CVT Workshop

October 31 – November 1, 2018

CVT: Year 4 Accomplishments

Professor Sara A. Pozzi

Director, Consortium for Verification Technology

Professor, Nuclear Engineering and Radiological Sciences

Department of Nuclear Engineering and Radiological Sciences

University of Michigan, Ann Arbor, MI

CVT Mission and Outcomes

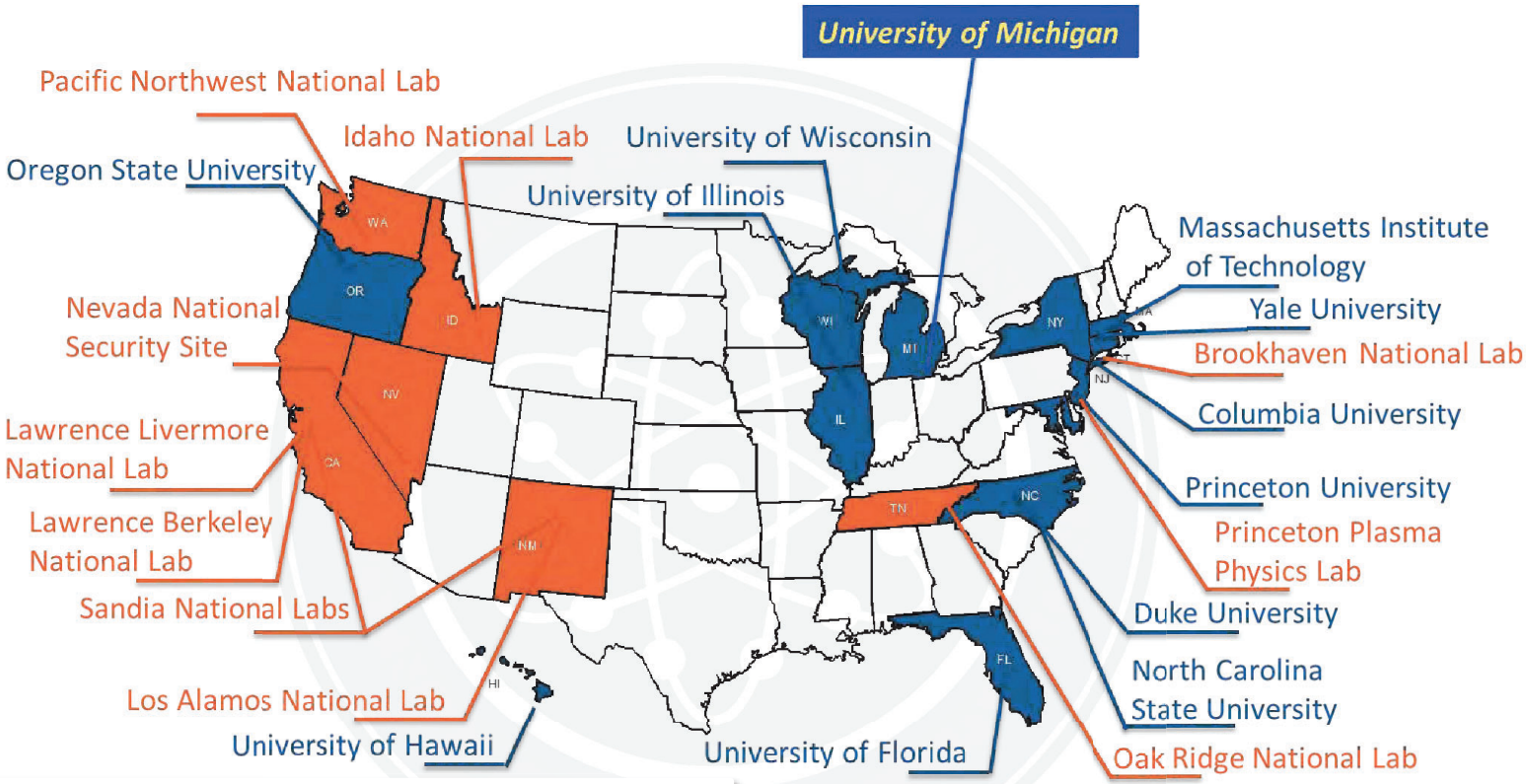
Mission:

1. Advancement of the state-of-the-art in technologies and policies related to the verification of nuclear treaties and training the next-generation of nuclear professionals

Outcomes:

1. A deep understanding of the policy and technical aspects of nuclear treaty verification
2. Next-generation set of computational capabilities
3. New, more effective and reliable instruments for treaty verification
4. More than 80 B.S., M.S., and Ph.D. graduates

Collaborating Institutions



CVT Team: 12 Universities and 9 National Labs
Total funding $25M over 5 years

CVT Leadership and Organization

LEADERSHIP

CVT Director
Prof. S. A. Pozzi,
Univ. of Michigan

Chief Scientist
Prof. D. Wehe,
Univ. of Michigan

CVT Assistant Director & Natl Lab POC
Dr. S. D. Clarke,
Univ. of Michigan

Project Manager
Mr. J. Rodriquez,
Univ. of Michigan

Research Coordinator
Dr. Patricia Schuster
Univ. of Michigan

THRUST AREAS

TA 1

TA 1 Lead
Prof. A. Glaser, PU

Prof. F. von Hippel, PU

TA 6

TA 6 Lead
Prof. K. Kearfott, UM

TA 2

TA 2 Lead
Prof. A. Hero, UM

Prof. S. A. Pozzi, UM

Prof. J. Mattingly, NCSU

Prof. John Fisher, MIT

Prof. L. Carin, Duke

TA 3

TA 3 Lead
Prof. Z. He, UM

Prof. S. A. Pozzi, UM

Prof. I. Jovanovic, UM

Prof. Kim Kearfott, UM

Prof. J. Baciak, UF

Prof. A. Enqvist, UF

TA 4

TA 4 Lead
Prof. M. Garces, UH

Prof. J. Lee, UM

Prof. P. Wilson, UW

Prof. P. Richards, CU

Prof. A. Farsoni, OSU

TA 5

TA 5 Lead
Prof. A. Danagoulian, MIT

Prof. R. Lanza, MIT

Prof. K. Huff, UIUC

Prof. F. d'Errico, Yale

Prof. A. Glaser, PU

Prof. D. Wehe, UM

ADVISORY BOARD

Prof. J. Duderstadt, UM

Dr. N. Nicholas, LANL

Dr. R. Kouzes, PNNL

Dr. M. Drecier, LLNL

Dr. V. Protopopescu, ORNL

National Laboratory Partners

Berkeley Lab

Dr. John Valentine

Brookhaven National Laboratory

Dr. Peter Vanier

Lawrence Livermore National Laboratory

Dr. Stephan Friedrich

PPPL Princeton Plasma Physics Laboratory

Dr. Rob Goldston

INL Idaho National Laboratory

Dr. David Chichester

Sandia National Laboratories

Dr. Alfred Morales

Los Alamos National Laboratory EST. 1943

Dr. James C. Miller

Pacific Northwest National Laboratory

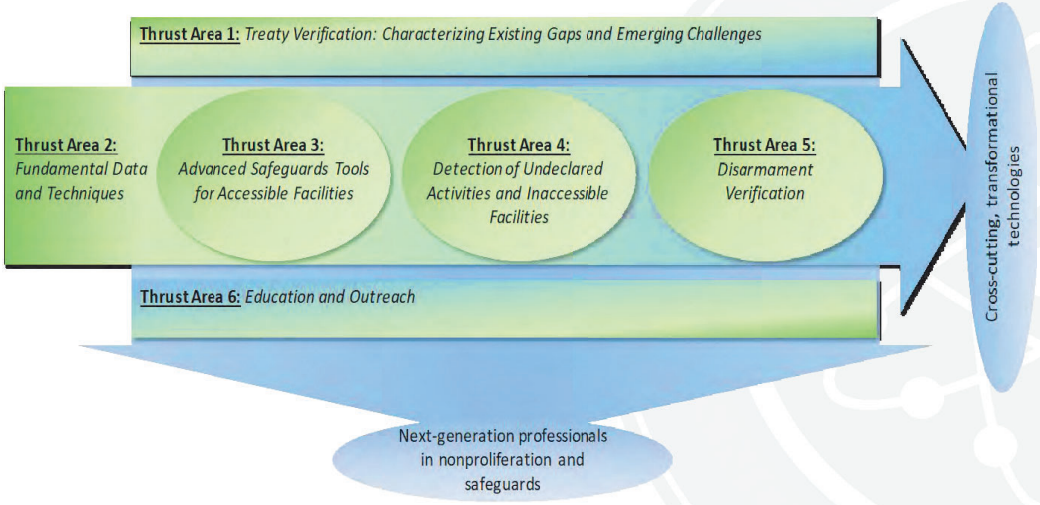
Dr. Allen Seifert

Oak Ridge National Laboratory

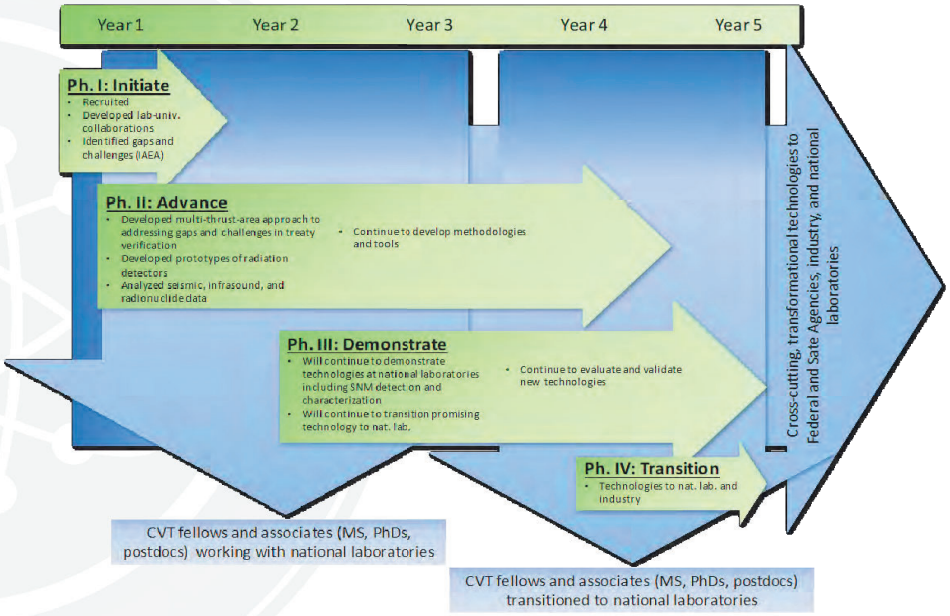
Dr. David Williams

CVT Overview

Thrust Areas and Outcomes

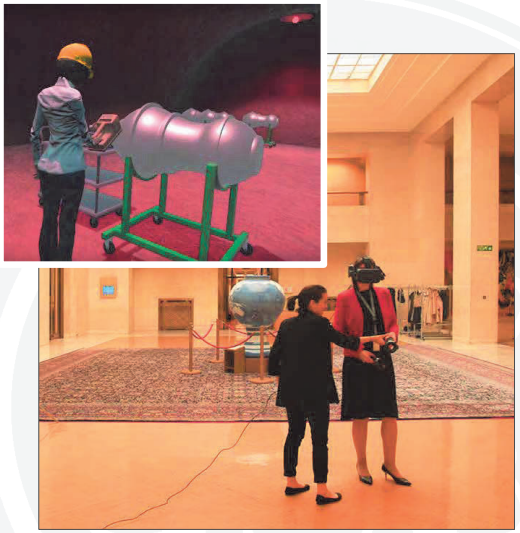


Timeline and Outcomes



Technical Highlights: Policy Research Thrust Area 1

Developed a step-by-step approach for a verified denuclearization of North Korea; first presented at UPR, then expanded and published in *Science, 361 (6406), pp. 981–983, 2018.*



Presented our virtual reality verification work at the UN in Geneva on the margins of a meeting of the Group of Government Experts on Nuclear Disarmament Verification; also used in a class-exercise with 35 Princeton undergraduate students.

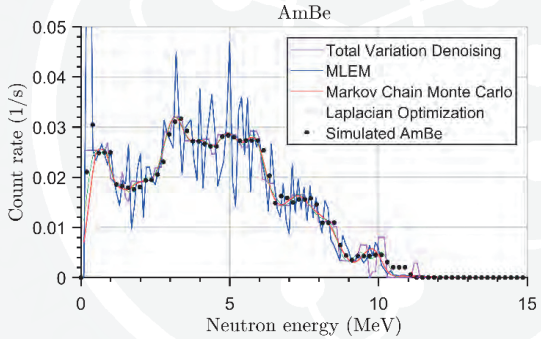
Assessed a new verification concept proposed by UNIDIR, called "Deferred Verification." Our research identifies the role of new verification technologies and approaches, including perimeter control; presented at INMM Annual Meeting.

Source: KCNA (left), Alex Glaser (center), and U.S. Department of Energy (right)

Technical Highlights: Fundamental Physics and Data Thrust Area 2

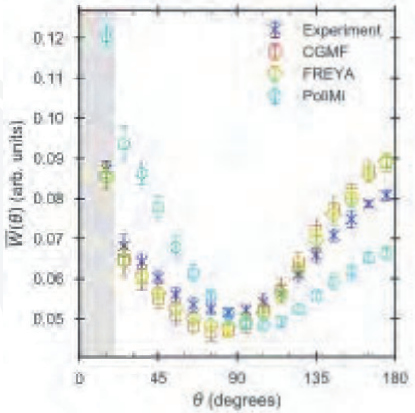
- Addressing the cross-cutting needs in nuclear treaty verification, we developed new algorithms and models for:
  - Emissions from nuclear fission
  - Correlation-based anomaly/diversion detection
  - Data acquisition and signal processing for emerging radiation detection technologies
  - Advanced image reconstruction

Modeling correlated emissions from fission



Algorithms for spectrum unfolding (TA2+TA3)

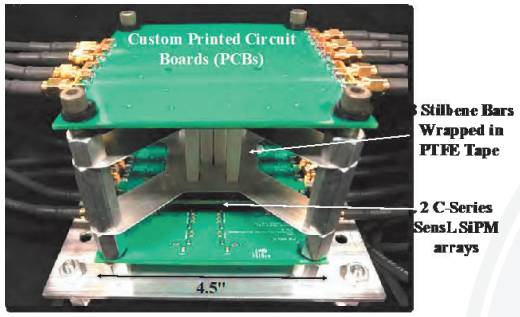
Simulated and measured Cf-252 fission neutron angular distribution



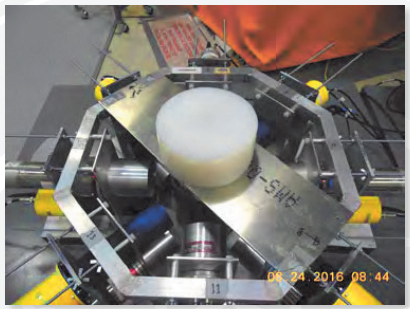
National lab collaborators: LANL, ORNL, LLNL, SNL, PNNL, LBNL

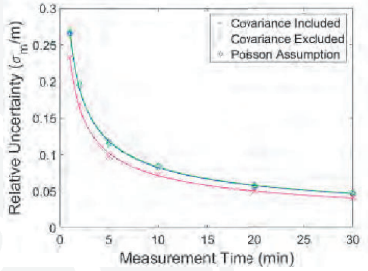
Technical Highlights: Advanced Safeguards Instruments Thrust Area 3

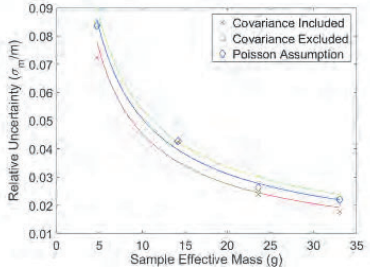
Handheld dual-particle imaging system



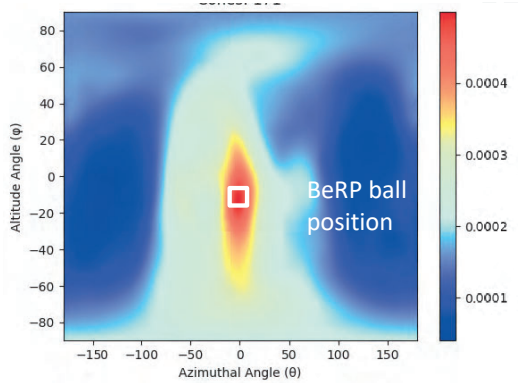
Active characterization of HEU at INL using the fast neutron multiplicity counter and development of analytic methods for uncertainty quantification



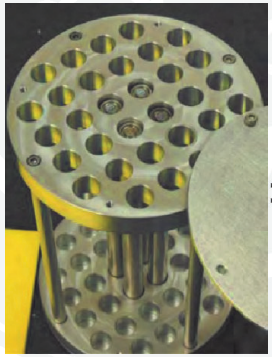


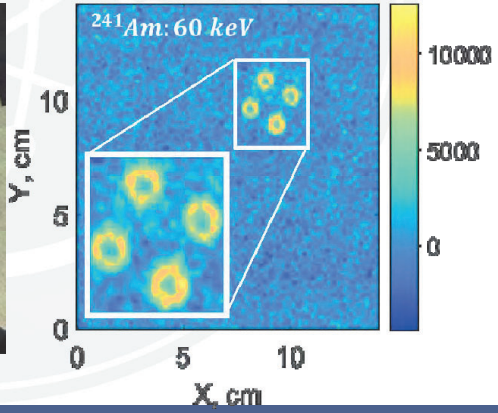


Imaging the W-reflected BeRP ball at DAF



CZT time-encoded imaging of MOX fuel pins at INL





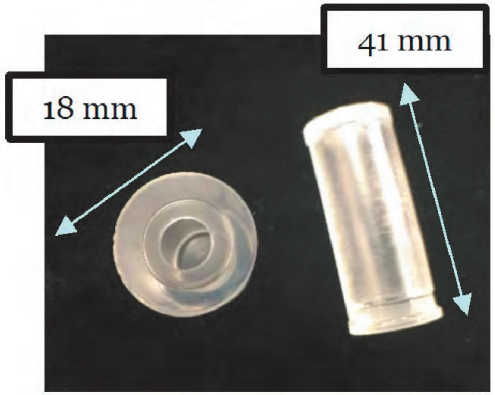
National lab collaborators:
INL, LANL, NNSS

Technical Highlights: Detection of Undeclared Activity Thrust Area 4

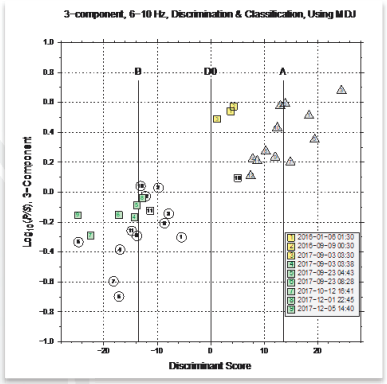
- Developing tools to enhance CTBT verification including seismic, radioxenon, and infrasound monitoring
- Analyzed data from recent DPRK nuclear tests
- Designed stilbene-based radioxenon cells
- Experimentally demonstrated the low memory effect of stilbene

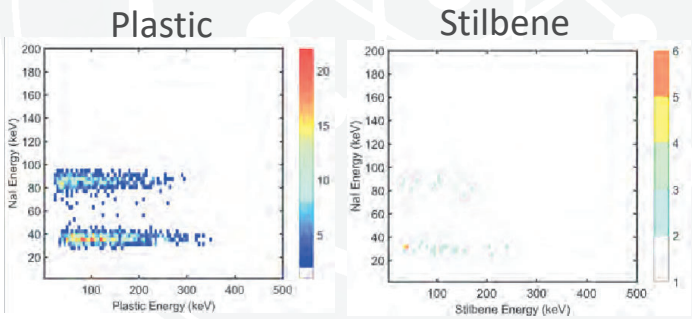
National lab collaborators: PNNL, LLNL

Stilbene cell designed by UM

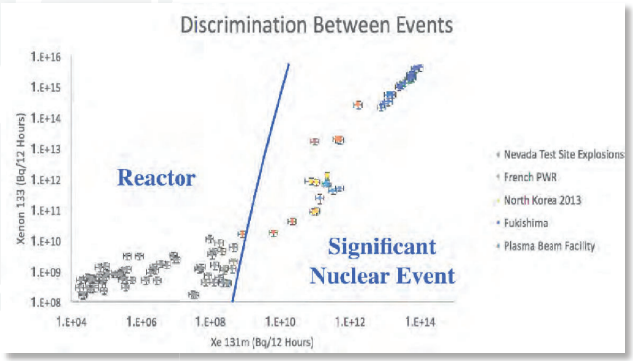


Seismic Analysis of DPRK Nuclear Testing





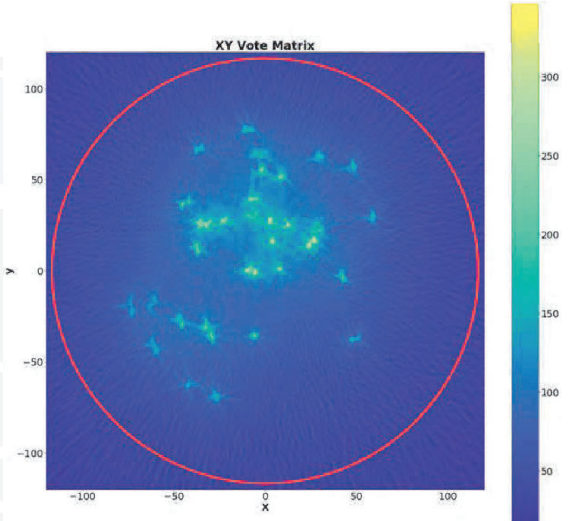
Stilbene demonstrates very low memory effect compared to plastic

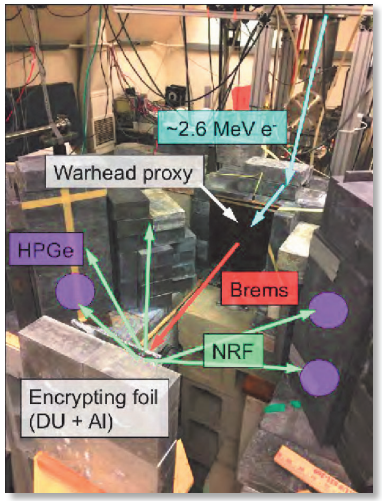


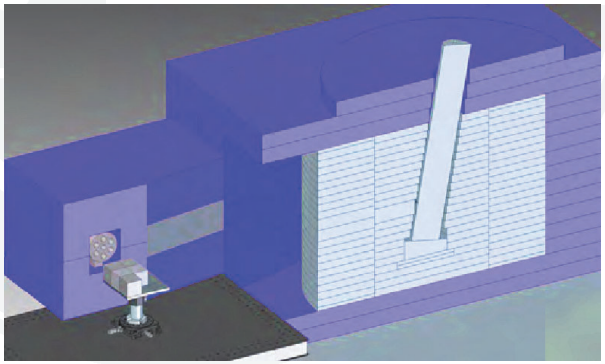
Technical Highlights: Disarmament Verification Thrust Area 5

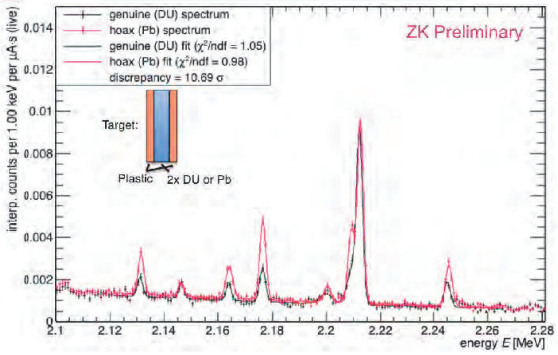
- Demonstration of a physical zero-knowledge proof
  - Designed moderated collimator for Uranium isotope discrimination using sub-MeV neutrons
  - Moderator material and collimator geometry optimization
  - 4.2 σ simulated detection of 0.5 kg U-235 removal
- Bubble counting to high numbers in emulsion detectors
  - Use multiple detector images to count and reconstruct unique bubble locations
  - 3.5 x increase in counted bubbles using experimental data
- First demonstration of physically encrypted isotopic warhead verification
  - use NRF and encrypting foil to interrogate proxy genuine (DU) and hoax (Pb) warheads
  - Compare NRF peak spectra near 2.2 MeV
  - Up to 11 σ detection in ~1 hr per 'warhead'
  - extended the concept to epithermal neutrons

National lab collaborators:
PPPL, PNNL, LANL/DAF









176 Peer Reviewed Publications

(cumulative from 09/01/2014 to present)

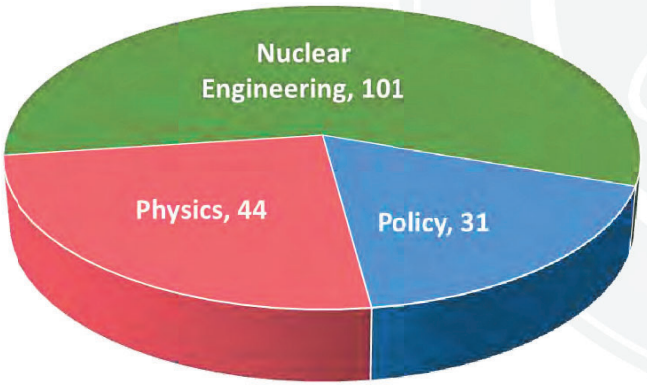
SECTIONS THE NEW YORKER

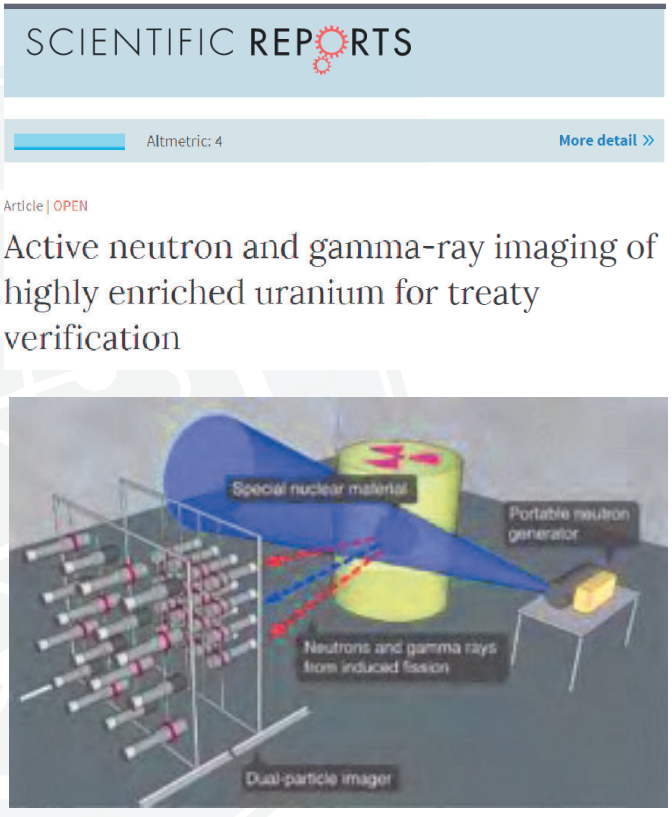
ELEMENTS

THE VIRTUES OF NUCLEAR IGNORANCE

By Alex Wellerstein, SEPTEMBER 20, 2016

Americans of a certain age are well acquainted with one of Ronald Reagan's pithier maxims: "Trust, but verify." It is a translation of a Russian proverb, and Reagan used it often in his dealings with the Soviet Union




SCIENTIFIC REPORTS

Altmetric: 4 More detail »

Article | OPEN

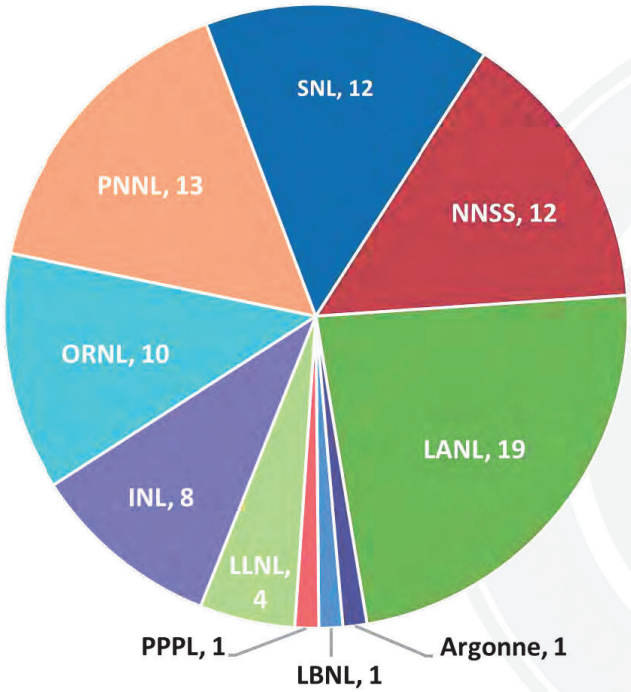
Active neutron and gamma-ray imaging of highly enriched uranium for treaty verification

Michael C. Hamel, J. Kyle, Polack Marc L. Ruch, Matthew J. Marcath, Shaun D. Clarke & Sara A. Pozzi, Aug 2017

University - National Laboratory Collaboration

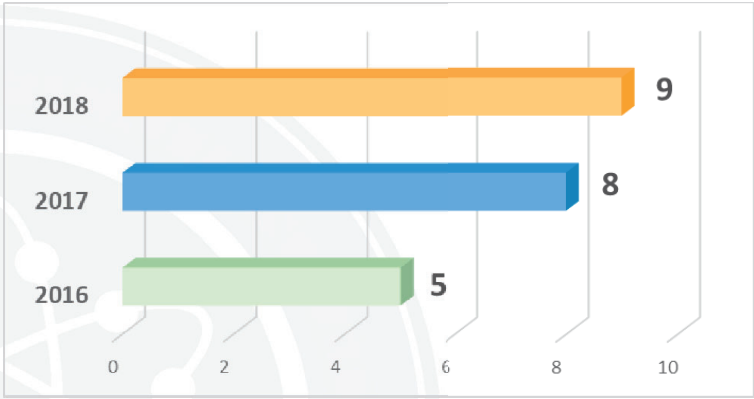
(cumulative from 09/01/2014 to present)

81* Student - Lab Internships



***2014 - Present**

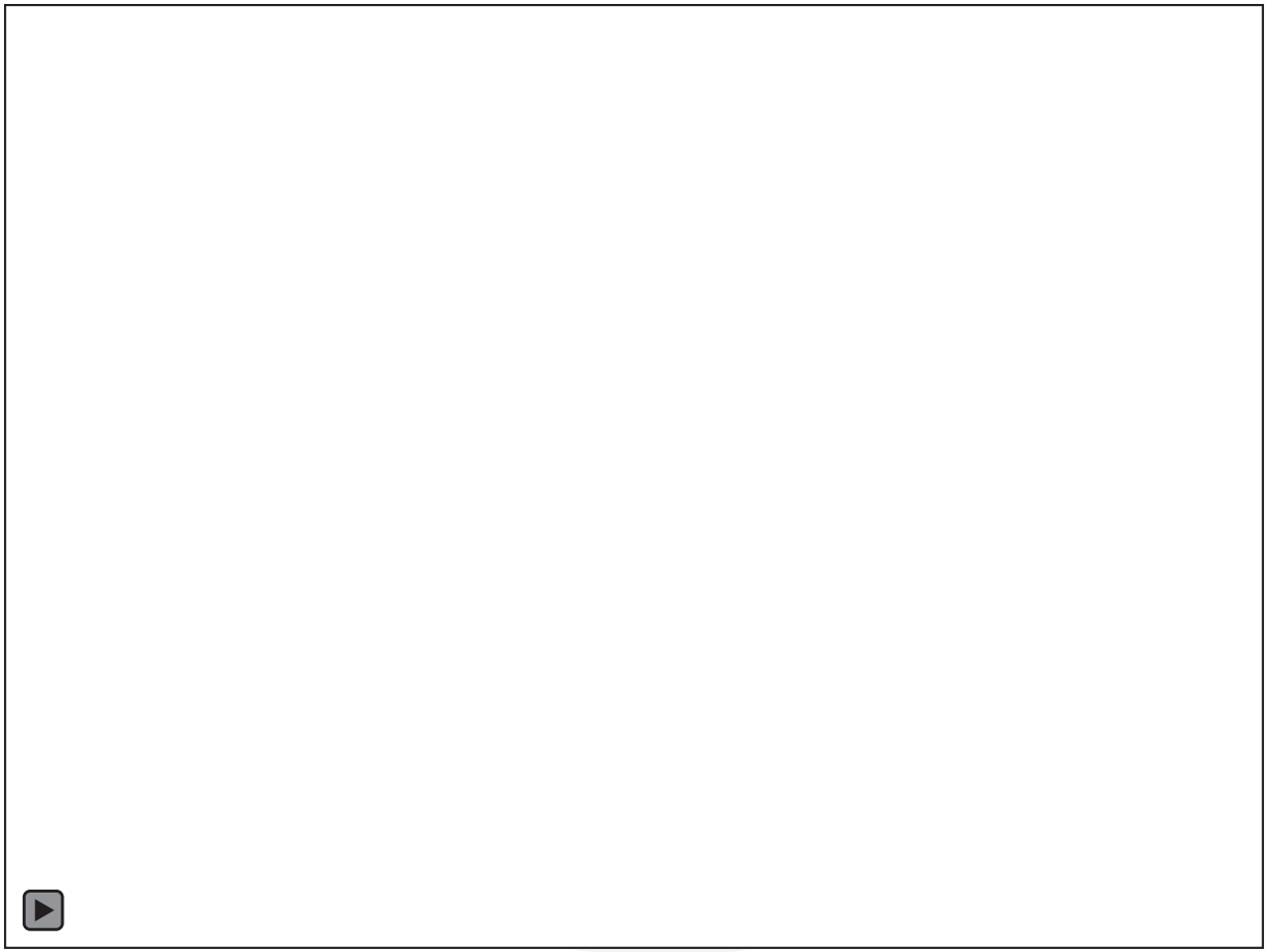
22* National Lab Scientist Fellowships



2018 Lab Fellows

- Dr. Eric Becker, PNNL-Michigan
- Dr. Hari Harilal, PNNL-Michigan
- Dr. Paul Johns, PNNL-Florida
- Dr. Kari Pazdernik, PNNL-NCSU
- Dr. Daniel Skroski, PNNL-Michigan
- Dr. Glen Warren, PNNL-MIT, OrStU, Princeton
- Dr. Amanda Rynes, INL-OrStU

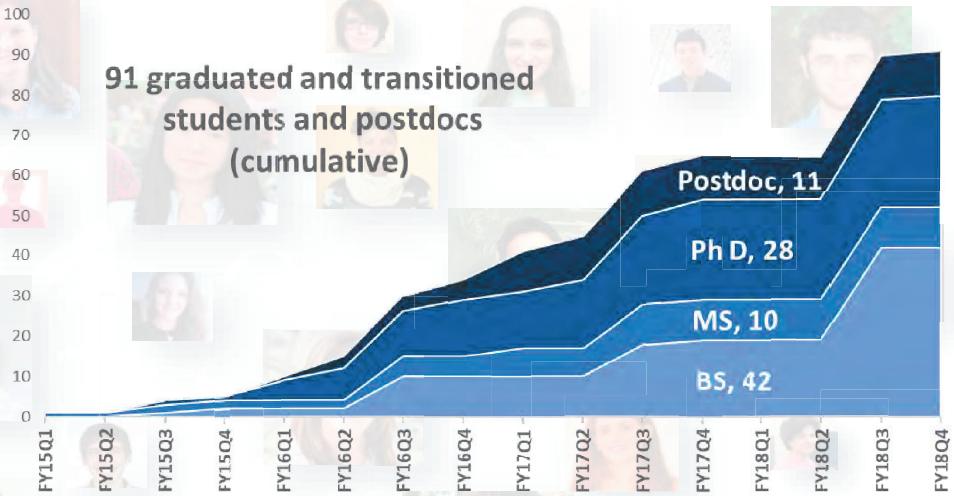
Student Laboratory Internships



291 CVT Fellows & Associates

September 2014 - Present

291 Students and Postdocs
- **103 Fellows (F)**
- **188 Associates (A)**



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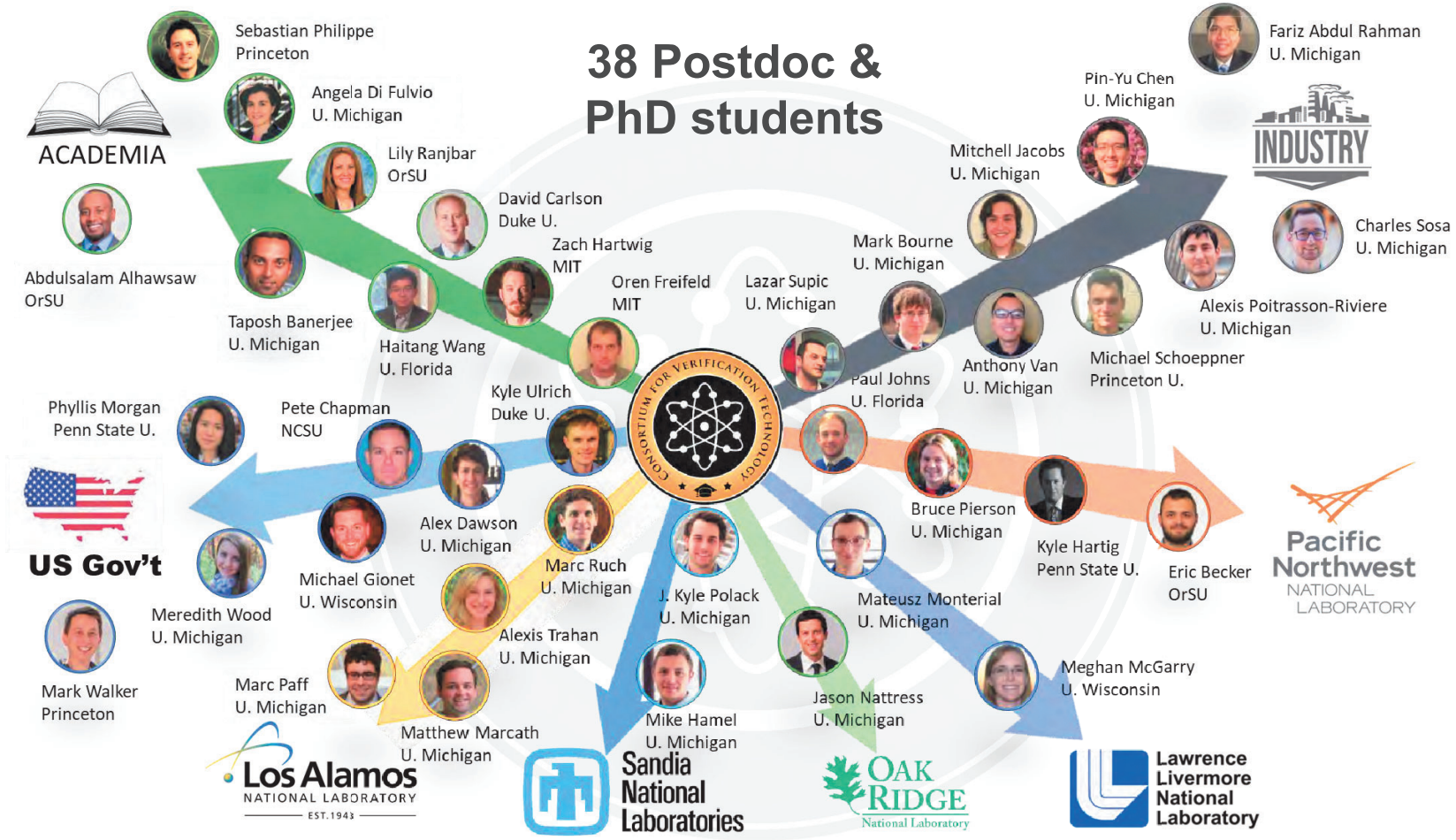
Subtotals	81	70	79	88	111	91	89	88	103	81	94	89	97	91	95	91
Transitions	1	0	3	2	4	5	16	4	6	2	16	4	0	0	3	4
Undergraduate Student Associates	12	11	12	9	6	10	8	8	8	6	7	7	4	13	12	23
Undergraduate Student Fellows	0	0	6	13	12	11	12	11	11	12	15	11	21	20	27	12
Graduate Student Associates	50	36	31	35	63	45	43	34	53	33	41	36	38	26	28	32
Graduate Student Fellows	11	14	19	20	18	14	14	22	22	23	23	25	25	26	23	20
Postdoc Associates	2	2	3	2	4	4	5	6	3	3	3	4	4	2	2	2
Postdoc Fellows	6	7	8	9	8	7	7	7	6	4	5	6	5	4	3	2

CVT Launching Careers



CVT Transitions: Launching Careers

CVT Transitions: Technology

Technology Transfer Panel

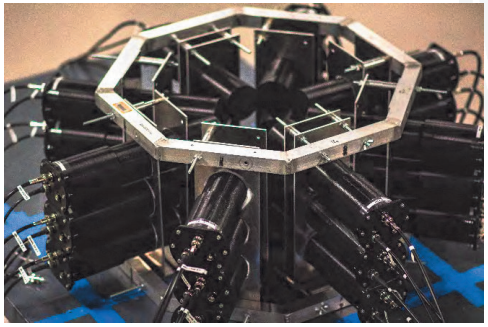
Prof. Zhong He
Univ. of Michigan

Prof. John Mattingly
North Carolina St. Univ.

Prof. Abi Farsoni
Oregon St. Univ.

Prof. Milton Garces
Univ. of Hawaii

Technologies



Well counter system, Sara Pozzi,
University of Michigan

H3D Company
Photo:
Industrial
Imaging
Spectrometer

Zhong He, University of Michigan

New Innovations in Research:
Duke University with LANL will research Generative Adversarial Networks (GANs) improve monitoring and detection of proliferation-related activities by developing machine learning tools that facilitate persistent surveillance, remote monitoring, and rapid analysis of large data sets.

CVT Undergraduate Students

73

73 undergrad student fellows and associates participating on research projects

34 students graduated with Bachelor's degrees in Nuclear Engineering, Physics, and other disciplines

44

44 students supported as undergraduate fellows

57 students receiving specialized training at CVT developed courses and workshops

315

Students have received support for **233** project quarters and counting

24 undergrad student presentations at research conferences

10

10 national laboratory internships have been awarded to undergrad students

Student Outreach

University Program Review 2018

The University of Michigan (UM) hosted the annual Department of Energy (DOE) National Nuclear Security Administration (NNSA) Defense Nuclear Nonproliferation Research and Development (DNN R&D) University Program Review (UPR) meeting at the Sheraton Ann Arbor, June 5 – 7, 2018.

IMAGE: Ms. Lisa Gordon-Hagerty awards a National Laboratory Impact award to Ms. Ciara Sivels. Left to right: Dr. Victoria Franques, Dr. Shaun Clarke, Prof. Sara Pozzi, Dr. Luke Erikson, Ms. Ciara Sivels, Ms. Lisa Gordon-Hagerty, Dr. Ed Watkins.

- **Ms. Lisa Gordon Hagerty, Administrator of the NNSA**
- **285 Attendees**
- **48 Technical CVT presentations**
  - 18 Talks
  - 30 Posters
- **3 CVT Student Impact Award Winners**
  - Ms. Ciara Sivels, U. Michigan, Best National Lab Impact
  - Mr. Robert Weldon, NCSU, Best Poster Presentation
  - Mr. David Goodman, U. Michigan, Best Oral Talk

Summary of CVT Accomplishments to Date

- An active-mode fast neutron multiplicity counter has been demonstrated as a viable technology for the IAEA, and they are adopting it
- A prototype stilbene cell has been developed and was used to measure radioxenon samples at PNNL
- Unique signatures of uranyl fluoride have been measured with time-dependent optical fluorescence techniques
- Zero-knowledge techniques based on NRF have been experimentally demonstrated
- A handheld version of the dual-particle imager has being developed, and deployed at the DAF
- CZT-based imaging technology is currently being assessed by the IAEA

Summary of CVT Metrics to Date

- Over 290 students and postdocs in program
- Over 90 student to lab internships
- 18 transitions to national labs and government
- 17 transitions to Industry
- 29 transitions to academia
- Over 170 journal publications
- Over 120 invited talks
- Over 210 conference papers
- Over 400 oral and poster presentations
- 100% of fellows intern at national labs throughout their career
- 22 national laboratory fellowships
- 8 technical workshops, 400 participants attending outreach events, and more than 35,000 visits to the CVT website
- More than 30 student and faculty awards

Acknowledgements

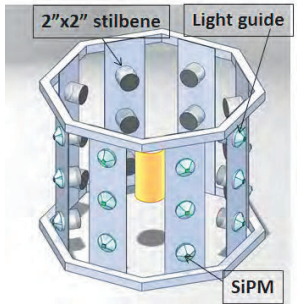
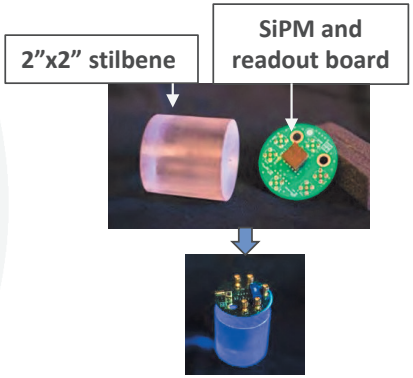
The Consortium for Verification Technology (CVT) would like to thank the NNSA and DOE for the continued support of these research activities.

This work was funded by the Consortium for Verification Technology under Department of Energy National Nuclear Security Administration award number DE-NA0002534

Connect with us online!

http://cvt.engin.umich.edu

@NNSA_CVT

CVT Expected Outcomes

- Continue to develop, test, and deliver transformational technologies for nuclear nonproliferation and arms control verification
  - Policy engagement – deep understanding of the policy and technical aspects of nuclear treaty verification
  - Computational capabilities for data analysis
    - New data analysis and compression methods for multi-channel readout systems
    - Anomaly detection methods for data from diverse sensing modalities
  - New, more effective and reliable tools for declared and undeclared facilities
    - CZT digital, imaging spectrometer complete with algorithms to determine size, shape of shielded SNM
    - FNMC prototype updated to stilbene, SiPM readout
    - Standoff detection of uranium enrichment via laser induced breakdown spectroscopy
    - Demonstration of two methods to verify disarmament without revealing classified information
- Continue transition of technology and students to laboratories, industry, government, academia, IAEA
- More than 80 additional graduates are expected