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Development of a Method for Image Analysis for Nuclear Forensic Examinations

As part of an agreement between the Japan Atomic Energy Agency (JAEA) and the U.S. Department of Energy's National Nuclear Security Administration (DOE/NNSA) Office of Nuclear Smuggling Detection and Deterrence (NSDD), the JAEA-ISCN (Integrated Support Center for Nuclear Non-proliferation and Nuclear Security) and DOE/NNSA cooperatively aim to advance technology development in nuclear forensics. The most recent project in nuclear forensics involves a benchmarking study of image analysis software used by the participating laboratories to characterize particle morphology of powder samples through scanning electron microscopy (SEM). For this study, two different software packages were applied by up to five different users, to determine the level of similarity and consistency of the results. The ability of computational software packages to perform a robust statistical analysis of SEM images is an important tool in a nuclear forensic examination in support of investigations. This statistical analysis includes sample characteristics such as the distribution of particle size, aspect ratio, diameter, and circumference. Since these morphological parameters can be characteristic of material process history or origin, they elucidate potential signatures of the nuclear material under investigation. However, further method development is required to ensure consistency between image analysis protocols and computational software packages, as well as the interpretation of the results.

This work will describe the preliminary conclusions of this on-going project, including the optimization of the image analysis and sample preparation procedures, the development of JAEA's computational tool for the quantification of particle images, and the automated particle analyses and comparisons between the JAEA-developed image analysis tool and the Morphological Analysis for Material Attribution (MAMA) software, an export-controlled program developed at Los Alamos National Laboratory (LANL) and used by the U.S. National Laboratories. Included in this effort is the development of protocols for quantifying overall uncertainty of morphological measurements and general reporting. This was completed by sharing a set of ten SEM images collected at LANL with analysts at Lawrence Livermore National Laboratory (LLNL) and JAEA. All analysts (JAEA, LLNL, and LANL) were to complete the quantitative particle analyses independently and then results from all ten images were compiled by LANL so that the four particle characteristics listed above could be compared.

The preliminary results of this project reveal that the new JAEA software and the established U.S. DOE MAMA software return generally similar results for the evaluated particle metrics. The benchmarking study, which was also designed to compare the influence of sample preparation by different analysts, suggests SRM 1984 is a reliable and robust test material, and confirms that the two software packages are converging on generating consistent results. These results encourage future work in developing enhanced sample preparation protocols based upon the results achieved with what may be considered an ideal sample, SRM 1984. Repeating the study with less ideal samples that more closely mimic samples that may be encountered in the international forensics community would provide significant benefit to the community.

This study supports the notion that the ability to objectively describe and quantify particle samples using SEM images and image analysis software is crucial for national and international nuclear forensic evaluations. Advancing the technology development and statistical evaluation tools in this area will provide the international nuclear forensics community with increasing capabilities for determining sample origin and process history through its morphological characteristics.

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