RaFTS: The Radiation Field Training Simulator

Training for the **realities** of radiological incidents and emergencies

By Greg White, Steve Kreek, William Dunlop, Joshua Oakgrove, Dan Bower, Dave Trombino, Erik Swanberg, and Steven Pike

One of the biggest challenges in training for incidents and emergencies that involve high-radiation-dose hazards is balancing between **realism** and **safety**. To be truly prepared for the realities of real-world nuclear and radiological emergencies, responder personnel need experience against those hazards but without introducing additional and very personal risks associated with unnecessary radiation exposure. The difficulty is in figuring out how we can achieve a level of realism that encompasses the entire process, from the initial detection of a hazard or threat, through its characterization, to recommending actions and leadership decision-making.

Facing page: Dave Trombino searches for a simulated plutonium source. The detector output is being controlled by the prototype RaFTS device. (Photo: LLNL)

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To ensure the highest level of preparedness, responder personnel ideally need to train against robust, real-life scenarios that occur in locations relevant to them and that enable them to utilize their own operational equipment. All too frequently, the vast array of health and safety, regulatory, and logistical challenges of hands-on radiological training using truly hazardous radiation sources can make this desired level of realism impractical or impossible.

In many cases, a simpler course of action would be for an event controller to spoon-feed radiological information to their trainees during an exercise—perhaps by communicating what their instruments should be reading or by using simulator detectors that have been preprogrammed to respond in a specific way. It's common for controllers to say, "Here's what your detection instrument would have said, had a real hazard been present," during an exercise.

The perennial problem with this approach is that real-world radiological instruments (spectrometers in particular) can often behave very differently when operating in high-hazard environments and against large or distributed radiation sources. Additionally, responders experience differences psychologically when facing an actual, invisible radiation hazard versus an artificial hazard. What is vital is that responder personnel can experience these differences for themselves, but without the risks associated with using real, hazard-level radiation sources. Nevertheless, we must ensure that they are not surprised by those differences during a real-world emergency.

Instructors who wish to conduct training using actual radiation detection equipment typically have two main choices: either to use some form of small, nonhazardous radiation point source or to employ virtual simulation, albeit based upon a digital representation of the equipment.

Both of these approaches face the common problem of satisfactorily approximating the physical complexities of a live, large-scale nuclear event with any sufficient degree of realism. For example, if using a small radiation source, it ideally needs to be placed either directly on top of or sufficiently close to the detector to elicit a response. A source becomes increasingly harder to observe at increasing distances—even if the source is set just a foot or two farther away. At larger distances, the hazard can become virtually undetectable.

Using small sources to represent large-scale contamination or hazard-level sources can also be problematic, with the physics of radiation detection being easily diluted, misinterpreted, or missed altogether. If conducting contamination exercises, small, contained radiation sources are not always able to replicate a distributed contamination zone, which can cause confusion for the operator, particularly because radiation detectors can behave as if the radiation is coming from all directions (which it is).

In the case of search exercises, the use of live sources can often result in trainees following the lead of the yellow-vested safety technician whenever their instruments are not reading anything.

When using live sources for training, the regulatory administration and whole-life-cycle economic impact of these live sources are also significant factors.

Virtual reality offers the benefit of being able to approximate how an instrument might "read" radioactivity. However, the use of virtual reality can also risk oversimplifying the true operational realities of emergency response. When training virtually, trainees also miss the ability to experience the crucial physical and physiological factors of hands-on training—whether it is the heaviness of their equipment, their screen becoming unreadable in the sunlight, or their device being too large for them to crawl through a tight space.

Greg White displays data being generated by a vehicle-transportable radiation detector controlled by RaFTS. (Photo: LLNL)

The Radiation Field Training Simulator

In a bid to address some of these shortcomings in radiological training, Lawrence Livermore National Laboratory, together with British simulator detector manufacturer Argon Electronics Ltd., has devised the Radiation Field Training Simulator (RaFTS).

RaFTS combines virtual hazard and real-world detection capabilities to enable responder personnel to experience highly realistic radiological training that recreates all the practicalities of operating against a live radiation hazard—and for them to be able do so while using their own operational detector equipment. In contrast to simulator detectors, which duplicate the look and feel of real detectors, RaFTS technology produces a response within the actual radiation detectors in use and replicates all the physics of real-world usage. RaFTS bridges the gap between simulation and how the personnel's actual equipment responds to realistic hazards, capturing the psychological aspect as workers see their instruments respond in real time and in ways that replicate the expected physics.

The technology also allows radiological exercises to be delivered in any location, from a parking lot to a downtown area (to simulate fallout, for example) or within a public building using discrete simulation sources.

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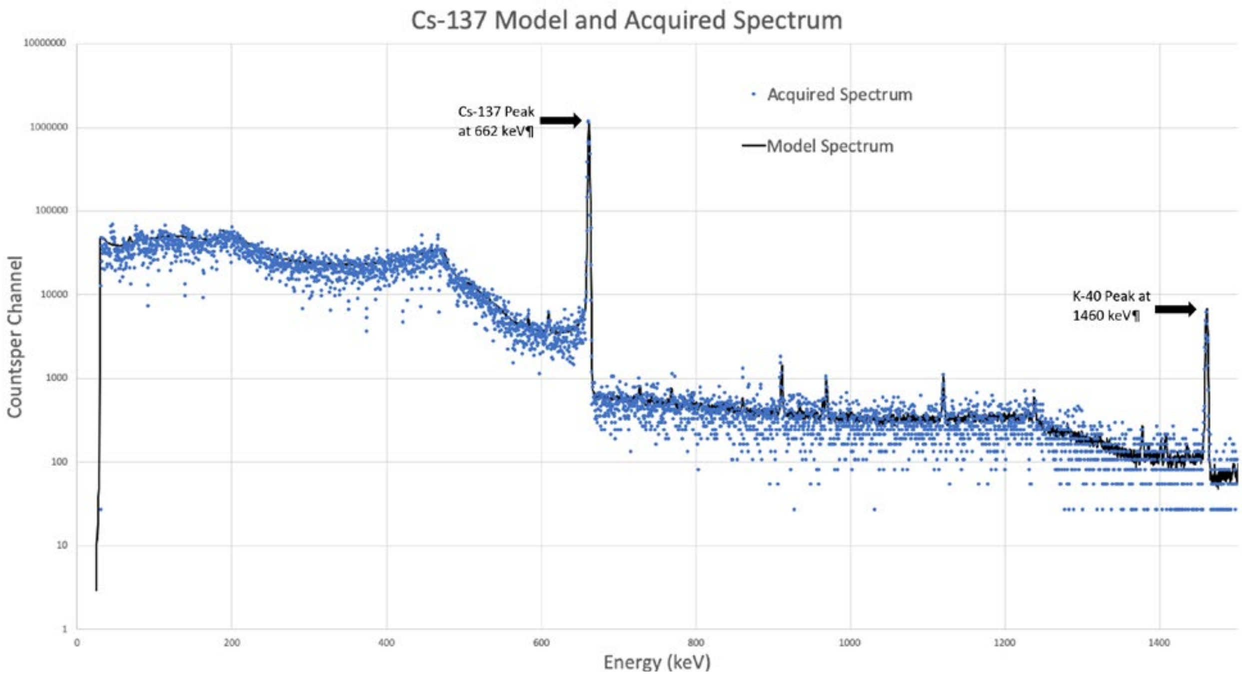
RaFTS capabilities

RaFTS provides radiological instructors with the ability to inject simulated data into the actual radiation detection instruments that responder personnel will use when responding to real-life radiological incidents. A precalculated scenario can be easily programmed into RaFTS, with the option to include multiple radiation sources, which can be either dispersed or in fixed locations.

The technology draws upon detailed scenarios based on actual U.S. national emergency response capabilities, such as those of the National Atmospheric Release Advisory Center. More sophisticated scenarios can be created with the direct support of LLNL.

The data generated for these sophisticated scenarios are prepared as inject signals that feed directly into the trainees' suitably adapted operational detectors, enabling them to practice both response and their reachback protocols with the highly realistic data collected by their instruments. The data injection occurs and is controlled by the physics of the operator's encounter with the hazard and how they are using their instrument, which significantly increases the realism of the training exercise—for example, reducing the need for exercise controllers.

RaFTS is able to generate signals that make the operational detector respond as if radiation sources are present, and it works with detection instrumentation that spans the range of capability that is commonly in use. Some detectors simply provide a measurement of the radiation dose (a simple rate), while others are capable of sorting the various energies that are present and are used to identify and characterize the source in detail. The generated signals are injected into detector systems in place of, or in addition to, the signals naturally present in background or other radiation sources that may be present, such as commercial products or even signals from persons that recently received medical treatments like stress tests or thyroid irradiation.



More sophisticated response instruments are able to separate radiation by the energies present needed to identify the radiation source(s). This graph shows a comparison of two sets of data: an actual cesium-137 radiation energy spectrum, combined with natural background (potassium-40 and radon-228), which is used as the model (black line) baseline; and the RaFTS-generated spectrum (blue dots). The RaFTS energy spectrum started as simulated preamplifier pulses, which went through a shaping amplifier and into the instrument energy sorting hardware (a multichannel analyzer). The energies of the detected peaks were then used to identify the radioactive isotopes that are present. Note that the Cs-137 peak is at 661 keV (the first large peak) and the background peaks are those such as K-40 at 1460 keV. The shapes of each peak (denoted as the full-width at half-maximum) are the same. The RaFTS spectrum was scaled to match the model spectrum counts.

While the primary concept has been to inject signals into a port provided on an adapted detector, it will also be possible to implement a dedicated simulator by means of sensor substitution. This provides maximum flexibility to the user community to be able to upgrade their existing equipment or procure capable instruments during recapitalization.

RaFTS outputs are of sufficient quality to ensure that the detection instruments respond exactly as they do to actual radioactivity. The data collected provide a sufficient degree of realism to enable the identification of the radioactive species present, its characterization, and the localization of a radioactive source.

A significant benefit provided by the integration of RaFTS is the extreme high quality of the output energy spectra, which can be processed and sent to reachback centers just like in real life. Therefore, reachback expertise and advice or recommendations can be incorporated into the exercise. The fidelity of the information contained in the "energy spectrum" is based on the type of detector, the source of the radiation, and the physics of how the user encounters the source and uses their instrument. The system allows any radioactive material or materials to be represented in the scenario. The strength of the signal will depend on the size of the source, the distance to the detector, and how long the operator uses their instrument. It can also be modified to allow for intervening shielding materials, just as would occur in reality.

The relationship between Argon and LLNL also provides RaFTS with compatibility with a wide variety of Argon's existing radiological training systems.

Trombino (right) demonstrates the RaFTS device with a high-purity germanium detector. (Photo: LLNL)

Testing, demonstration, and optimization

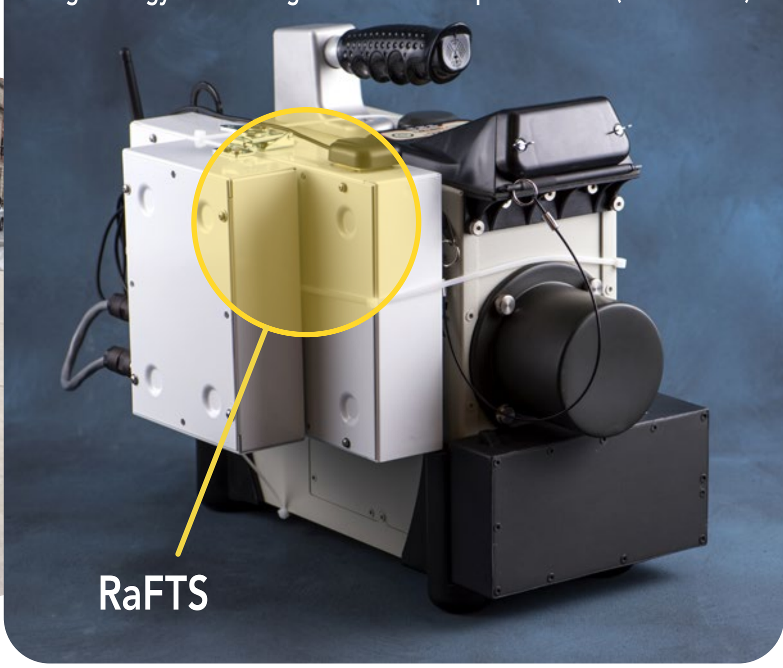
RaFTS was first publicly demonstrated in Washington, D.C., in 2016 using the operational semiconductor-based detector the Ortec Detective X high-purity germanium radioisotope identification device. The HPGe-based detector provides the highest ability to separate gamma rays of different energies, useful for identifying and characterizing the sources.

RaFTS has also been successfully integrated with a commonly available detector based on sodium iodide. The NaI-based detector is less capable of separating the energies but is more commonly available—for example, in devices such as the TerraTracker adaptable radiation area monitor (ARAM)–enabled mobile SUV, used by the Department of Homeland Security and local authorities in the New York/New Jersey region.

The integration with ARAM demonstrates the ability to incorporate RaFTS into mobile as well as handheld detectors. Body-worn "backpacks," fixed-site detectors, and portal monitors are also suitable candidates for integration.

The developers of RaFTS are confident that the same technology will work on a variety of instrument types through a common interface, which will yield a universally adaptable simulation tool that can be used to train against a broad array of radiological sources and scenarios.

RaFTS is shown attached to the exterior of a commercial high-energy-resolution gamma radiation spectrometer. (Photo: LLNL)



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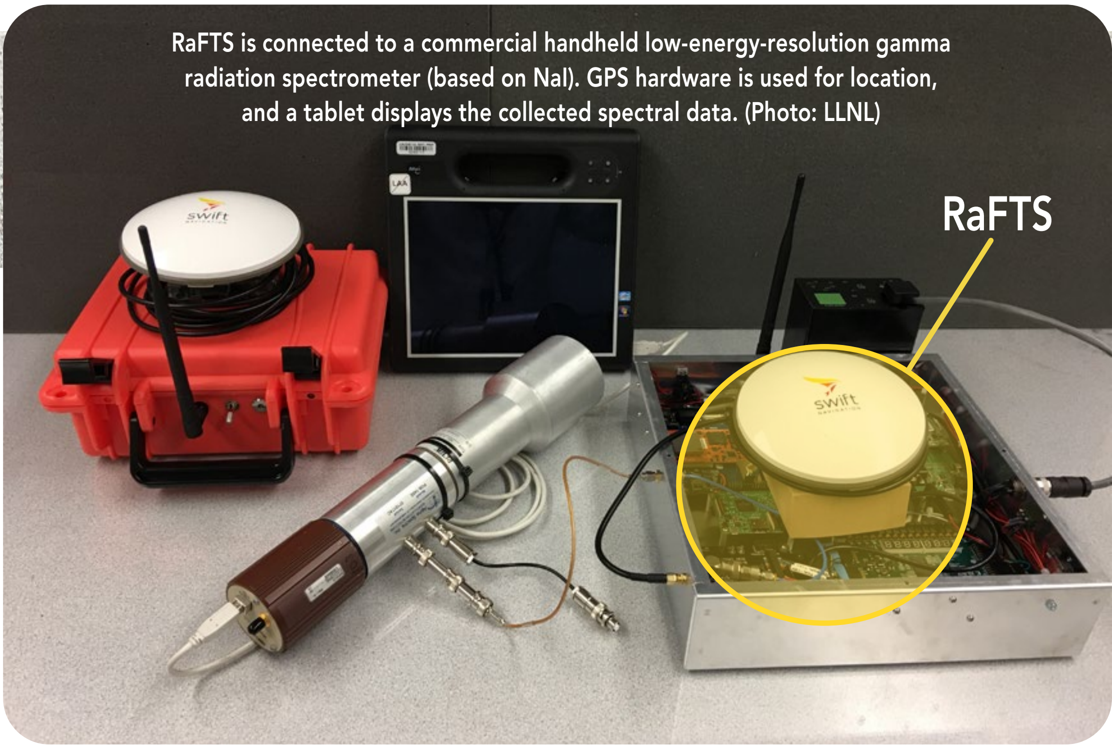

RaFTS is connected to a commercial handheld low-energy-resolution gamma radiation spectrometer (based on NaI). GPS hardware is used for location, and a tablet displays the collected spectral data. (Photo: LLNL)

To date, the technology has also been viewed by the Department of Energy, various components of the Department of Homeland Security, the State Department, and the Defense Threat Reduction Agency, as well as international organizations such as the International Atomic Energy Agency and the Comprehensive Nuclear-Test-Ban Treaty Organization.

Technical development of RaFTS

Work is now underway to reduce the size and weight of RaFTS to make it easily portable (the size of a typical pager is the objective). The current RaFTS equipment has been tested in extreme environments, down to temperatures well below freezing. As the design is miniaturized, continual quality tests will be conducted to ensure performance is maintained across a broad range of environmental conditions including cold, high humidity, and other outdoors environments.

The RaFTS hardware and software are also being enhanced to handle more complex scenarios—for example, to allow for instances where a source is moving (e.g., within a vehicle) or where the scenario is changing over time due to radioactive decay, weather conditions, etc. (e.g., a plume release). LLNL is also leveraging its scenario generation capabilities to support Argon's wide-area instrumented training system PlumeSIM, which will enable the staging of even more involved scenarios.

The developers of RaFTS have worked in close collaboration with the manufacturers of radioactive measurement devices to gain the required access to their signal chain and continue to welcome additional detector manufacturer partners. In the shorter term, LLNL and Argon are developing a standard RaFTS interface that can be retrofitted with existing detectors to enable them to accept RaFTS inputs. Longer term, the goal is to coordinate with detector manufacturers in the standardization of their next-generation detection equipment so such devices could come pre-equipped with a RaFTS injection port.

The future of radiological training

To be truly prepared for the challenges and the complexities of real-world emergencies involving high-radiation-dose or high-threat hazards, it is vital that responder personnel can practice using their actual equipment in those environments. The effectiveness of current radiological training methods can often be constrained by safety considerations—that is, the difficulties of creating realistic scenarios and yielding realistic configurations using (for safety reasons) only small-quantity, hard-to-detect radiation sources.

With the development of RaFTS, there is now the opportunity for responder personnel to develop vital familiarity with their actual equipment, and to do so while operating against highly realistic and scientifically sound scenarios that replicate the conditions they will encounter in real life. ⌘

Steven Pike (left) and Philip Dunn (middle) of Argon Electronics Ltd., which has licensed the RaFTS system, are being shown its operation by Dave Trombino (right). (Photo: LLNL)

G. White, S. Kreek, W. Dunlop, J. Oakgrove, D. Bower, D. Trombino, and E. Swanberg are with Lawrence Livermore National Laboratory in the United States, and S. Pike is with Argon Electronics Ltd. in the United Kingdom. This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344, Lawrence Livermore National Security LLC.