UNCERTAINTY QUANTIFICATION FOR NUCLEAR SAFEGUARDS AND NON-DESTRUCTIVE ASSAY

Benefit
Improve Uncertainty Quantification (UQ) in nuclear safeguards
• Improve identification of trends in material balances, which will help inspectors assess the need for investigation
• Enable more cost efficient assay systems
• Reduce material unaccounted for (MUF)
• Increase consistency with the State Level Approach

Applications
Nuclear Safeguards
• Accountancy reports
• Process monitoring decision-making
Consensus best practice standards & guides

Project Description
UQ is the scientific art of generating confidence statements. Without defensible UQ physical measurements and calculations have no meaning. UQ in non-destructive assay for materials control and accountancy has been essentially dormant for the last two decades, while computing resources have increased and the formal approach to uncertainty has matured. The engrained approaches used today no longer represent good practice and often do not provide the information needed. This project showcases modern UQ methods applied to nuclear safeguards through a series of relevant case studies which can be adapted by others.

Accomplishments
The UQ team performed a series of case studies with the following results:
• Minimum detectable activity of a Tomographic Gamma-Ray Scanning system was determined using the Currie formalism (top figure)
• Bootstrapping method was used to generate fluorescence yield parameters and uncertainties (middle figure). For Hybrid K-Edge Densitometry (HKED) measurements, these parameters can be used to predict the concentration of plutonium and quantify uncertainty in HKED models for nuclear safeguards measurements.
• Detection efficiency was determined for a coincidence counter using covariance data (bottom figure). The use of covariance information drastically reduced the total uncertainty in the average detection efficiency.

Anticipated Final Capabilities
• Strengthened consensus standards and guide with realistic and consistent bias and error treatments
• Workshop, publications, case study templates, and promotion of findings to give direction and provide leadership
• Improved neutron calibrations through $^{252}$Cf metrology challenge (using $^{252}$Cf as a calibration surrogate for Pu)
• Virtual On-Line Enrichment Monitor software used to develop an uncertainty budget
• Bayesian methods applied to neutron counting experiments to improve Pu mass inferences

Further Reading