Personnel Dose Assessment during Active Interrogation

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INTRODUCTION

A leading candidate in the detection of special nuclear material (SNM) is active interrogation (AI). Unlike passive interrogation, AI uses a source to enhance or create a detectable signal from SNM (usually fission), particularly in shielded scenarios or scenarios where the SNM has a low activity. The use of AI thus makes the detection of SNM easier or, in some scenarios, even enables previously impossible detection. During the development of AI sources, significant effort is put into determining the source strength required to detect SNM in specific scenarios. Usually during this process, but not always, an evaluation of personnel dose is also completed. In this instance personnel dose could involve any of the following: (1) personnel performing the AI; (2) unknown stowaways who are inside the object being interrogated; or (3) in clandestine interrogations, personnel who are known to be inside the object being interrogated but are unaware of the interrogation. In most instances, dose to anyone found smuggling SNM will be a secondary issue. However, for the organizations performing the AI, legal if not moral considerations should make dose to the personnel performing the AI, unknown stowaways, or innocent bystanders in clandestine interrogations a serious concern.

DESCRIPTION OF THE ACTUAL WORK

The purpose of this work is to evaluate the doses that personnel involved with AI can expect. Since these doses are dependent on the AI source and the object being interrogated, only a few scenarios will be considered. All of these evaluations are performed using the MCNPX [1] Monte Carlo radiation transport code, version 2.6.0. However, weight windows and biased source distributions are generated using the latest version (version 2.0) of the code ADVANTG [2,3,4]. The scenarios are limited to the AI of a small ship, more specifically a luxury yacht and a standard 20 ft cargo container (2.44 × 2.60 × 6.10 m). The MCNPX geometry of the luxury yacht is shown in Fig. 1. The analysis of the luxury yacht is performed with the AI source directed toward a cabin room (low density—low Z, where Z is the proton number) and the engine room (high density—high Z). The analysis of the cargo container is performed for a high Z loading, a low Z loading, and a loading with a mixture of high- and low-Z materials. The density of each cargo container loading is such that the container is fully loaded based on weight regulations. Of all the possible AI sources, only neutron or photon (via electron bremsstrahlung) sources are considered. The doses inside the luxury yacht and outside the cargo container are calculated using mesh tallies and flux-to-dose conversion factors. In addition to the mesh tallies, a computational phantom is also included in the calculations of doses to specific organs. The phantom in these calculations is the VOXMAT [5], developed at Oak Ridge National Laboratory. VOXMAT is a hybrid phantom that combines the details of a voxelized phantom around the major organs with the extremities of a mathematical phantom.

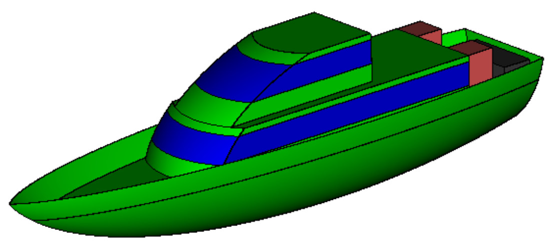

Fig 1. Luxury yacht MCNP model.

RESULTS

In all the analyses performed, no SNM is present in any of the models. Therefore, the reported doses are attributable only to the AI source particles. Figures 2 and 3 show mesh tally dose results for a bremsstrahlung source, created by 25 MeV electrons, interrogating a lower-deck cabin of the luxury yacht. Figures 2 and 3 show the mesh tally photon and neutron dose results, respectively. In each figure, the results are superimposed on the yacht geometry in the *x*-*y* plane and a second image is then shown with isodose contour lines. The bremsstrahlung source is on the left side of the yacht in Figs. 2 and 3, and the beam of photons is traveling from –*x* to +*x* (left to right). The source is located at a height of *y* equals –100 cm. The isodose contours have units of millirems per hour per source proton.

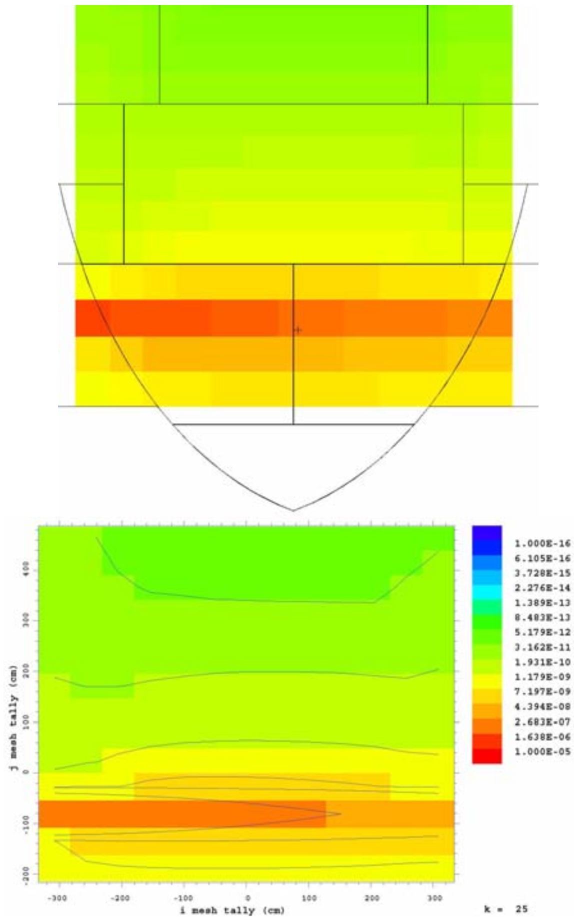

Fig. 2. Photon isodose contours for a 25 MeV bremsstrahlung source directed towards a luxury yacht lower-deck cabin (low density, low Z, and units of millirems per hour per source photon).

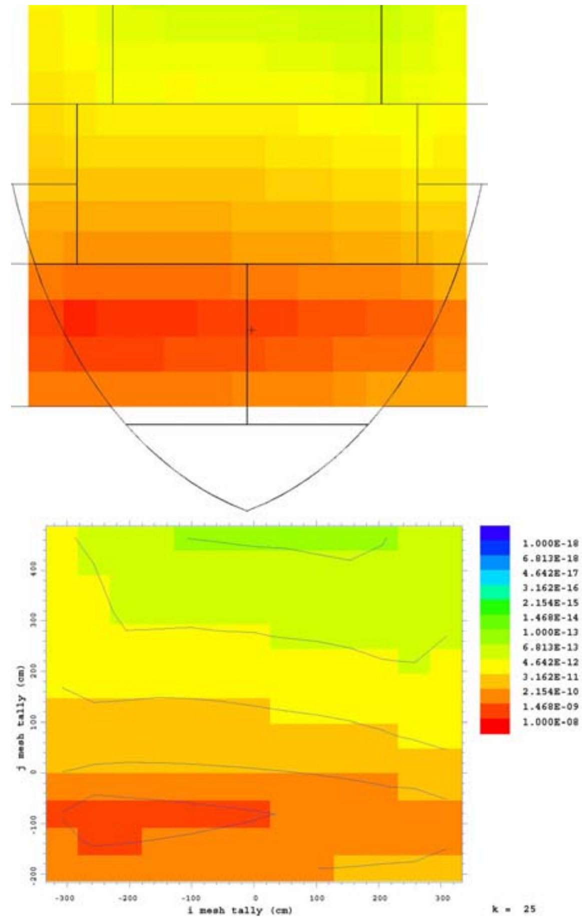

Fig. 3. Neutron isodose contours for a 25 MeV bremsstrahlung source directed towards a luxury yacht lower-deck cabin (low density, low Z, and units of millirems per hour per source photon).

One can see from the isodose contours in Figs. 2 and 3 that the dose is dominated by photons for the 25 MeV bremsstrahlung source, a finding that makes sense physically. The maximum photon dose rate in Fig. 2 is 1.107E-6 mrem/h/source photon. The maximum neutron dose rate in Fig. 3 is 3.501E-9 mrem/h/source photon. The total dose rate is 1.111E-6 mrem/h/source photon. Therefore, with a bremsstrahlung source that creates 10^6 photons per second, the dose rate would exceed 1 mrem/h. More results of this nature and results of organ doses calculated with the VOXMAT phantom will be presented.

REFERENCES

1. D. PELOWITZ (Ed.), “MCNPX User’s Manual Version 2.6.0,” LA CP-07-1473, Los Alamos National Laboratory (2008).

2. J. C. WAGNER, “An Automated Deterministic Variance Reduction Generator for Monte Carlo Shielding Applications,” *Proceedings of the American Nuclear Society 12th Biennial RPSD Topical Meeting*, Santa Fe, New Mexico, April 14–18 (2002).

3. S. W. MOSHER et al., “Automated Weight-Window Generation for Threat Detection Applications Using ADVANTG,” *Proceedings of the International Conference on Mathematics, Computational Methods & Reactor Physics (M&C 2009)*, Saratoga Springs, New York, May 3–7 (2009).

4. S. W. MOSHER, “A New Version of the ADVANTG Weight-Window Generator,” in this proceedings.

5. H. Akkurt et al., “Preliminary Results for VOXMAT: Phantom Model with Combination of Voxel and Mathematical Geometry,” *Trans. Am. Nucl. Soc.*, **98**, 475 (2008).