Office of Defense Nuclear Nonproliferation Research and Development

CVT – Consortium for Verification Technology

Thrust II: Fundamental physical data acquisition and analysis

November 30, 2017

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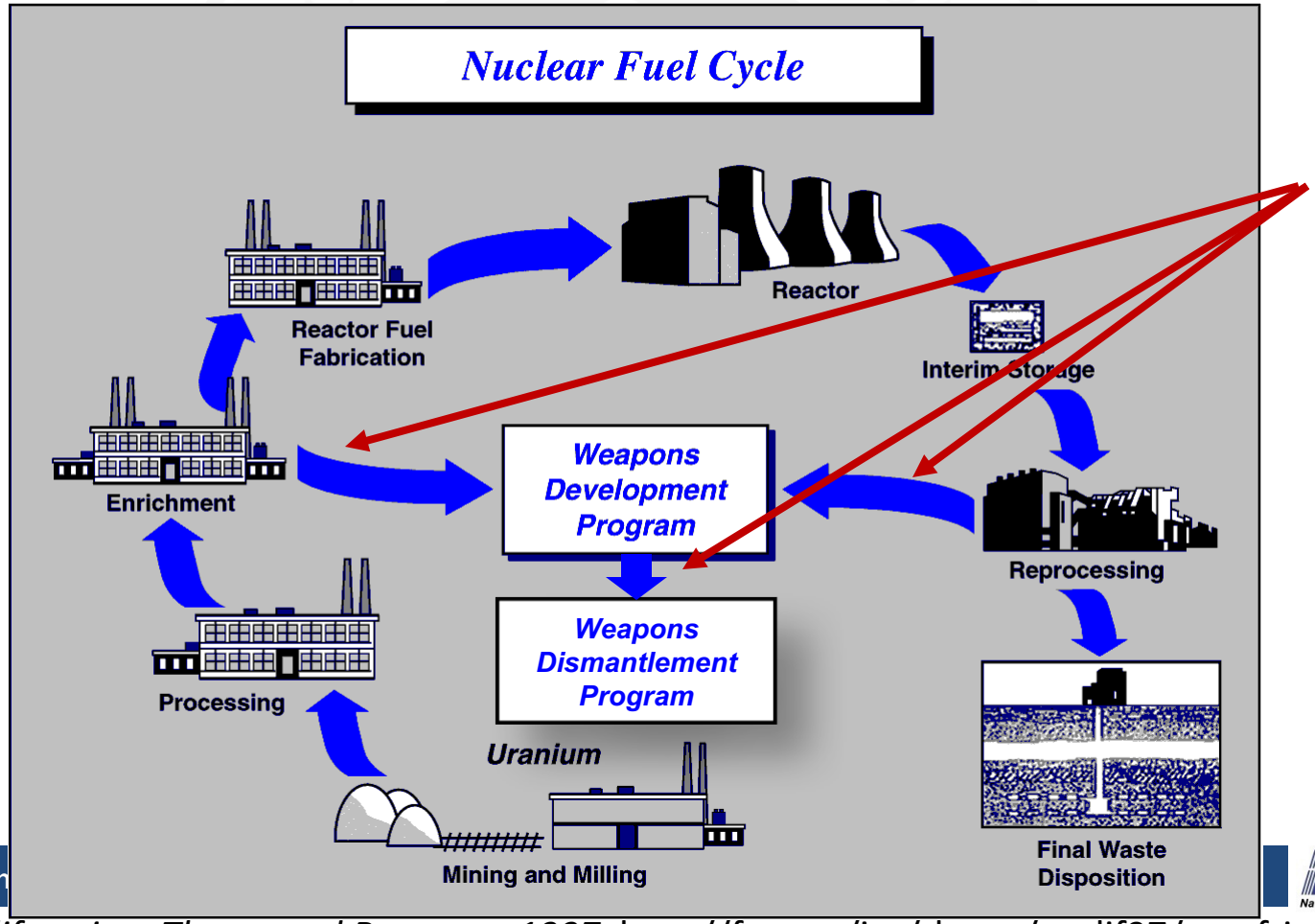
Nuclear fuel cycle

Objective of IAEA safeguards: "...the *timely detection* of any diversion of significant quantities of nuclear material and to deter diversion by creating the risk of *early detection*." Leonard Weiss, Bulletin of Atomic Scientists, vol. 47, no. 4, 1991.



Potential diversions

Proliferation: Threat and Response 1997. http://fas.org/irp/threat/prolif97/meafrica.html

CVT Thrust II Goals

- **Goal 1: Diversion detection and localization**
  - Objective: To develop sensitive statistically based methods for most quickly detecting material diversions from nuclear fuel cycles
  - Methods: active sensing, sparse learning, anomaly detection, information fusion, nuclear fuel cycle simulation

Link analysis (Hero, LANL)

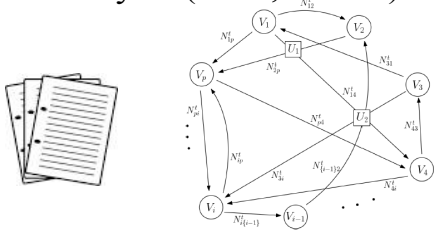
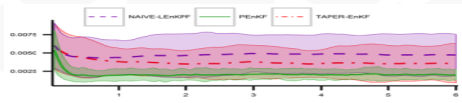


TABLE I. Sample shipments of 1 ton with duration and average power consumption observations.

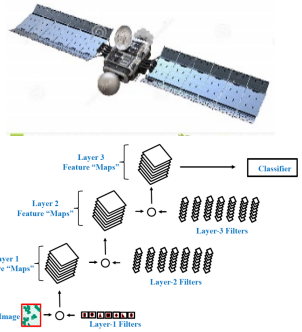
Shipment no.	Duration (days)	Average Power Consumption (MTSWU/day)
1	17.11	0.2015
2	43.33	0.1018

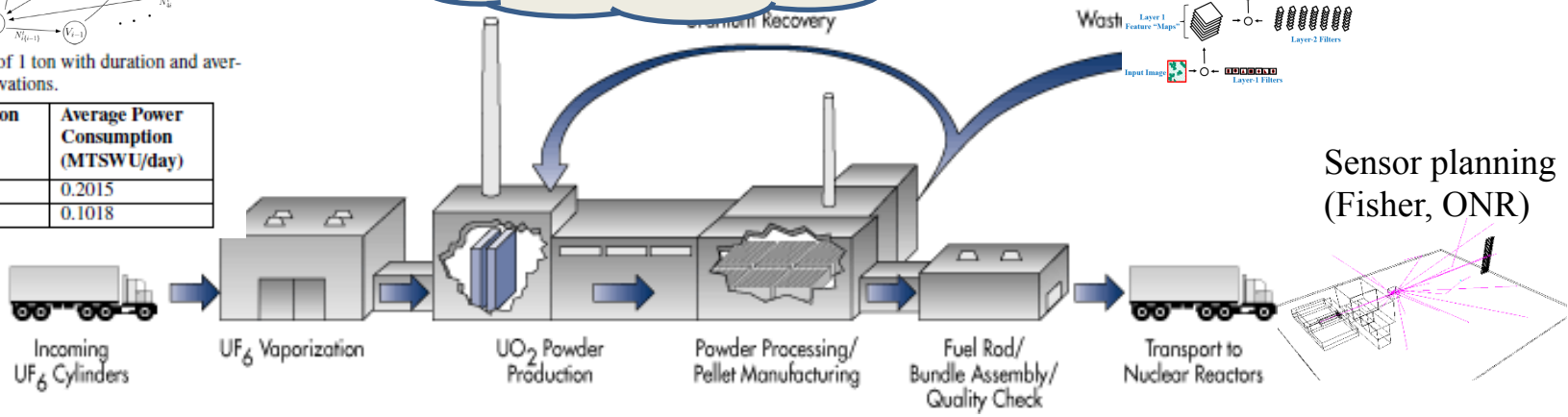
Aerosol sensing (Hero, Fisher, LANL)



$$\mathbf{y}_t = h(\mathbf{x}_t) + \epsilon_t, \qquad \mathbf{x}_t = f(\mathbf{x}_{t-1}) + \omega_t$$

Deep learning (Carin, ORNL)





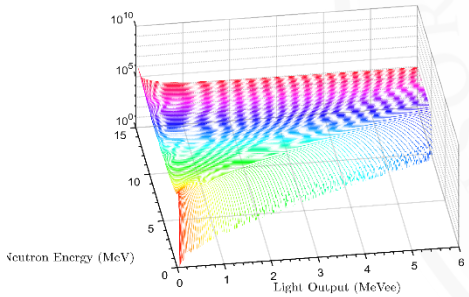
Sensor planning (Fisher, ONR)

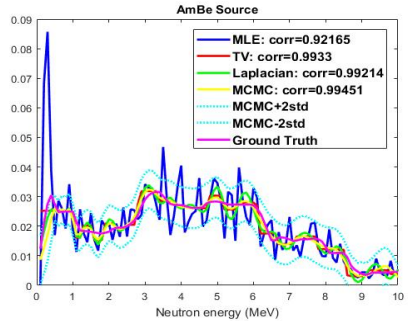
https://www.nrc.gov/images/materials/fuel-cycle-fac/fig030.gif

CVT Thrust II Goals

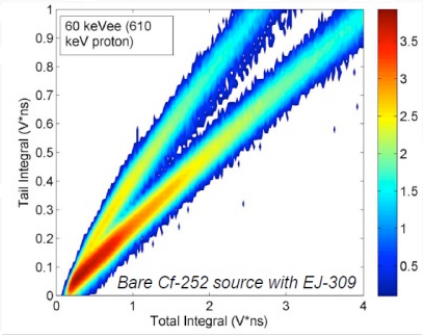
- **Goal 2: Fundamental physics modeling of radiation detectors**
  - Objective: To simulate and experimentally validate new models for gamma and neutron detection for SNM
  - Methods: source/detector interaction physics, neutron correlation, nuclear unfolding, pulse discrimination

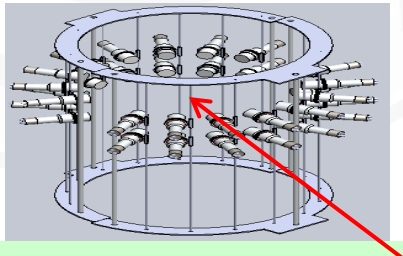
Bayesian unfolding (Pozzi, Hero)





Pulse discrimination (Pozzi, LANL)

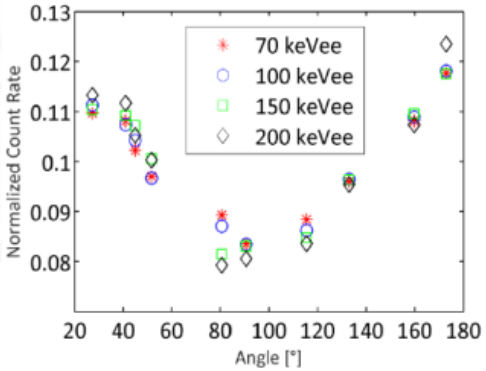




Liquid organic and NaI(Tl) scintillator array

SNM source position

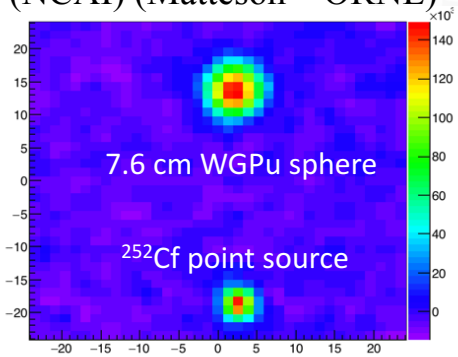
Neutron-neutron coincidence ⊱ (Pozzi)

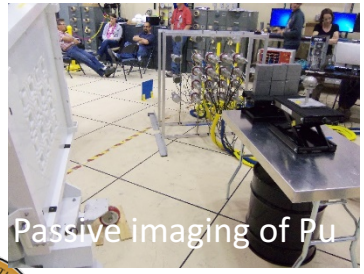


CVT Thrust II Goals

- **Goal 3: Signal and image processing for radiation detection**
  - Objective: to develop signal processing algorithms for emerging radiation detection technologies
  - Methods: Bayesian methods, frequency domain multiplexing, neutron track reconstruction, fission image reconstruction

Neutron coded aperture imager (NCAI) (Matteson – ORNL)





Single volume scatter camera using pillars of plastic scintillator(Matteson – SNL)

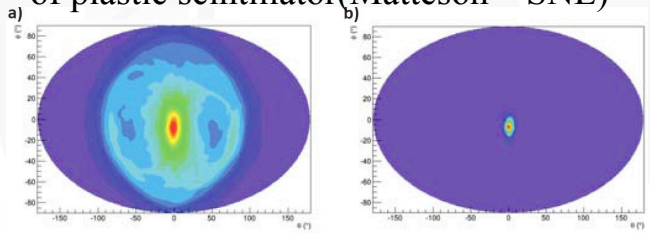
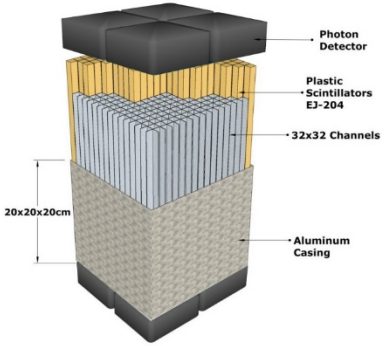
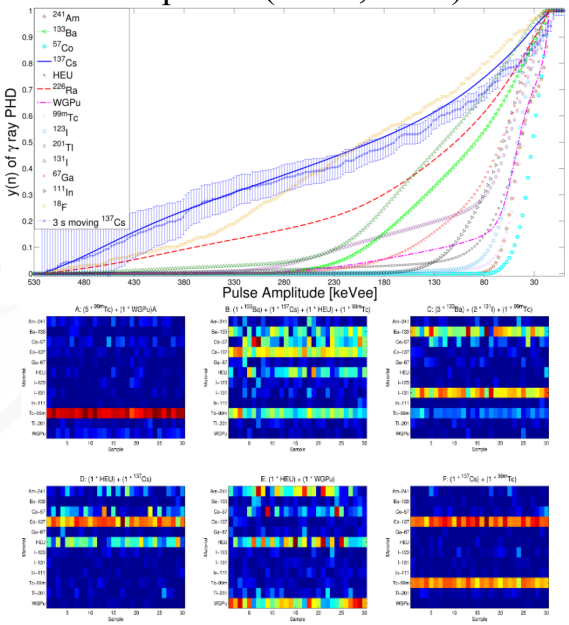


Figure 6. Cf-252 source located at (0°, 0°)



Bayesian unmixing of radiaton portal monitor spectra (Pozzi, Hero)



Thrust II oral presentations

1. Ms. Elizabeth Hou: Sequential Detection of Unusual Documents (UM)
2. Mr. Matthew Marcath: Measured and simulated Cf-252 spontaneous fission prompt neutron-photon competition (UM)
3. Mr. Christopher Dean: An Efficient Nonlinear Dispersion Model Using Continuous-Piecewise-Affine-based Transformations (MIT)
4. Prof. Larry Carin: Deep Generative Models for Anomaly Detection (Duke)
5. Ms Sue Zheng: Robust Monte Carlo Methods for Sequential Planning and Decision Making (MIT)

Thrust II poster presentations

1. Mr. Haonan Zhu: Comparison of unfolding algorithms for monenergetic and continuous fast-neutron energy spectra methods (UM)
2. Ms Patricia Schuster: Measurements of prompt fission neutron correlations in Cf252 (UM)
3. Charles Sosa: Improvements in Energy Resolution using Conical Stilbene (UM)
4. Mr. Christopher Dean: Multimodal Multiscale Data Fusion in Spatial Processes Using the Hierarchical Beta Model (MIT)
5. Mr. Mudit Mishra: Frequency domain multiplexing of multiple organic scintillator detectors (NCSU)
6. Dr. Jonathan Mueller: Using Time-Correlated Neutron and Gamma-Ray Measurements to Distinguish Point-like Sources From Spatially Distributed Sources Without Imaging (NCSU)
7. Mr. Kyle Weinfurther: Model-based Design Evaluation of a Compact, High-Efficiency Neutron Scatter Camera (NCSU)
8. Mr. Robert Weldon: Characterization of the Anisotropic Scintillation Response of Stilbene to Neutrons (NCSU)