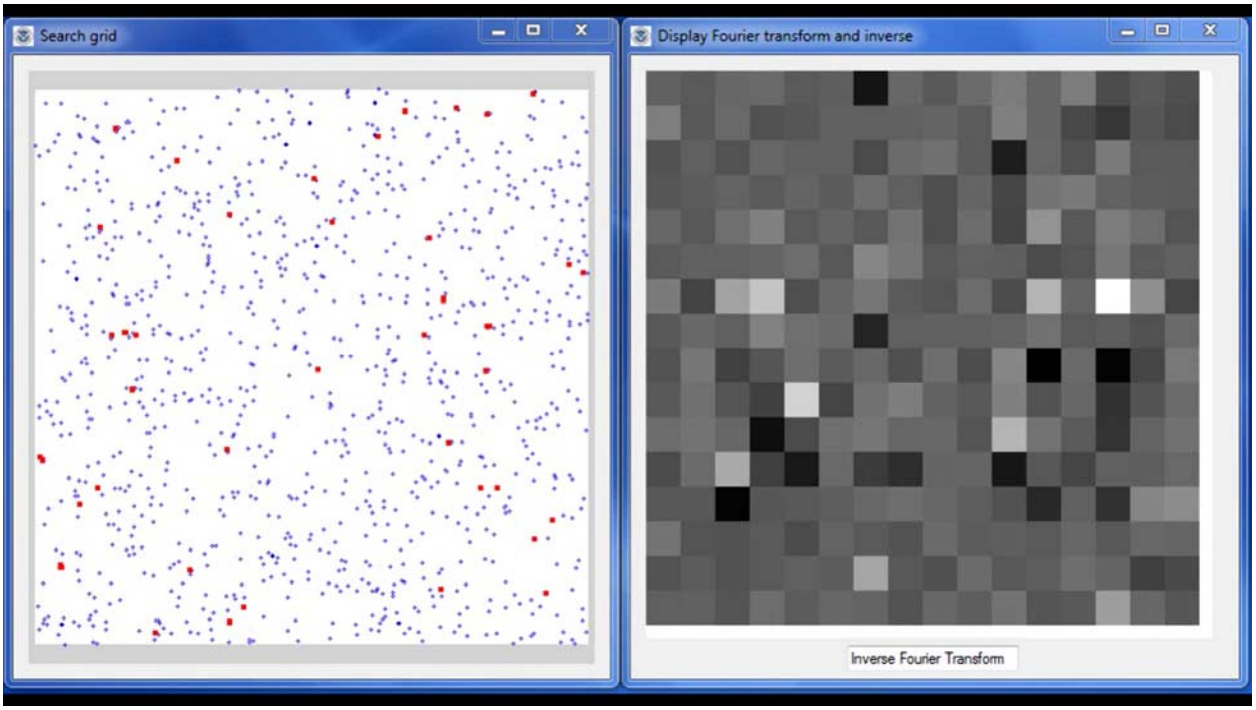

FIGURE 7. Source detected in a networked system using the inverse Fourier transform.

CONCLUSIONS

- Radiation detection must be part of a broader nuclear security strategy
- Architecture should be defined by overall strategy
- Architecture options facilitated by technological developments
- Revolutionary changes in detection have occurred in the past two decades
- Need to reinforce these changes with new technology and craft an Architecture that takes advantage of these technological changes, which will ultimately be based on intelligent networking using advanced anomaly detection algorithms.