Radiological Disaster Simulators for Field and Aerial Measurements

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Abstract

Simulators have been developed to dramatically improve the fidelity of play for field monitors and aircraft participating in radiological disaster drills and exercises. Simulated radiological measurements for the current Global Positioning System (GPS) location are derived from realistic models of radiological consequences for accidents and malicious acts. The aerial version outputs analog pulses corresponding to the signal that would be produced by various NaI (Tl) detectors at that location. The field monitor version reports the reading for any make/model of survey instrument selected. Position simulation modes are included in the aerial and field versions. The aerial version can generate a flight path based on input parameters or import an externally generated sequence of latitude and longitude coordinates. The field version utilizes a map-based point and click/drag interface to generate individual or a sequence of evenly spaced instrument measurements.

Need For Simulators

Various safety procedures, government regulations, and general proficiency requirements require participating in drills and exercises to validate the performance and capabilities of various radiological response teams. This presents a significant challenge for the exercise designers. A

good exercise is one that accurately judges the participants on their skills in responding to a radiological release, not how well they follow the limited script of an exercise event. This requires the available sampling and measurement locations to be completely unrestricted. Therefore, the designers perfectly predict the behavior of the players or have data readily available for all locations and times. With the simulators described in this paper, data is generated in real time for the specified time and location.

Various methods have been attempted with varying degrees of success. When designing simulators it is important to keep in mind what is being tested, the field team response, the operations center response, the controller capabilities, or the simulator's response time and ease of use. Optimally, the simulator should be completely transparent with the data being injected with minimal effort on the part of either controller or player.

The first consideration of a simulator's design should be at what level to inject the data into the exercise play. There are three primary levels: instrument hardware, field team, and operations center. Injecting data into the instrument hardware is the most desirable when you wish to test the capabilities of the field teams, although this is also the most difficult since it requires modification of or utilization of specialized instruments. Supplying data directly to the operations center is a viable option when all that needs to be tested is the assessment scientists and response managers playing in the exercise. Unfortunately, it completely overlooks decisions that would be made in the deployment, operation, and communication of the field teams. While appropriate for some table-top (classroom confined/textbook) exercises it fails to simulate a significant component of an actual radiological disaster response. Sending a controller out with

field teams has been an effective compromise, enforcing the limitations on available monitoring locations or generating data for the team's instruments as needed. The problem that arises in this situation is the consistency and reliability of controllers can be flawed without extensive training. Presented in this paper are two simulators designed to greatly simplify the training needs and ensure the reliability of controllers, to the point of removing the need for controllers at the field-team level.

Realism Of Data

In addition to being introduced into the exercise transparently the data needs to be realistic. While the gaussian plume model is fairly easy to calculate, it requires near perfect weather conditions and relatively flat, even terrain. For most cases this is only a rough approximation of real-life conditions. The simulators discussed in this paper rely on the creation of plume models by scientists at the National Atmospheric Release Advisory Center (NARAC) and Sandia National Laboratories (SNL) for requested release conditions. These files are then processed by the simulators in combination with the current location and characteristics of the instrument of concern to produce a simulated measurement.

Data Production

The two programs discussed here both generate data in real time. The aerial version is specifically designed to simulate the U.S. Department of Energy National Nuclear Security Administration Aerial Measurement System's instruments. The aerial simulator is of the class

that injects its values directly into the instrumentation within the aerial platform as a variable-rate

pulsar. The number of pulses to generate is accomplished by first obtaining the current location

from a GPS receiver. The area below the platform is then divided into 10 concentric rings, each

divided into 16 sectors. The largest ring is calculated to have a distance of 10 mean free paths

(MFP) from the detector platform to the ring circumference. The remaining rings are calculated

so the angle formed between the detector and any two adjacent rings are all equivalent. For each

of the rings an aerial efficiency for the current detector is calculated as specified in Equation 1.

$$eff = \left(\frac{A}{4p \bullet R^2}\right) \bullet \left[1 + a \bullet \frac{R}{MFP} \bullet e^{\left(b \bullet \frac{R}{MFP}\right)}\right] \bullet \left[e^{\left(\frac{-R}{MFP}\right)}\right] \tag{1}$$

Where A is the area of a sector, R is the range to the center of a sector, A and B are the Berger

buildup coefficients, and MFP is the mean free path of the specified radiation in air. The

calculated efficiency is then multiplied by the activity per unit, within the area specified in the

imported deposition files created by either NARAC or SNL.

Once the pulse rate has been calculated the program directs a piece of custom hardware to

introduce pulses at the specified rate into the detection system. After setup, the program

performs without user awareness. Additional options include specifying a large point source,

removing build-up from the calculation, and utilizing simulated location sources (Fig.1).

Fig. 1: View of the RATS application main window. The components of the scenario are in the

pane on the left. A GIS map window on the top right can display shape files, CAD files, georeferenced images, etc. The instrument pane on the bottom right displays all instruments and either their measurement value or a button for spectra generating instruments.

The second simulator is designed for field team use and can be deployed on a GPS enabled handheld computer operating the PalmOS™. The reported data is produced in real time from the interaction of several different components that form an exercise scenario. The first is called the source term. The radiation released from a source term depends on the isotopic mix assigned to the source. Each isotopic mix is composed of various fractions of isotope parents. The isotopes that form a mix are imported from parent type ENDSF files, which can be freely obtained from Brookhaven National Laboratory.

In addition to specifying the isotopic mix of a source term, a scenario designer must specify the point location, resuspension factors, temporal scale points, and the source type. The meaning of the point location varies depending on exactly what source type is chosen but can usually be considered as a release point. The resuspension factors enter into the calculation when there is a deposition and a user is reading the air concentration. Temporal scaling allows the scenario designer to add points during the exercise timeline where the strength of the source is multiplied by a certain value. The program will then linearly interpolate between those times. This allows the scenario to simulate the passing of a plume, a point source that is occasionally removed from a shielding package, a nuclear criticality, and various other situations (Fig.2).

Fig. 2: View of the PalmOS(tm) program when logged into field mode. The number of satellites

locked is zero due to the use of a simulated GPS source signal. Instruments can be changed by accessing the popup menu under Current Instrument.

The source types fall into two primary categories, either plume or deposition. Plume sources do not use resuspension in calculating the air concentration; instead it is assumed the activity is all airborne. The four source types developed are: Point, NARAC, Handwave, and Background. The point source allows you to specify the total activity of the parents and is located at the previously specified position. The NARAC source lets you import a single nested grid format file as produced by NARAC on special request. The grid is only unique to the UTM zone (3 degrees longitude) and the zone is specified by the previously specified position. The handwave source allows up to four contours of any value that can be drawn on the program's map view as rectangles, polygons, or ellipses. The background source specifies a source present at all locations with either constant or randomized levels.

Once the sources have been specified, the designer needs to create or utilize field instruments that will generate reportable measurements. Each instrument has four primary specifications: the type, error parameters, bounds, and efficiencies. Instrument types include alpha, beta, and gamma spectrums, exposure, and counting. Displayed units can be set for each instrument. Error parameters are either randomized, constant percentage bias, or a combination of both. Randomized error varies the measurements by a value that is generated from a gaussian distribution about the true value or by a linear distribution over a given percentage of the true value. For example, an alpha counter that reports counts per second with 100% efficiency will have a gaussian distribution around the measurement with a sigma of the square root of the

measurement. The bounds of each instrument essentially provide limits on what is presented as

the instrument measurement, allowable collection times, and instruments sensitivity to various

energy ranges. Instrument efficiencies for each source term are automatically calculated based

on the source radiations and energy-based efficiencies curves provided by the user.

Once the scenario is designed, there are multiple methods in which to access the data produced

by it. The available methods are governed by the permission level the user has authenticated to

him/her self. Four levels are available: master, author, oracle, and field. The master level can

change anything about the scenario at any time, and see all the values at those times. The author

level has essentially the same permissions as the master level with the exception of changing the

password of the master level. The oracle authentication level has access to all the values

produced by the instruments for any time and place. The field permission level will only report

instrument values for the current location and time as specified by a GPS input. Without any

authentication the only viewable data is the scenario description and title. The PalmOS™

version of the program only supports oracle and field-permission levels.

As seen in the attached figures, the PalmOS™ version allows a user to view only one instrument

at a time, with a pop-up menu listing available instruments. For spectra generating instruments

the PalmOS™ is currently limited to having the user wait at that location for the designated

collection time; recording the parameters of location, current time, and elapsed collection time in

a database; and then displaying the spectra after connecting to a desktop or laptop computer.

The desktop version allows a user to view all instrument values that can be fit into the viewable

area. Spectra results are generated immediately for oracle users, and after the collection time for field users. Users authenticated at oracle level or above can move the mouse over the displayed map as the instrument values relate to the mouse location on the map. This allows a controller to act as a phantom field team and determine instrument values at any points in the field of play and inject them into the operations center.

Conclusions

The two simulators discussed here produce a greater level of realism than that commonly found in current radiological exercises. Utilizing the products of sophisticated atmospheric plume dispersion models increases the likelihood that the exercise is an accurate simulation of a potential real-world event. By allowing operations centers to direct field teams to any location provides a degree of flexibility that shifts the burden of characterizing a release from preplanning by the controllers to field monitoring plans designed by the players.

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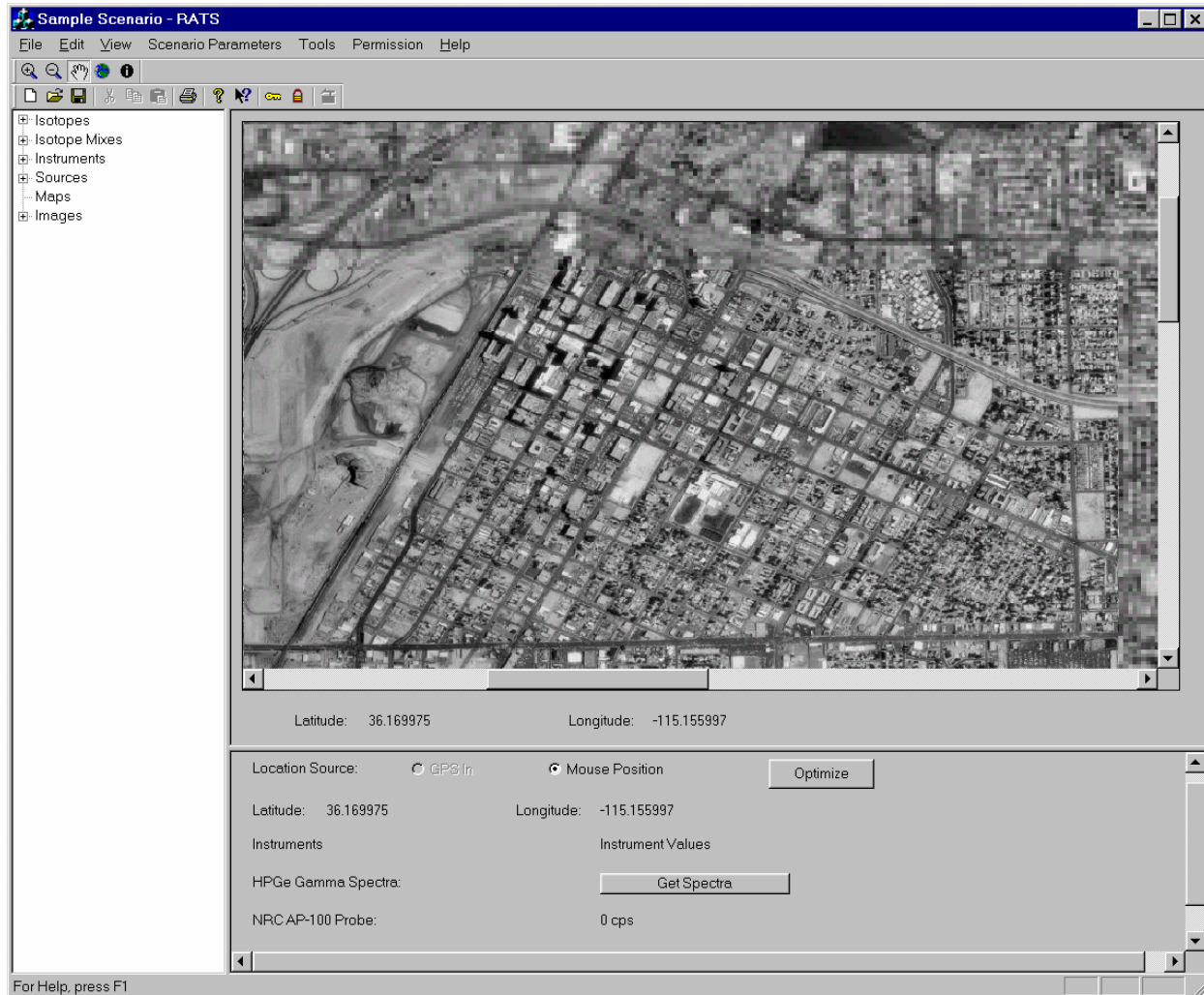
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