Information Barriers based on Enhanced Automated Isotope Identification

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Goals and Objectives

- Create a black box for treaty verification
  - Whole spectra, or parts of spectra are analyzed
  - A 'green light' or 'red light' is output, indicating a treaties requirements are met or not
- Automated isotope identification algorithms for low resolution detection systems
  - provide information barriers for treaty verification
  - Independent to detector resolution, efficiency

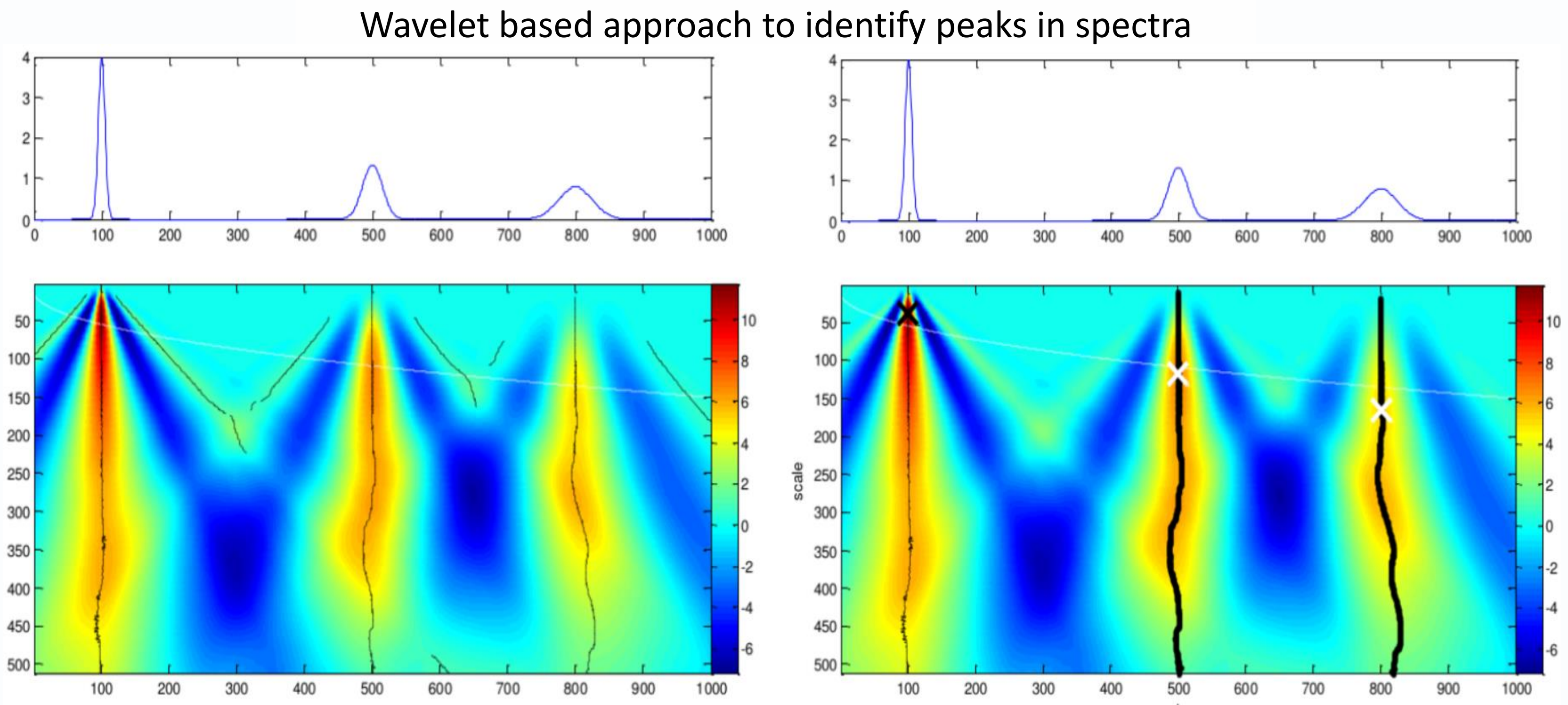
Introduction

- Certain verification treaties require information barriers
  - These barriers are meant to protect sensitive state information
  - Common information barriers are to obscure parts of a spectra from inspectors, require lower resolution detectors
- Information barriers present an issue for NNSA, IAEA treaty monitors
  - Abuse of information barriers could lead to material being diverted against treaty specifications
- Isotope identification algorithms for low resolution detectors provide a black box that preserves information barriers while allowing a 'green light' or 'red light' for different treaties

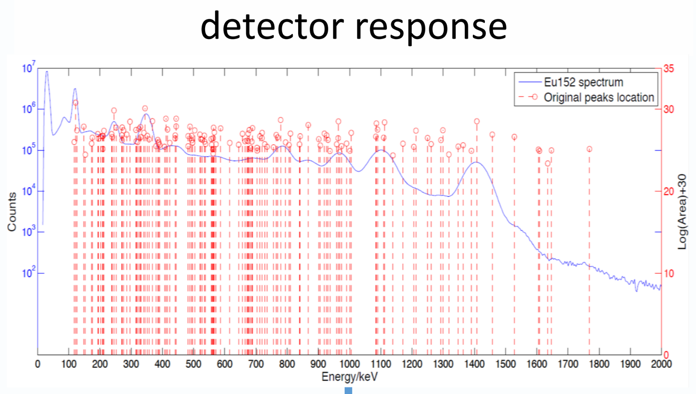
Methods

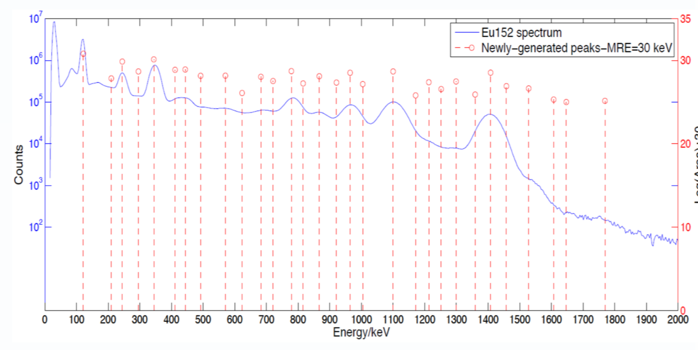
- (0) Custom library is generated from a master library
  - New library incorporates detector characteristics like FWHM vs energy, efficiency vs energy
- (1) Wavelet algorithm is used to detect energy peaks in spectra
  - Outputs peak channel location, peak area, and peak area uncertainty
- (2) A Bayesian algorithm is used to determine the probability an isotope in the library is in the given data
  - Assigns probabilities to combinations of isotopes
  - Factors used to assign probabilities include:
    - Percentage of library peaks identified
    - Percentage of data peaks identified
    - Peak centroid positions
    - Peak areas
- (3) Bayesian algorithm outputs the likelihoods that single and multiple isotopes are responsible for the data

Wavelet based approach to identify peaks in spectra



(0) Custom library generator based on detector response





(1) Peak channel location, peak area, and peak area uncertainty

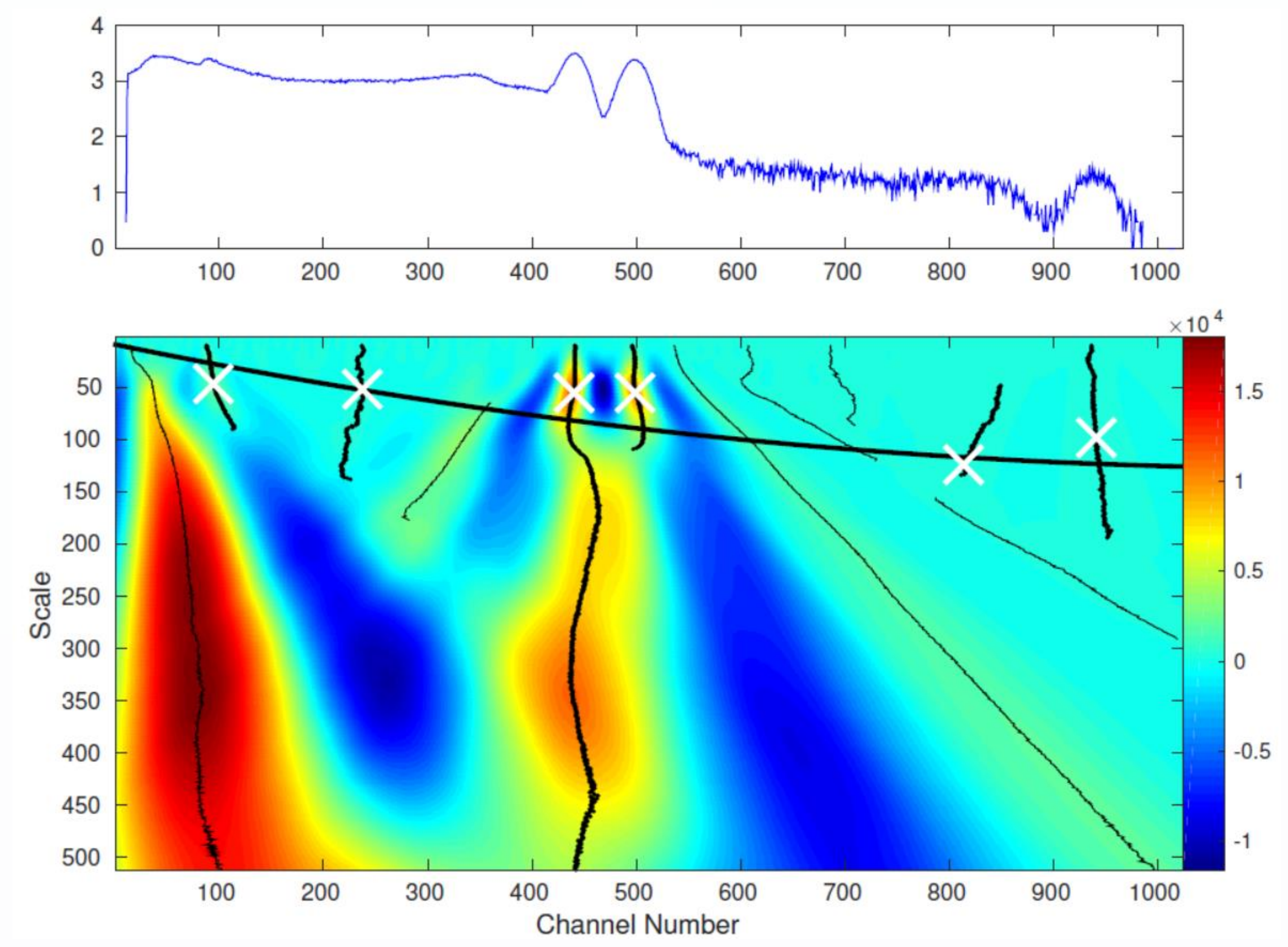
(2) Bayes' Theorem

$$P(isotope|data) = \frac{P(data|isotope)\,P(isotope)}{P(data)}$$

(3) Isotope identifications with probabilities given

Results

Co-60



NNLS fit of all local maxima Co-60 scalogram

Centroid	Energy (keV)	Area (A)	Area Uncertainty (σ_A)	σ_A/A
95.96	191.67	126307.11	422.69	0.33%
235.40	600.29	63804.96	802.32	1.26%
418.00	1108.48	5888.24	434.81	7.26%
441.01	1170.35	84947.12	513.03	0.60%
498.10	1321.77	69485.15	3368.69	4.85%
758.00	1973.37	133.80	128.06	95.70%
782.00	2030.42	565.58	147.14	26.02%
805.00	2084.60	496.03	138.94	28.01%
830.54	2144.19	258.80	61.75	23.86%
855.48	2201.81	498.36	48.24	9.68%
890.00	2280.62	26.14	33.24	127.14%
937.08	2386.35	934.01	21.83	2.34%
981.00	2483.15	28.60	31.73	110.93%

- False peaks discriminated from true peaks based on the area uncertainty found from the wavelet code.

Combination probabilities from Bayesian algorithm using energy and area values that have $\sigma_A/A < 5\%$

Isotope 1	Isotope 2	Isotope 3	Probability
'Co60'	[--]	[--]	0.93967
'Co60'	'Pu240'	[--]	0.003238
'Co60'	'Ra226'	[--]	0.003202
'Co60'	'Se75'	[--]	0.016823
'Co60'	'Th232'	[--]	0.032402

Discussion and Next Steps

- Begin statistical analysis against large number of spectra
  - Analyze energy centroid distribution found by the wavelet code from:
    - NORM sources
    - Special nuclear material to be measured at the DAF in Nevada
- Investigate how changing detector resolution effects accuracy of the Bayesian algorithm
- Investigate alternative approaches to low resolution isotope identification
  - Neural networks
  - Machine learning
- Perform statistical analysis against specific treaty requirements

Conclusions and Program Relevance

- Will provide statistically sound set of tool for an automated isotope identification algorithm
- The method presented can allow for partial or complete information barrier of spectra

National Nuclear Security Administration