LLNL-CONF-410197

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January 29, 2009

American Nuclear Society
Atlanta, GA, United States
June 14, 2009 through June 18, 2009

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January 30, 2009

In this paper, we consider a mobile source that we attempt to detect with man-portable, vehicle-mounted or boat-mounted radiation detectors. The source is assumed to transit an area populated with these mobile detectors, and the objective is to detect the source before it reaches a perimeter. We describe a simulation model developed to estimate the probability that one of the mobile detectors will come in to close proximity of the moving source and detect it. We illustrate with a maritime simulation example.

Our simulation takes place in a 10 km by 5 km rectangular bay patrolled by boats equipped with 2"x4"x16" NaI detectors. Boats to be inspected enter the bay and randomly proceed to one of seven harbors on the shore. A source-bearing boat enters the mouth of the bay and proceeds to a pier on the opposite side. We wish to determine the probability that the source is detected and its range from target when detected.

Patrol boats select the nearest in-bound boat for inspection and initiate an intercept course. Once within an operational range for the detection system, a detection algorithm is started. If the patrol boat confirms the source is not present, it selects the next nearest boat for inspection. Each run of the simulation ends either when a patrol successfully detects a source or when the source reaches its target.

Several statistical detection algorithms have been implemented in the simulation model. First, a simple *k*-sigma algorithm, which alarms with the counts in a time window exceeds the mean background plus *k* times the standard deviation of background, is available to the user. The time window used is optimized with respect to the signal-to-background ratio for that range and relative speed. Second, a sequential probability ratio test [Wald 1947] is available, and configured in this simulation with a target false positive probability of 0.001 and false negative probability of 0.1. This test is utilized when the mobile detector maintains a constant range to the vessel being inspected. Finally, a variation of the sequential probability ratio test that is more appropriate when source and detector are not at constant range is available [Nelson 2005].

Each patrol boat in the fleet can be assigned a particular zone of the bay, or all boats can be assigned to monitor the entire bay. Boats assigned to a zone will only intercept and inspect other boats when they enter their zone. In our example simulation, each of two patrol boats operate in a 5 km by 5 km zone. Other parameters for this example include:

- Detection range: 15 m range maintained between patrol boat and inspected boat
- Inbound boat arrival rate: Poisson process with mean arrival rate of 30 boats per hour
- Speed of boats to be inspected: Random between 4.5 and 9 knots
- Patrol boat speed: 10 knots
- Number of detectors per patrol boat: 4 - 2"x4"x16" NaI detectors
- Background radiation: 40 counts/sec per detector
- Detector response due to radiation source at 1 meter: 1,589 counts/sec per detector

Simulation results indicate that two patrol boats are able to detect the source 81% of the time without zones and 90% of the time with zones. The average distances between the source and target at the end of the simulation is 5,866 km and 5,712 km for non-zoned and zoned patrols, respectively. Of those that did not reach the target, the average distance to the target is 7,305 km and 6,441 km respectively. Note that a design trade-off exists. While zoned patrols provide a higher probability of detection, the non-zoned patrols tend to detect the source farther from its target. Figure 1 displays the location of the source at the end of 1,000 simulations for the 5 x 10 km bay simulation.

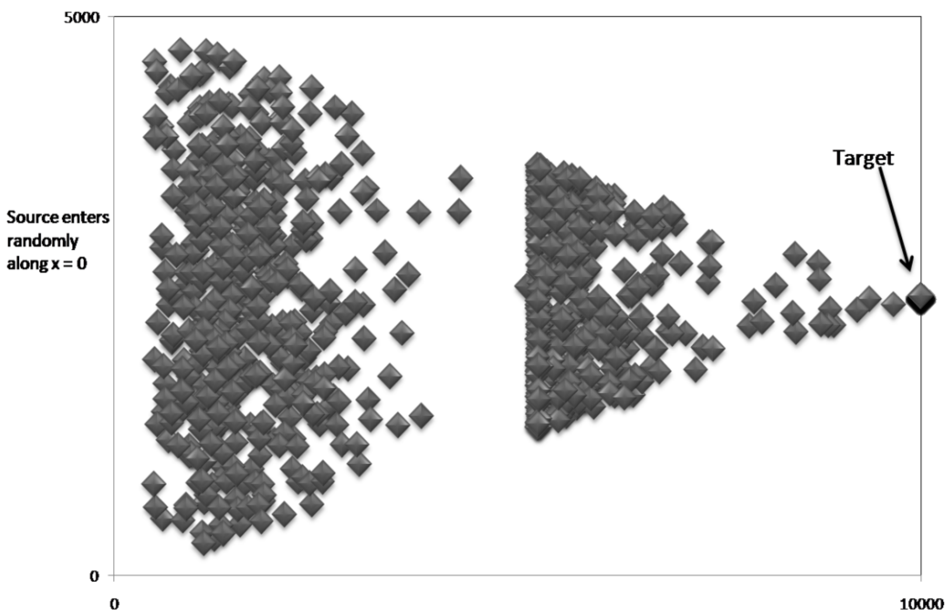

Figure 1

The simulation model and analysis described here can be used to determine the number of mobile detectors one would need to deploy in order to have a have reasonable chance of detecting a source in transit. By fixing the source speed to zero, the same model could be used to estimate how long it would take to detect a stationary source. For example, the model could predict how long it would take plant staff performing assigned duties carrying dosimeters to discover a contaminated spot in the facility.

References

[Wald 1947] Wald, Abraham, *Sequential Analysis*, Dover, New York.

[Nelson 2007] Nelson, Karl E., John D. Valentine and Brock R. Beauchamp, Radiation Detection Method and System Using the Sequential Probability Ratio Test, U.S. Patent 7,244,930 B2 (July 17, 2007).

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.