Interdiction of Smuggled Nuclear Material

N. Dimitrov, M.A. Gonzalez, D.P. Michalopoulos, D.P. Morton, M. Nehme,
F. Pan, E. Popova, K.J. Saeger, E. Schneider and G. Thoreson[a]

The University of Texas - Austin
Pickle Research Campus, R-9000
Austin, Texas 78712
[a] *gthoreson@mail.utexas.edu*

INTRODUCTION

The lack of reliable nuclear material accounting at a global level creates opportunities for groups to illegally acquire this material, and possibly construct a nuclear bomb or radiological dispersion device. However, the construction and delivery of such a weapon requires the transportation of nuclear material over a network of roads, seaports, and airports. Placing radiation detectors throughout the network creates a second line of defense with which an interdictor can potentially catch a smuggler. Up to this point, radiation detector development has been at the forefront of interdiction efforts. While this is vital to the defense system, considerably less effort has been committed towards strategic placement of these detectors, an essential component with finite resources.

STOCHASTIC INTERDICTION GAME

To formulate a strategy in the deployment of radiation detectors, we propose a class of stochastic interdiction models on a transportation network in which the interdictor and smuggler are involved in a strategic game. In this game, the interdictor first installs radiation detectors on the network; these detectors are mostly comprised of currently installed radiation portal monitors. A threat scenario is then generated which specifies the smuggler's origin and destination, the type of nuclear material and shielding, and the mechanism by which the smuggler will select a smuggling route. Intelligence may then be made available to the interdictor, who in response deploys mobile radiation detectors. The smuggler simultaneously chooses a path over the network in a two-person zero-sum Cournot game. The interdictor's goal is to minimize the probability the smuggler avoids detection. Two models of the smuggler's behavior are considered: In one, the smuggler chooses a maximum-reliability path and in the other a Markov chain governs his path.

DETECTION PROBABILITIES

Should a smuggler attempt to traverse a network node at which a radiation detector is present, there exists a finite probability of detection. Quantifying this probability is critical to the game and unique to each threat scenario and node. Scenarios are defined by a variety nuclear materials, shielding materials and thicknesses, vehicle types (both terrestrial and maritime), and vehicle cargo. At each radiation detection node, different radiation detector types and alarm algorithms are considered. Novel detection systems such as photon-induced fission are studied as well. The quantity of parameters and their varieties for each scenario make accurate experimental determination infeasible. Thus, each is modeled computationally using the code package Monte Carlo N-Particle eXtended (MCNPX) [1]; however, the number of possibilities still imposes an enormous computational burden.

This burden is lessened by the superposition of multiple solutions from MCNPX without a significant loss in accuracy. For example, the flux of natural background radiation emanating from soil and concrete can be considered independent of surface objects to a first order approximation. Similarly, the radiation field leaving the vehicle can be calculated separately. Assuming it is independent of the environment as well, the results of these two transport calculations can be used in a third, where the transport of radiation from the ground surface and vehicle surface to the detector is calculated. The proposed process of superposition is summarized for a passive detection system in Figure 1. From Figure 1, there are essentially four regimes of MCNPX calculations, each of which may be composed of multiple superpositions in of themselves: the transport of (1) source radiation through shielding and cargo vehicle surface, (2) the radiation field leaving the vehicle surface to the detector, (3) natural radiation through soil to the ground, and (4) the radiation field leaving the ground to the detector. These solutions are combined and weighted by their respective source strengths, effi-

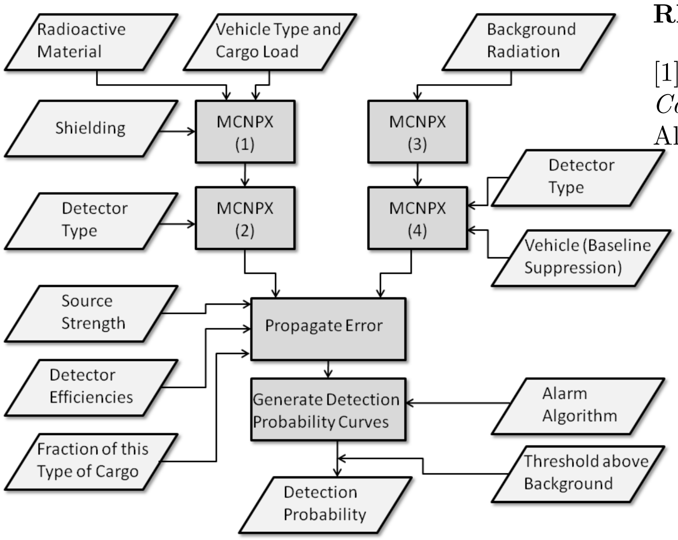

Figure 1: Outline of Parameters and the Superposition of MCNPX Solutions

ciencies, and cargo fractions; and, given an alarm algorithm and threshold (how sensitive the alarm is to count rate fluctuations) a detection probability is calculated. The superposition of these solutions drastically reduces the computation time.

MCNPX GUI PROGRAM

A great interest exists to detach the intricacies of MCNPX and the calculation of detection probabilities from a user interested in such information. A proposed solution to this is the creation of a specialized GUI. This program requires a user to choose different combinations of aforementioned parameters to construct a threat scenario. It then produces a visual model of the geometry, runs MCNPX, extracts the results, and post-processes the information into useful and meaningful data. A person with no experience in radiation transport or MCNPX can operate this GUI. At the same time, it is flexible enough such that additional tallies and user-built geometries and functions can be input. It also stores important results from previous simulations such that future scenarios with similar environments can be partially determined by superposition. This serves to drastically reduce computation time for the end user, and also provide an organized method to build a library of solutions for our interdiction models. A tool such as this would be of great value to the scientific community.

REFERENCES

[1] MCNPX, "*MCNPX – A General-Purpose Monte Carlo Radiation Transport Code, Version 2.5.0*", Los Alamos National Laboratory, (Mar. 2005).