Neutron Activation Analysis Tool for Assessment of Isotopic and Elemental Signatures of Manufacturing Processes

MTV Kickoff Meeting

May 21, 2019

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Introduction and Motivation

- There is a need for **new tools and techniques to monitor nuclear material at various stages of the fuel cycle:** mining and milling of uranium, conversion and fabrication of fresh fuel, enrichment at uranium enrichment facilities, and plutonium separation from irradiated fuel at reprocessing facilities.

- We propose to develop a **high-sensitivity, fast, non-destructive, neutron-activation technique** for assessing elemental and isotopic signatures important for monitoring of the aforementioned nuclear-material activities.

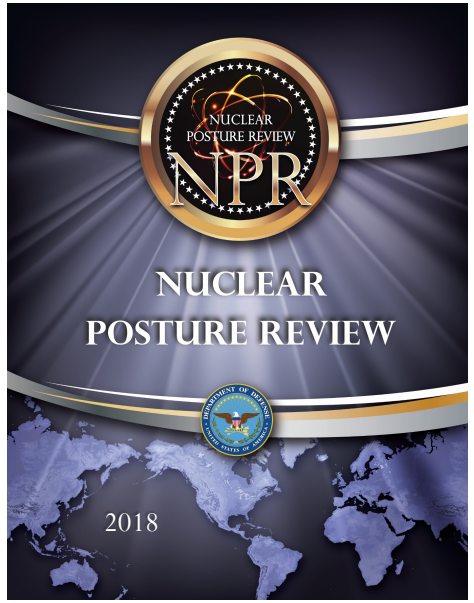
Mission Relevance

- The proposed work is relevant to the NNSA mission by complementing the current state of the art in the area of **Signals and Source Terms for Nuclear Nonproliferation.**
  - We propose to develop a prompt- and delayed-gamma neutron activation analysis system based on thermal and epithermal neutrons.

- *NNSA Mission*
  - *Website:* https://www.energy.gov/nnsa/missions/nonproliferation

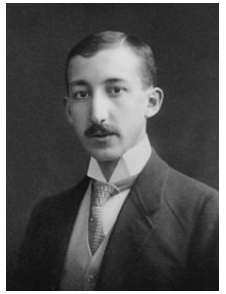
  Preventing nuclear weapons proliferation and reducing the threat of nuclear and radiological terrorism around the world are key U.S national security strategic objectives that require constant vigilance.

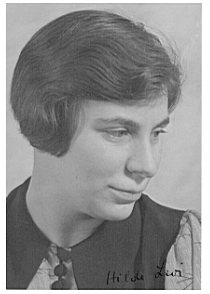
  NNSA's Office of Defense Nuclear Nonproliferation works globally to prevent state and non-state actors from developing nuclear weapons or acquiring weapons-usable nuclear or radiological materials, equipment, technology, and expertise.

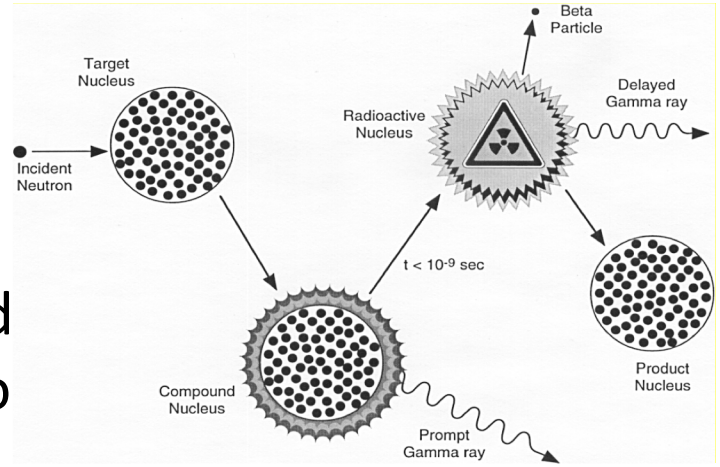


Neutron Activation Analysis

- Discovered by Hevesy and Levi in 1936
- NAA is an analytical, non-destructive, quantitative technique to determine elemental and(or) isotopic composition of various materials.
- **Advantages:**
  1) Simultaneous multielement analysis
  2) Very high sensitivities – detection limits at ppm - ppb
  3) Nondestructive
  4) Straightforward and fast analysis that can be automated
  5) Most materials are relatively transparent to neutrons so the samples can be uniformly irradiated – bulk analysis

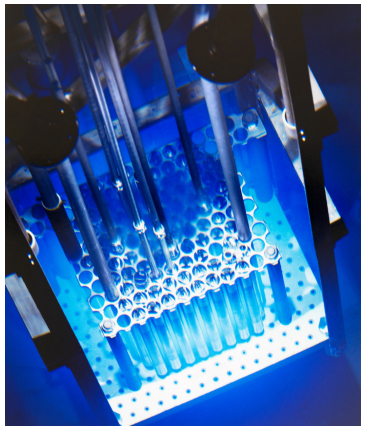




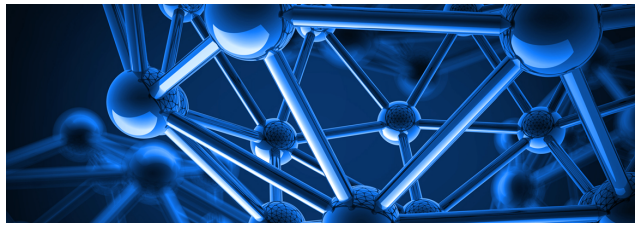


Neutron Activation Analysis Continued

- **Additional Advantages:**
- Most nuclear reactions are independent of the electron configuration of element(s) of interest
- Measurements of specific isotopes allows for assessing **altered isotopic ratios**
- Various neutron sources are available – nuclear reactors, neutron generators, isotopic sources

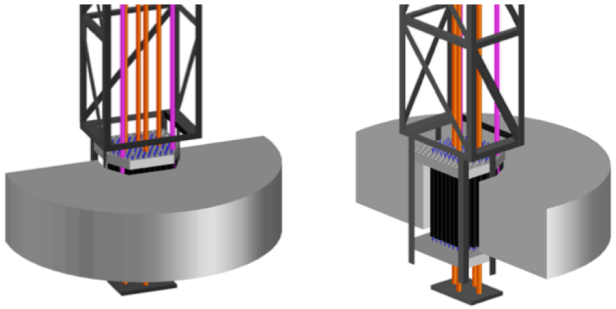


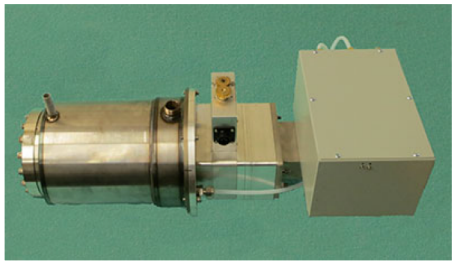
- **Applications:**
  1) Forensics
  2) Material science
  3) Archeology
  4) Environmental samples
  5) Coal and its effluents
  6) Biological materials, etc.

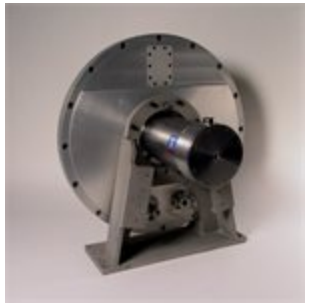


NAA Sources at Penn State

- **Currently Available:**
- The Penn State Breazeale Reactor (PSBR)
  - 1 MW TRIGA reactor
  - Up to 3e13 n/cm^{2}s
  - Reactor core is mobile in two directions and rotates 180°
- Two Adelphi Technology D-T generators
  - 1e8 neutrons/second D-T generator with alpha detector
  - 1e10 neutrons/second D-T generator
- **Work in Progress:**
- Custom-made filter designed to allow for epithermal NAA (ENAA) – many elements have **large advantage factors in the epithermal region**
- Multi-disk neutron chopper as neutron-energy selector for ENAA



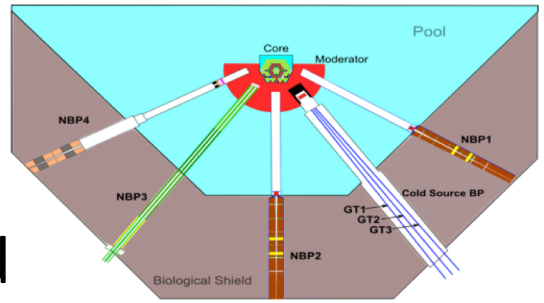


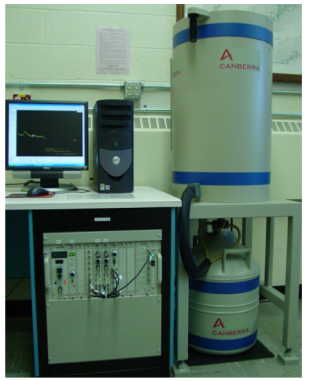


Technical Work Plan

- **Year 1** – Thorough review of the different stages of the fuel cycle – key samples/elements/isotopes of interest identified
  - NAA capabilities at Penn State upgraded/completed
- **Year 2** – Initial NAA calibrations/experiments with samples identified in Year 1 – the sample list modified accordingly
  - Reference mass spectroscopy experiments
- **Years 3-4** – Extensive INAA and ENAA experiments – assessment of detection limits for all elements/isotopes of interest
- **Year 5** – Final experiments and comparisons to assess the impact of the proposed technology on the NNSA mission

- Planned collaborations with PNNL, INL; any additional interest/feedback welcome!

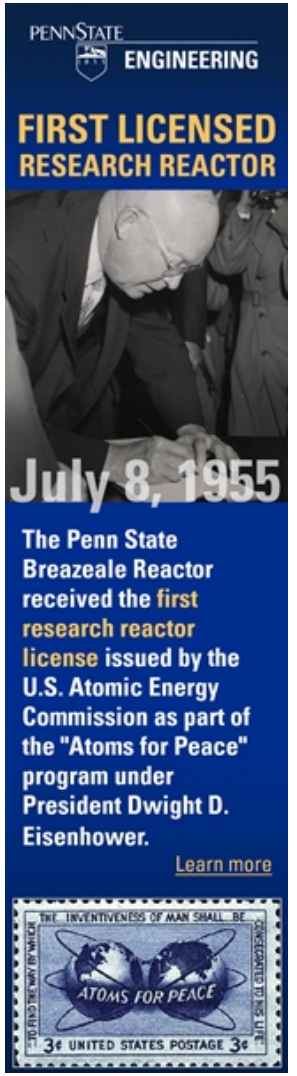




Expected Impact

- The expected impact of this work lies in providing a **new nondestructive tool for monitoring nuclear materials at various stages of the fuel cycle**

- The proposed technology provides **high-sensitivity and expedience,** and is based on sample activation with thermal and epithermal neutrons



MTV Impact on This Project

- This project will greatly benefit from the expertise available in the MTV Consortium – multi-discipline collaborations are foreseen to maximize the project outcome
- It is expected that two undergraduate, one MS, and 3 PhD students, as well as one postdoc will be involved in this project. They will actively participate in MTV workshops and will network with other MTV participants. These students will also apply for internships at MTV National Labs to further strengthen the project outcome, and the project impact on the MTV.
- It is expected that some of these students will be employed at one of the National Labs after graduating

Conclusion

- This project aims at helping to ensure that nuclear science and technology is used solely for peaceful purposes
- It is the MTV mission to meet this challenge by providing advanced tools and trained talent for careers in nuclear security and nonproliferation
- The proposed tool will provide high sensitivity, expedience, and nondestructive sample-assessment capability
- This project is a single component of a much larger, integrated, multi-disciplinary effort under MTV to address current and emerging nuclear proliferation threats by developing advanced technology
- Finally, this project will help mitigating the problem of ageing workforce in nuclear science and engineering by actively involving several students

Acknowledgements

The Consortium for Monitoring, Technology, and Verification would like to thank the NNSA and DOE for the continued support of these research activities.

This work was funded by the Consortium for Monitoring, Technology, and Verification under Department of Energy National Nuclear Security Administration award number DE-FOA-0001875