SAND2019-13785PE

Nuclear Non-proliferation / Nuclear and Radiological Sciences

Presented by: Kristin Hertz

UC Berkeley/Sandia National Laboratories Research Collaboration Workshop

November 8, 2019

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Sandia Rad/Nuc Nonproliferation and Science

R&D informed and driven by mission needs

Strong partnerships within Sandia between mission focused departments and technology development departments.

Mission Areas

- SNM detection
- Warhead Verification
- Safeguards
- Emergency Response

SWAP

- size
- weight
- power

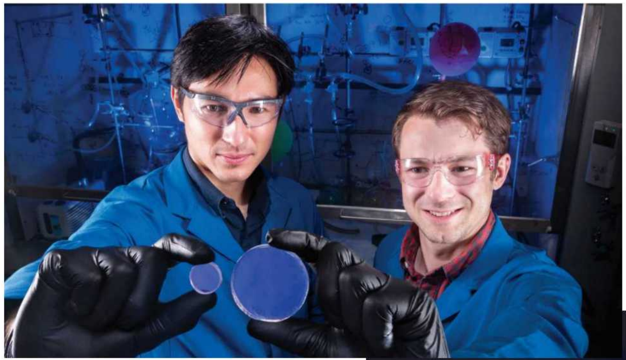
Technical Areas

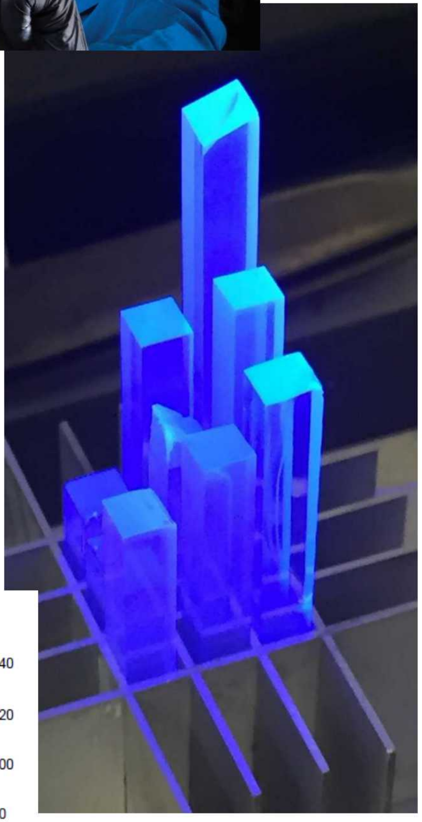
- Detector Materials Development
- Detector Development (rad, EM, bio)
- Electronics
- Data Analysis
- Algorithm Development

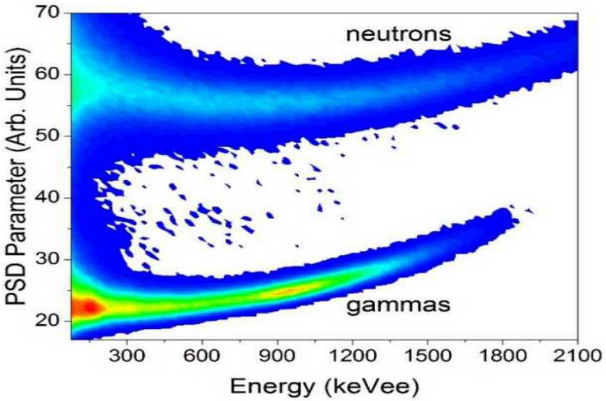
Detector Materials Development

Organic Glass Scintillators

- pulse shape discrimination capable
- compatible with SiPM and PMT
- cheap and easy to fabricate into various shapes
- Tunable performance (emission spectra, spectroscopy, thermal neutron)
- Robust for long term deployment (strength, oxidative stability, radiation hardness)

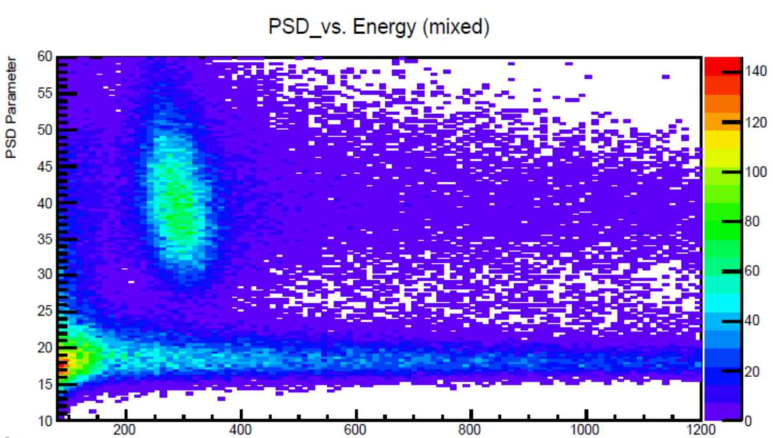






SNL-Boron-1.2%

Organic Glass with 1.2% boron (0.24% ^{10}B)



Current Collaboration:
SNL: Patrick Feng, Joey Carlson
UC: Bourret-Courchesne, Goldblum, Laplac

Single Volume Scatter Camera (SVSC)

Neutron Scatter Camera

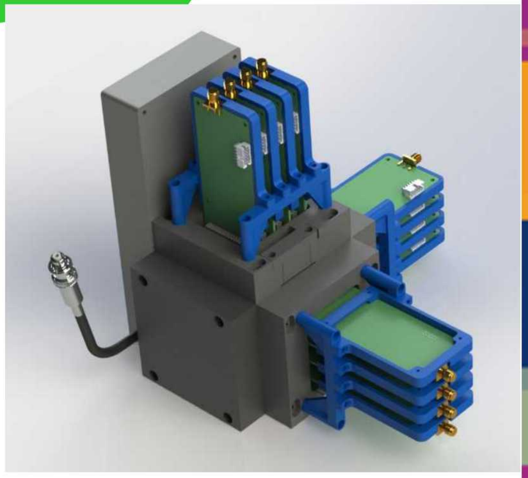
- 2 planes of 16 5” diameter liquid scintillators
- Variable planar gap

Mobile Imager of Neutrons for Emergency Response (MINER)

- 16 3”x3” liquid scintillators
- Compact form factor
- Battery operable
- More uniform Field of View

Single Volume Scatter Camera (SVSC)

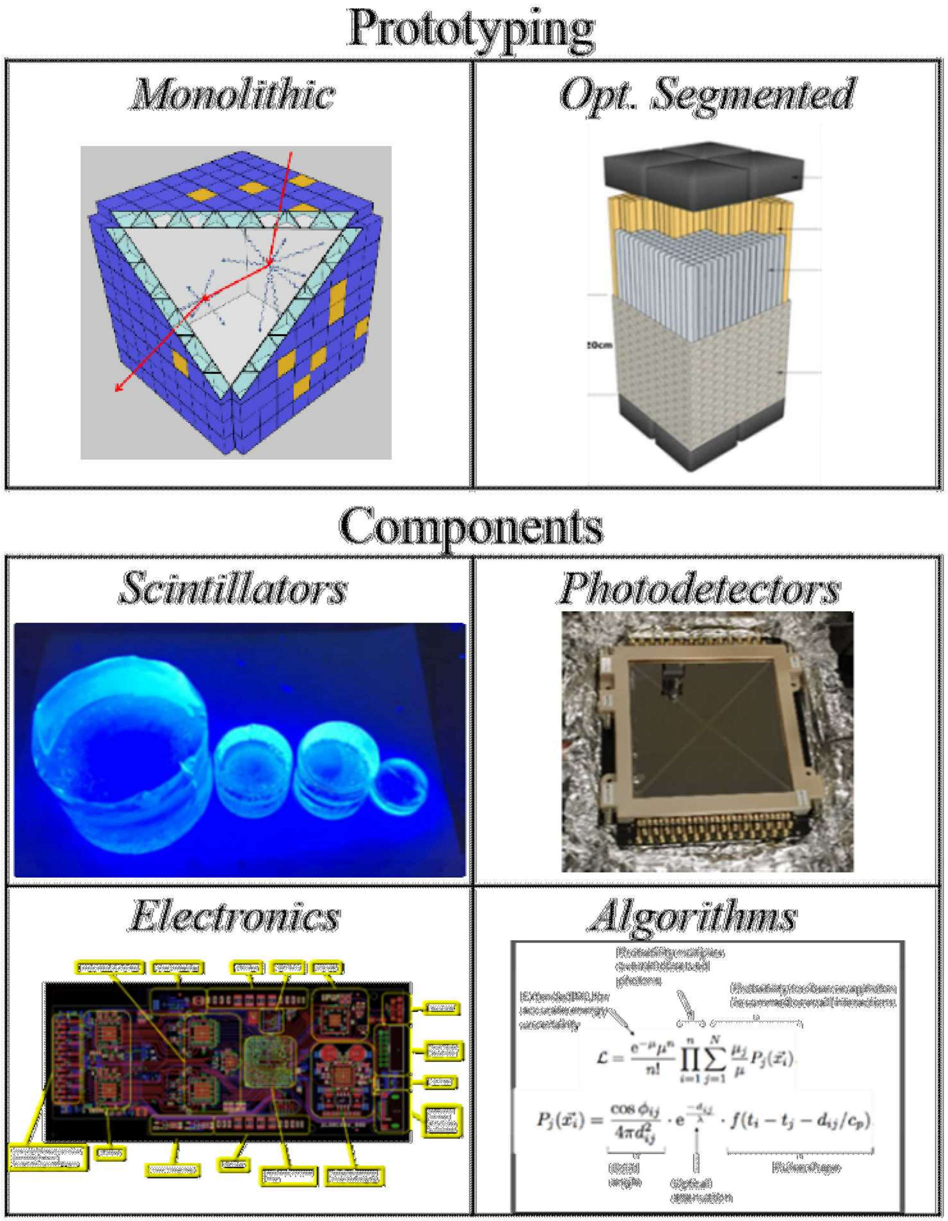
- Single scintillating volume 10x10 cm
- Same efficiency



Single Volume Scatter Camera

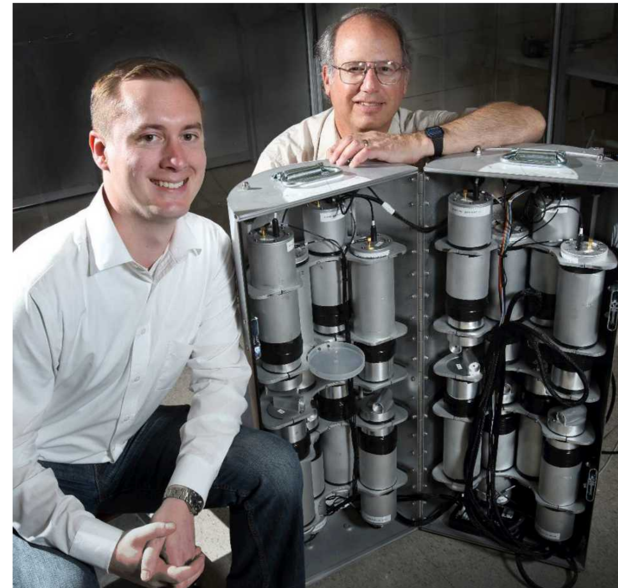
Outcomes/deliverables:

- prototypes, performance studies; improved photodetectors, electronics, scintillators;
- papers, theses, human capital

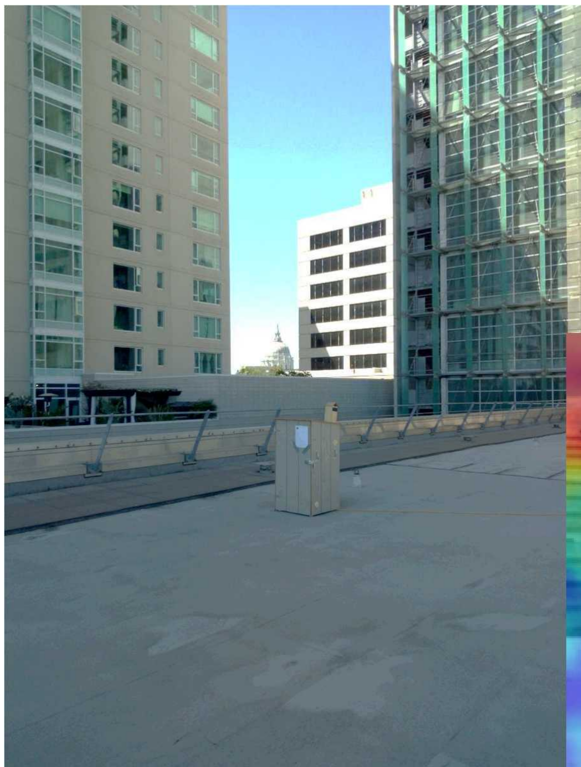


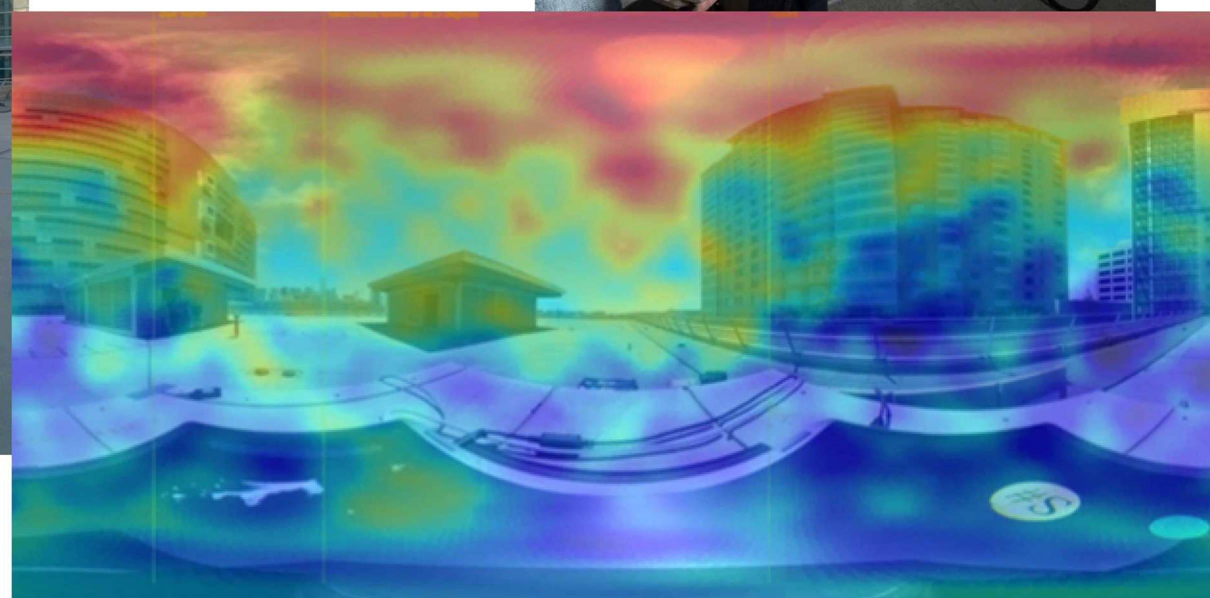
Current collaboration:
UC: Goldblum, Laplace, Brown, Manfredi, Gabella, Orebi-Gann, Ben Land
SNL: Erik Brubaker, et al

MINER – Urban Neutron Background



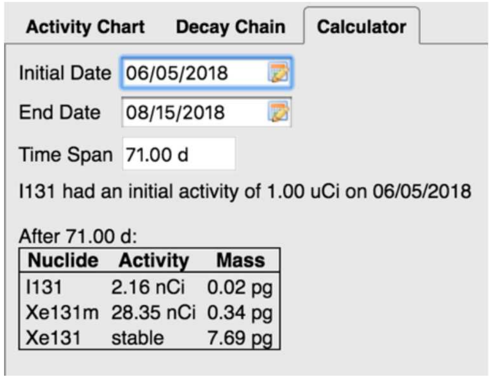
Neutron Scatter Camera using pulse shape discrimination plastic to characterize neutron background in an urban environment





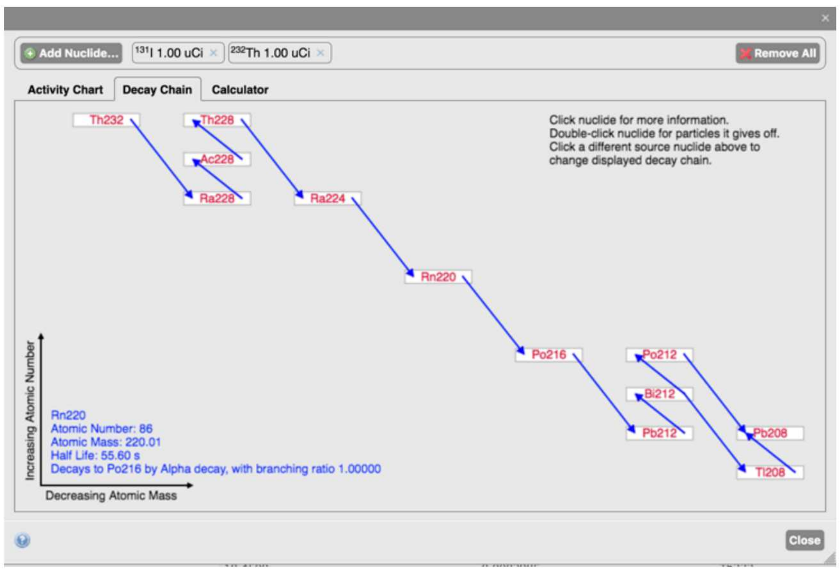
Current collaboration:
UC: Adam Glick
SNL: Cabrera-Palmer, Gerling, Brubaker

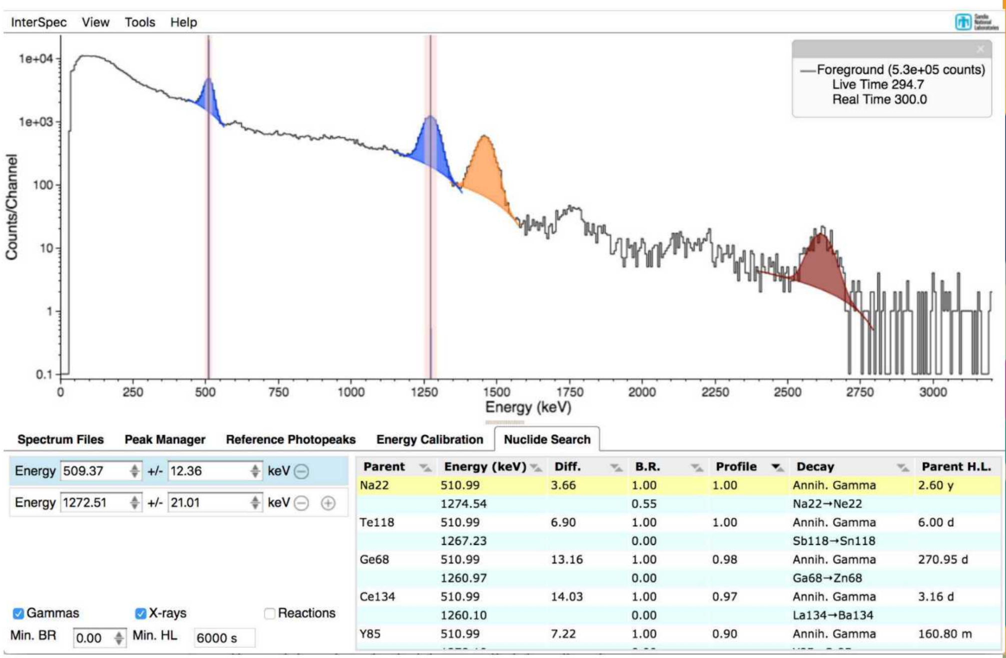
Interspec



InterSpec is a cross-platform application for interactive analysis of spectral gamma radiation data

- Runs natively on iOS, Android, macOS, Windows, Linux, and as a web-app
- It uses a peak-based approach to help users identify what isotopes are present, determine their activities, fit for shielding
- Also contains a number of other useful tools for analyzing radiation data





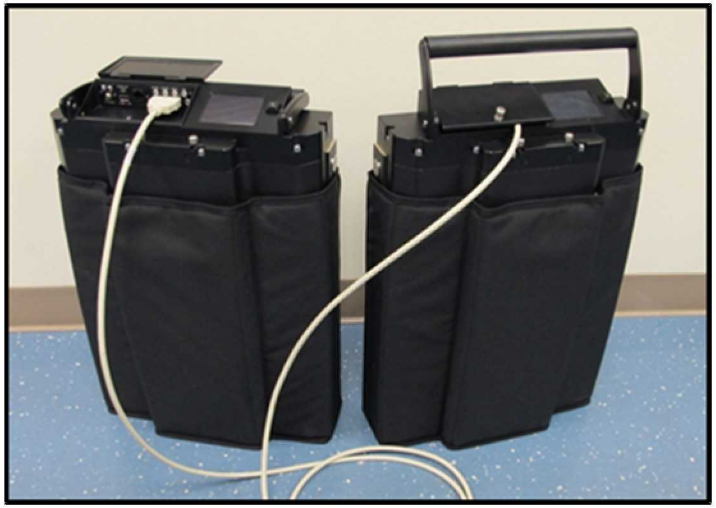
Current work

SNL: Will Johnson

Muon interactions in matter

Understand the source term interactions of muon with materials to facilitate instrument capability, background, and modeling

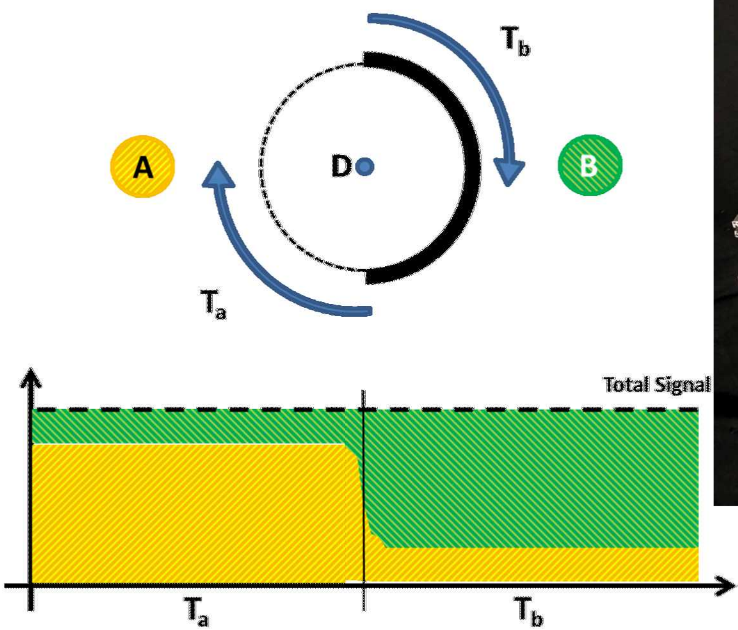
- Recently SNL acquired LANL's 3D muon tracker
- Enhance our capability to study these effects

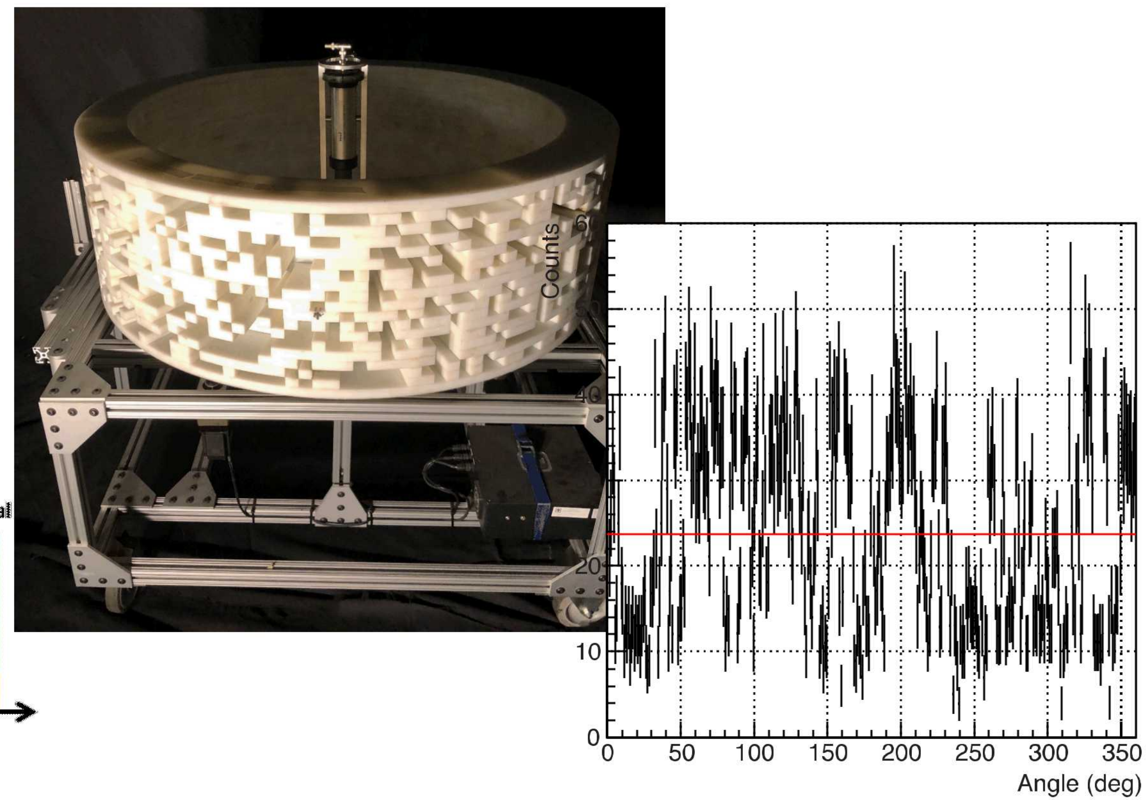


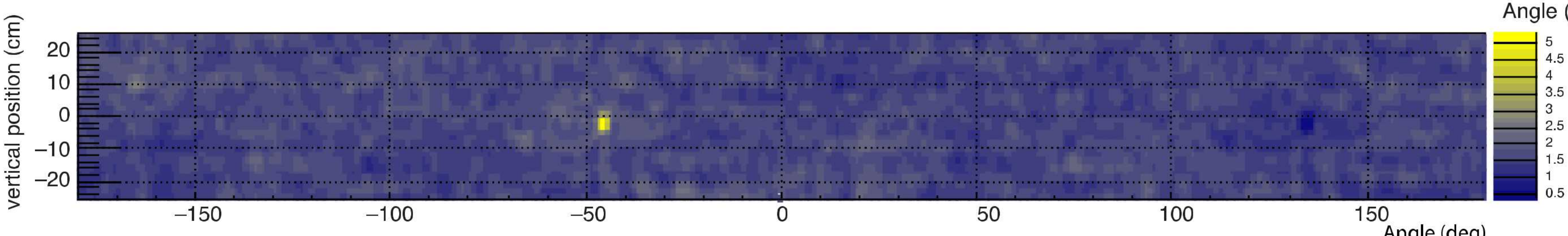
SNL: Scott Kiff

Warhead Verification

CONFIDANTE – CONFirmation using a Fast-neutron Imaging Detector with Anti-image Null-positive Time Encoding







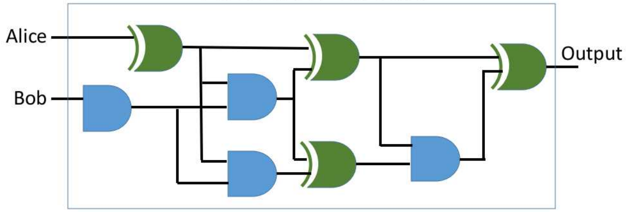
Current collaboration:
UC: Rebecca Krentz-Wee, SNL: Pete Marleau

UCB-SNL: Sharing Proprietary Data from Reactor Facilities

Data is considered proprietary by the nuclear facility operators

Use of Multi-Party Computation (MPC) could obviate the proprietary issue since the operator never reveals the underlying data

Function Circuit

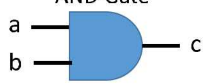


Circuit is shared to Alice & Bob

AND Gate

Alice **a** = {11001011.....}

Bob **b** = {01001101.....}



Alice has 128-bit Random Number Generator: $R_{\text{bit}}^{\text{owner}}$

Alice has 256-bit symmetric key encryption: e_{256}^{label}

AND Truth Table

a	b	c
0	0	0
0	1	0
1	0	0
1	1	1

Alice Creates Random Labels →

a'	b'	c'
R_0^a	R_0^b	R_0^c
R_0^a	R_1^b	R_0^c
R_1^a	R_0^b	R_0^c
R_1^a	R_1^b	R_1^c

Alice Encrypts Random Labels →

R(c')
$e^c_{R_0^a R_0^b}(R_0^c)$
$e^c_{R_0^a R_1^b}(R_0^c)$
$e^c_{R_1^a R_0^b}(R_0^c)$
$e^c_{R_1^a R_1^b}(R_1^c)$

Alice Shuffles Random Labels →

R(c')
$e^c_{R_1^a R_0^b}(R_0^c)$
$e^c_{R_0^a R_0^b}(R_0^c)$
$e^c_{R_1^a R_1^b}(R_1^c)$
$e^c_{R_0^a R_1^b}(R_0^c)$

Alice sends Bob her label for each of her input bits (R_0^a or R_1^a), and encrypted, shuffled table
Bob randomly chooses α or β for every one of his bits {$\alpha\beta\beta\alpha\beta\alpha\alpha\beta$, ...},
and requests his R_α^b or R_β^b from Alice using Oblivious Transfer
Bob decrypts each row of the table using Alice's supplied R^a and R^b to reveal R^c
Alice can then share the meaning of R^c, then both Alice and Bob know the answer of the gate

Modality	IAEA Data Sources	Operator Data Sources
Quantitative Sensors	Gamma ray spectrometry (U and Pu isotopics)	Water chemistry (pH, ppm levels, conductivity, hydrogen, oxygen, chloride, fluoride, boric acid concentrations),
	X-ray spectrometry (element identification, container thicknesses)	Primary and secondary loop temperatures, pressures, flow rates, water levels
	Neutron counting (U and Pu amount/enrichment verification)	Accelerometers (vibration FFT)
Operational Signatures	Power monitor (Advanced Thermo-hydraulic Power Monitor)	Ex-core neutron flux (noise shows vibration, phase differences between detectors)
		Reactor power
		Control rod positions
		Steam generator pressures & flow rates
		Valve settings (open/closed)
	Cerenkov radiation viewing	Radiation monitors
		Motor current signature analysis (>350 motors to drive pumps, fans & compressors)
		acoustic emissions monitoring (emitted from equipment and pressure boundaries)
		Odor, burning, fumes
Containment & Surveillance	Camera surveillance	Security cameras
	Load cells (weight measurements)	
	Seal inspection	RFID tracking
	Containment verification (e.g. laser reflectometry)	
Off-site Laboratory	Destructive Assay (alpha, x-ray, gamma, mass spectrometry, etc.)	Personnel radiation monitors
Environmental Sampling	Particles	Gas effluents
Documentation	Inspector reports, Inventory ledger reconciliation	Maintenance reports, INPO/WANO visits, Regulator event notification reports
Design Information	3-D laser range finder	Security personnel

Table 1: Types of data sources typically used by the IAEA for safeguards at nuclear power plants; and typical data sources used by civilian reactor operators.

Current collaboration:
SNL: David Farley
UCB: Slaybaugh, Negus

Partnership possibilities for nuclear safeguards

Prototype Distributed Ledger Technology of UF_6 Cylinder Tracking in Ethereum

Nicholas D. Pattengale
David R. Farley

SANDIA REPORT
SAND2014-19008 R
Official Use Only • Privileged Information-Applied Technology
Printed October 2014

Uranium AVLIS Safeguards Approach

David R. Farley

An Enhanced Safeguards Approach for Accelerator Driven Systems utilized to Close the Fuel Cycle

David R. Farley
Eva C. Uribe
Steven M. Horowitz
Alexander A. Solodov

SANDIA REPORT
SAND2017-3105
Official Use Only • Privileged Information-Applied Technology
Printed March 2017

Strategic Planning for Molten Salt Reactor Safeguards

David R. Farley and Matthew R. Sternat

SNL: David Farley

Potential for further nuclear/data analytics partnerships

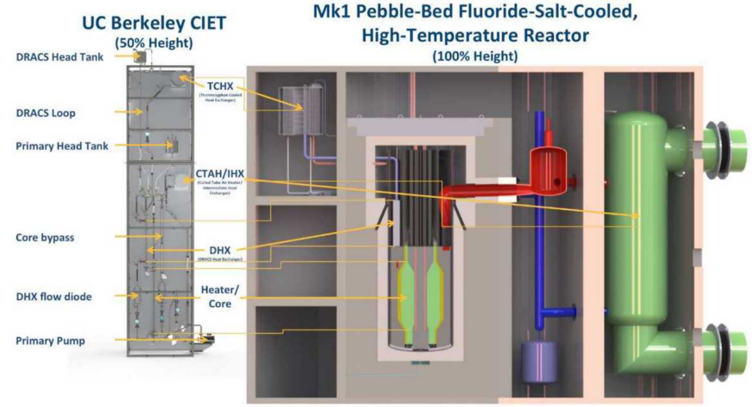
SANDIA REPORT
SAND2018-12807
Unlimited Release
Printed November 2018

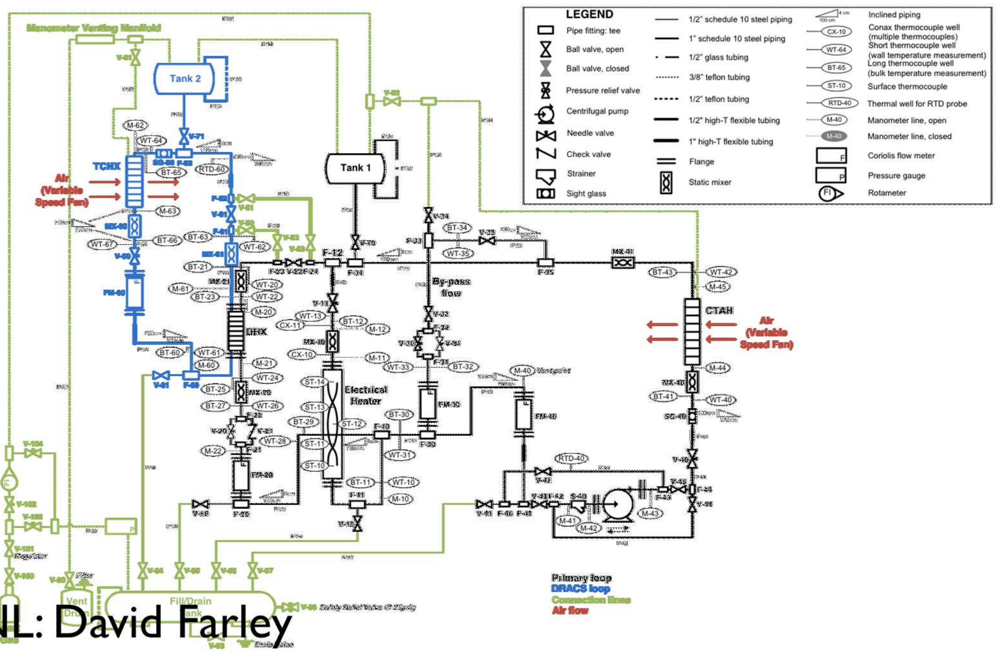
Industrial Internet-of-Things & Data Analytics for Nuclear Power & Safeguards

David R. Farley
Sandia National Laboratories

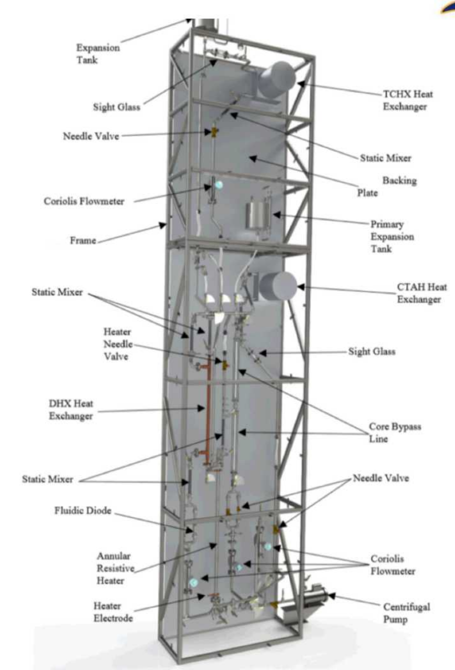
Mitch G. Negus
Rachel N. Slaybaugh
University of California, Berkeley

The UCB Compact Integral Effects Test (CIET) Facility Scaling Matches the Mk1 Reactor Design





CIET/Mk1
heat sources and sinks

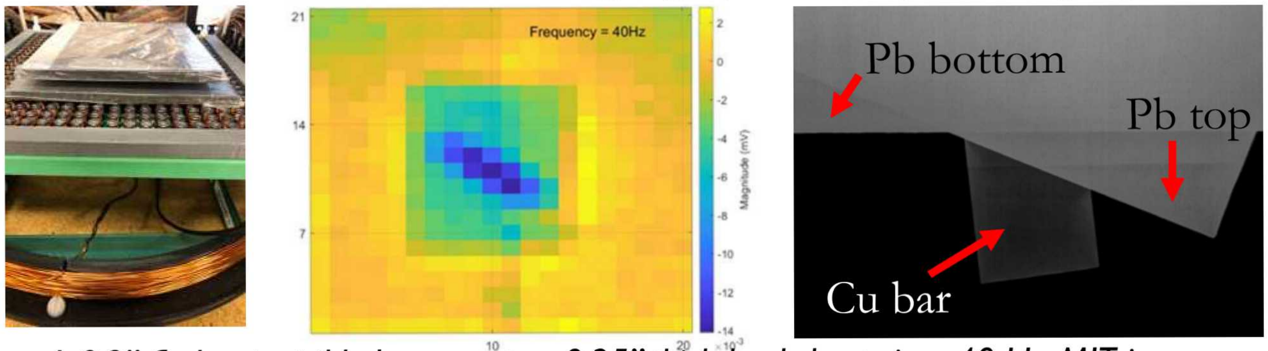


SNL: David Farley

Alternative Signatures – Magnetic Induction Tomography

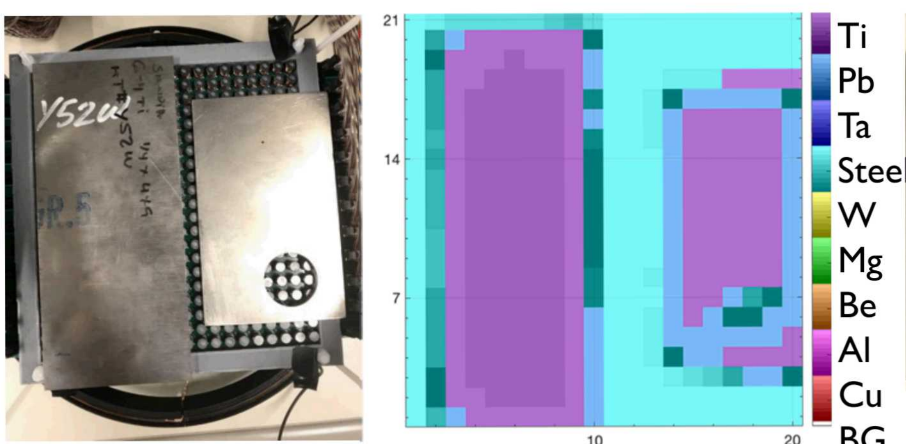
Electromagnetic properties provide a complementary signature to traditional radiation detection techniques for detecting and characterizing special nuclear material and other threats

Magnetic Induction Tomography vs. x-ray Radiography



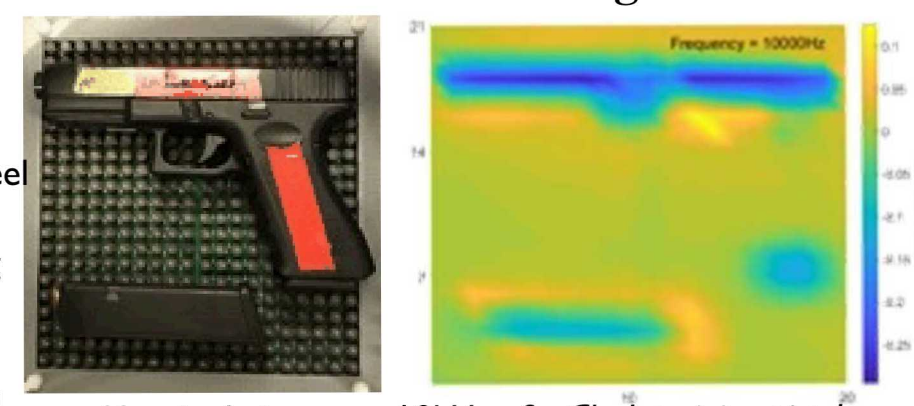
A 0.2" Cu bar is visible between two 0.25" thick lead sheets in a 40 Hz MIT image but is not visible in a 3-minute 450 kVp x-ray image

Material Characterization



Characterization results for 1/4" (left) and 1/16" (right) titanium sheets

Firearm Screening

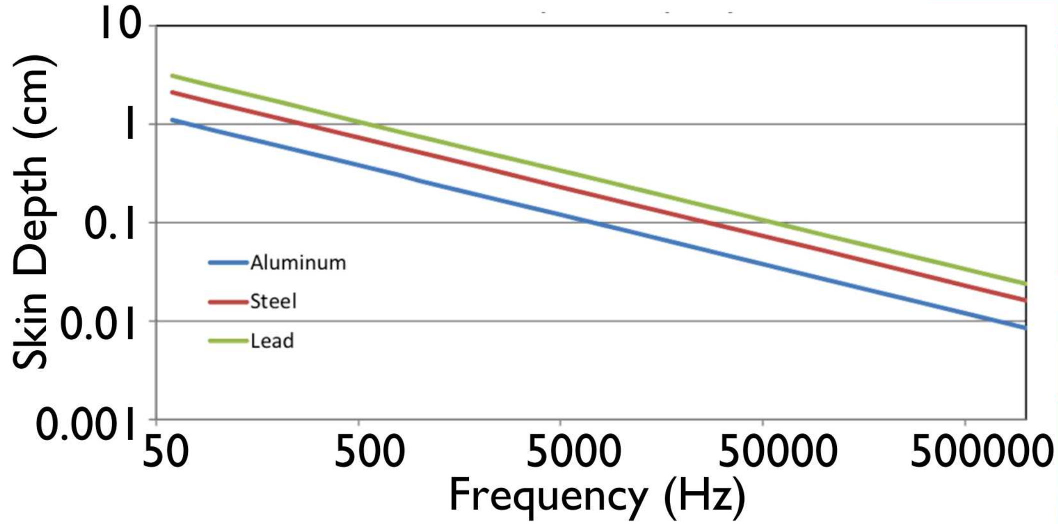


Magnitude image at 10kHz of a Glock training pistol

Current work
SNL: Kyle Polack

Alternative Signatures – Low Field Nuclear Magnetic Resonance (NMR)

- NMR is used to identify the chemical nature of organic compounds, applied to any nuclei with and odd number of protons and/or neutrons
- Earth's field NMR utilizes low-frequency (≲ 2 kHz) excitation pulses to stimulate nuclei at their characteristic Larmor frequency
- low-frequency magnetic fields can be used to penetrate shielding
- Can we use to detect and potentially characterize shielded threat objects?



Approximate skin depth as a function of frequency for common shielding materials

QuSpin Zero Field Magnetometer

	Isotope	Natural abundance (%)	Gyromagnetic ratio (MHz/T)	Larmor frequency at Earth's field (Hz)
Select Explosives Isotopes	^{1}H	99.98	42.6	2059.2
	^{13}C	1.1	10.7	517.9
	^{14}N	99.6	3.02	148.9
	^{19}F	100	40.1	1937.1
	^{31}P	100	17.2	833.6
	^{35}Cl	76	4.13	202.0
SNM	^{235}U		-0.79	40.0
	^{239}Pu		3.02	149.3

Current work:
SNL: Kyle Polack

Extra

Neutrino coherent scattering

The COHERENT Collaboration – Office of Science

Background measurements with MARS detector at ORNL's Spallation Neutron Source's (SNS) basement.

COVER OF SCIENCE:
"Observation of coherent elastic neutrino-nucleus scattering", D. Akimov *et al.*, *Science* 357, 1123 (2017).