NuFor

Nuclear Forensics

1–3 October 2024

Core Technology Facility, University of Manchester, Manchester, UK and Online

NATIONAL NUCLEAR LABORATORY

AWE NUCLEAR SECURITY TECHNOLOGIES

IOP Institute of Physics

MIRION TECHNOLOGIES

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Personal Radiation Dosimeter

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High Definition Camera System

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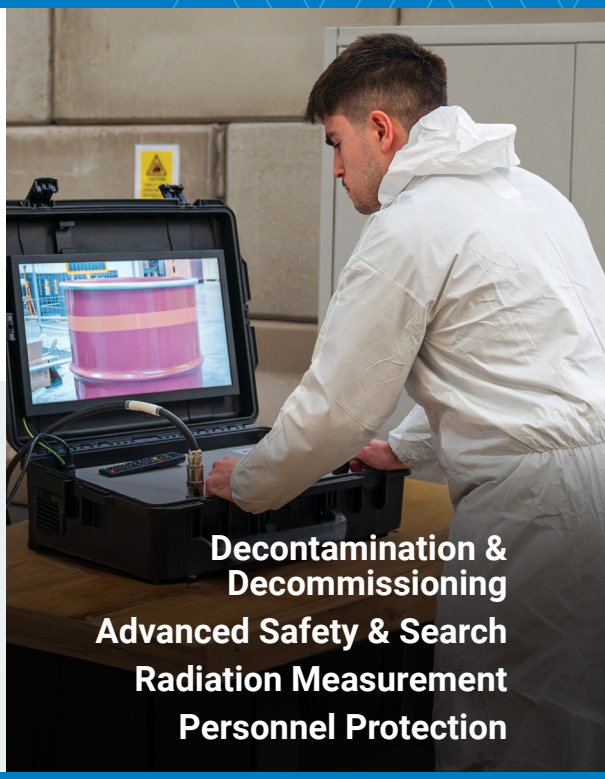


Decontamination & Decommissioning
Advanced Safety & Search
Radiation Measurement
Personnel Protection

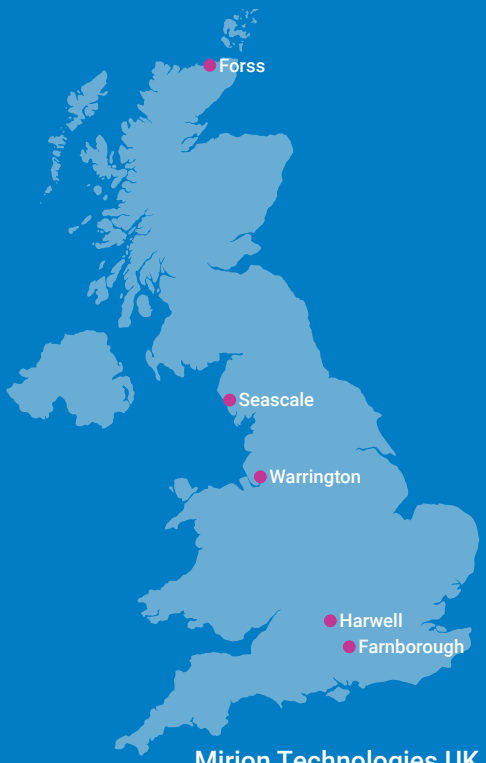
Who We Are

Market Leader – A leading provider of detection, measurement and monitoring products, systems and services for over 60 years

Solutions Provider – Committed to solving our customers' most difficult radiation safety, measurement and characterisation challenges

Customer-Focused – Passionate about delivering exceptional service and unsurpassed support

Global Presence – Our organisation employs more than 2,700+ professionals and subject matter experts worldwide



Mirion Technologies UK

For further information, contact us at uksales@mirion.com

MKTG-2396 08/2024

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Programme

Tuesday 1 October

08:30	Registration
09:00	Welcome and Opening Remarks **Roy Awbery (**AWE)
	Chair: **Chris Brook** (AWE)
09:20	Keynote 1 **James Black** (MOD)
10:00	Keynote 2 **Clive Nixon** (NDA)
10:30	Coffee Break
	Chair: **Lucy Millington** (AWE)
11:00	Career Pathways / Professional Institutes **Michael Curry** (Los Alamos National Laboratory) and **Marina Dawes** (AWE)
12:00	Lunch, Posters and Exhibition
	Chair: **Peter Hiller** (NNL)
13:30	Keynote 3: **A National Lab Perspective on Nuclear Forensics** **Jonathan Hyde**, National Nuclear Laboratory
14:00	Keynote 4: Nuclear Forensics R&D Program Manager? **Richard Gostic** (NNSA)
14:30	Tea Break
	Chair: **Karen Kennedy**, AWE
15:00	Law Enforcement Session: Panel Discussion **Kevin Swearingen** (FBI), **Jason Keen** (SO15)
16:00	Flash Posters
16:30	Poster Session
18:00-20:00	Drinks Reception (Whitworth Gallery)

Wednesday 2 October

09:10	Introduction and Notices
	Chair: **Jonathan Hawkett** (NNL)
09:20	Keynote 5: Fancy Fingerprints – From Mineral to Materials Provenance Strategies **Amanda Quadling** (UK Atomic Energy Authority)
09:50	Invited: Nuclear Forensics R&D at the JRC-Karlsruhe (virtual) **Klaus Mayer,** European Commission Joint Research Centre)
10:10	Coffee Break
	Session: Analytical Techniques Chair: **Assel Aitkaliyeva** (University of Florida)
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Keynote 1

James Black[1]
[1]UK Ministry of Defence, UK

Biography: *James studied Physics at University, and after industrial placements in optoelectronics and defence research, has spent most of his 30-year career in the National Security community. He was promoted to Deputy Director level in 2014, where his roles have included helping create and launch new programmes and supporting digital transformations. James has now held a director position at the MOD as of 2023.*

James is married with three school age children, and lives in Worcestershire. The family enjoy hiking, river sports and skiing.

Keynote 2

Clive Nixon[1]
[1]Group Chief Nuclear Strategy Officer, Nuclear Decommissioning Authority, UK

Biography: *Clive joined the Nuclear Decommissioning Authority (NDA) in April 2005, after 15 years with British Nuclear Fuels, where he undertook roles across research and development, technical and commercial areas. Through this he covered the full range of activities and facilities at Sellafield, including reprocessing, waste management and decommissioning, He also spent time in the US and overseas.*

Roles undertaken within NDA, culminating in the role of Group Chief Nuclear Strategy Officer, have allowed Clive to gain a comprehensive understanding of the NDA's estate, the strategy and policy landscape, and provide leadership on strategy development and implementation for the group, and with DESNZ, through strong collaborative relationships.

Clive has a BSC and MSC in Engineering and Applied Mathematics, is a graduate of the Cabinet Office Project Leadership Programme and was part of the first NDA Leadership Academy cohort.

Career Pathways / Professional Institutes

Marina Dawes[1]
[1]Director of Science, AWE, UK

Biography: *Marina studied chemistry at the University of Kent at Canterbury and joined AWE in 2003 onto the graduate scheme. She started out her working life in the fascinating area of plutonium science and has held a variety of roles during her 20+ years with AWE, including Group Leader Metals and Tritium and Head of Materials and Analytical Sciences. She has been Director of Science since June 2023; she and her team provide the strategic direction and empower people to innovate and deliver the science and technology capabilities required to underpin the UK's nuclear deterrent and nuclear security, for today and the future. Much of her career at AWE has been in leadership roles where her primary aim has been to enable and empower great scientists to do great science in a highly regulated environment.*

She has had two (separate) years of maternity leave, to take time out of her career to have her children and has worked part-time for the past 14 years to manage her work-life balance as she is the primary carer. She is passionate about role modelling flexible working alongside career progression and supporting working parents to manage their work-life balance to achieve their version of the best of both worlds; being a parent and pursuing career goals.

As well as her two amazing daughters (now aged 12 and 13), she is step-mum to three wonderful kids (aged 9, 12 and 15) with her partner Lee.

Keynote 3: A National Lab Perspective on Nuclear Forensics

Jon Hyde[1]
[1]National Nuclear Laboratory, UK

Biography: *Following his PhD, Jon was awarded a Fellowship at Oxford before briefly working at Oak Ridge National Lab. On returning to the UK, Jon joined UKAEA and rapidly gained experience managing and delivering nuclear research for international customers. He led the 'Materials and Chemistry' team at Harwell that was then acquired by BNFL and later became the National Nuclear Laboratory (NNL). Within NNL he took on several roles combining scientific research and management, including Chief Technologist and Senior Fellow. In his current position as Head of R&D, Jon is responsible for NNL's internal investment in R&D and engagement with academia. Internationally, Jon now has board positions representing the UK on several programmes including the Halden Reactor, the Jules Horowitz Reactor, and the NEA FIDES programme.*

In this presentation I will provide an overview of the UK Nuclear landscape and NNL's role as the UK's National Laboratory for fission. Using examples of cutting-edge science, I'll outline the capabilities needed to support nuclear forensics and show how government and international policy are influenced. I'll also explain how these interdisciplinary skills and capabilities are supporting exciting new areas of nuclear research such as the development of space batteries and extraction of radioisotopes for medical purposes.

Keynote 4: Nuclear Forensics R&D Program Manager?

Richard Gostic[1]
[1]NNSA, USA

Biography: *Rich Gostic is a senior program manager within the National Nuclear Security Administration (NNSA). He has over 20 years' experience working in R&D and technical operations within the USA Department of Energy (DOE), USA Department of Defense (DOD) and private industry. He holds a PhD in radiochemistry with research interests in actinide chemistry and data interpretation. In his current role he manages the Nuclear Forensics R&D portfolio within the NNSA Defense Nuclear Non-Proliferation Office of Research and Development. The main objective of this R&D portfolio is to fund science and technology*

that enhance the USA pre and post detonation nuclear forensics capability.

In this presentation I will attempt to walk young and old scientists through the narrow cross section of the USA bureaucracy that supports mission focused R&D in areas such as International Safeguards, Proliferation Detection, Nuclear Forensics. This will include a discussion on the role of the Senior Program Manager, an individual that is equally loathed, feared, and misunderstood by the scientists they serve. My goal is to convince the audience that Program Managers aren't bad and describe opportunities that bridge R&D, policy, and operations that you usually don't learn about until later in your career. This is intended to be an interactive talk so please bring your questions.

Panel Discussion

Kevin Swearingen[1]
[1]US Federal Bureau of Investigation, USA

Biography: *Dr Kevin Swearingen is a Radiological and Nuclear Chemist Forensic Examiner at the Federal Bureau of Investigation Laboratory. In support of the radiological and nuclear mission, Dr. Swearingen works with a broad range of partners throughout the government and across the Department of Energy National Laboratory system. Since 2022, Dr. Swearingen has been dual qualified as examiner in both radiological/nuclear and Chemical Warfare Agent analysis. Prior to joining the FBI, Dr. Swearingen was a chemistry instructor at Washington State University, where he also earned his PhD. Before that, Dr. Swearingen was a research associate at Pacific Northwest National Laboratory. He received his undergraduate degree from Western Oregon University.*

Jason Keen[1]
[1]Detective Sergeant, SO15 Counter Terrorism Command, Metropolitan Police, UK

Biography: *Jason has a BSc in Computing Mathematics and after graduating worked as a computer programmer. However, he decided this wasn't the career he wanted and joined the Metropolitan Police.*

He has been a police officer for 27 years and worked in a variety of roles investigating serious and complex crime. He is a qualified Scene Evidence Recovery Manager, Police Mortuary Operations Coordinator, Crime Scene Manager and Counter Terrorism Forensic Coordinator. He is also trained in Disaster Victim Identification and the recovery of CBRN contaminated fatalities.

Since joining the Counter Terrorism Command Jason has been the Forensic Coordinator for a number of high-profile cases. In his current operational role, he is the lead for CBRNe scene exploitation. He was the lead Forensic Coordinator for UK Counter Terrorism Police for the Five Eyes CBRNe Capability Exercise held at Salisbury in 2022 and will be an assessor at the 2024 exercise held at Virginia Beach in November.

Jason has been deployed operationally overseas working with foreign law enforcement agencies in counter terrorism investigations.

Keynote 5: Fancy Fingerprints – From Mineral to Materials Provenance Strategies

Amanda Quadling[1]
[1]UK Atomic Energy Authority, UK

Biography: Amanda is an Executive Director at UKAEA responsible for the Materials Division. She co-manages the UKAEA's £77m EPSRC-funded UK Fusion Programme and is also Senior Responsible Officer for LIBRTI, the new £200m programme to build a UK Fusion Fuel Capability.

Amanda is a mineralogist with a PhD in Materials Science and Engineering. She has spent the last twenty years creating and managing laboratories, incubators, commercial service divisions and Centres of Excellence focused on products and services in the energy sector and other industries. She was previously on the Technology Advisory Board of global corporate Morgan Advanced Materials and Technical Director for UK manufacturer M&I Materials (tungsten, dielectrics, electroceramics). In 2021, Amanda published the UK Fusion Materials Roadmap.

Understanding how elements of the earth combine in ore body minerals before and after mining and beneficiation, has been pivotal in developing fingerprinting methods to deter conflict mineral trade globally. Successful examples of what is achievable in gold may add value in ensuring good ethics in new coltan supply chain initiatives. Diamonds have been harder to track!

In a very different vein, understanding the provenance and evolution of isotope combinations before and after irradiation of materials allows the fission and fusion communities to predict performance of components in nuclear engineering and subsequent nuclear waste – a different ethics goal. From 2024, the UK will decommission its first large fusion machine – the Joint European Tokamak (JET), at Culhum. A forensic analysis of its materials, exposed to globally unique deuterium-tritium reaction campaigns, will be the first major postmortem of its kind. Isotope analysis of first wall samples will allow scientists to validate the degree of activation predicted for compositions like Inconel, and to explore trapped tritium fuel in tungsten armour.

Invited: Nuclear Forensics R&D at the JRC-Karlsruhe

Klaus Mayer[1]
[1]European Commission, Joint Research

The Joint Research Centre Karlsruhe has a track record in nuclear forensics which reaches back to the early 1990's. Initially, nuclear forensics was driven by urgent needs (arising from "nuclear smuggling" of materials supposedly originating from the disintegrated Soviet Union) and analytical methods and interpretation of data was very much ad-hoc and relying on the expertise of knowledgeable individuals. Over time, a systematic approach was taken for the

operational aspects and the methodology was gradually put on sound scientific basis. The presentation will focus on recent research and development activities providing new signatures or improved uncertainties on nuclear signatures.

Session: Analytical Techniques

Developing a Nuclear Forensics Capability with Existing NNL Infrastructure and Capability

Jonathan Hawkett[1]
[1]National Nuclear Laboratory, UK

Biography: I am a Senior Technical Manager at the National Nuclear Laboratory specialising in the analysis of radioactive materials for radiometric, chemical and physical characterisation. This spans the activity ranges from very low active (environmental) samples through to high alpha (glovebox) and high beta/gamma (cell) samples. As well as experience of the nuclearisation of analytical equipment and processes into these higher levels of containment.

In the context of NuFor I am interested in the use of existing infrastructure and capabilities within the NNL estate to support UK nuclear provenance activities.

At the National Nuclear Laboratory (NNL) we are embarking on utilising our knowledge, skills, infrastructure and capability built up over decades of supporting the UK Civil nuclear sector to assist and support Nuclear Forensics provenance activities within the UK Nuclear Forensic Library (UKNFL) construct. NNL has a broad experimental capability that are directly applicable to supporting nuclear forensics provenance activities, with new developments in analytical chemistry for our varied customers. These capabilities are continually being expanded for the betterment of nuclear science which can be used with little amendment for provenance samples. This capability consists of active facilities that can handle very low active material through to high alpha and high beta/gamma samples with examples of unique techniques with these handling limits within the UK. Across these activity ranges NNL has an array of radiometric, chemical and physical characterisation techniques varying from non-destructive analysis through to digestion and more traditional wet chemistry methodologies. Currently only our Preston (Springfields) site is UKAS accredited for various methods and this is being expanded to the Central Laboratory on the Sellafield site. We continue to expand and develop our microscopy capability including a recent addition of Plasma-FIB-SEM with ToF-SIMS and establishing our high precision accountancy methods with a multi-collector inductively coupled plasma mass spectrometer. Through establishing a strong link between NNL and the UKNFL provenance activities within the UK, the UKNFL is able to access a fully maintained, up to date and operational analytical capability in support of any future UKNFL provenance requirements without the need to develop bespoke additional capabilities.

Femtosecond laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS) in support of a nuclear forensics investigation of uranium oxide powders

Gregory Hull[1], Jeremy D. Inglis[1], Matthew E. Sanborn[1], and Joanna S. Denton[1]
[1]Los Alamos National Laboratory, Los Alamos, USA

Biography: *Dr. Gregory Hull is a nuclear chemist and laser physicist. He earned his PhD from the University of Manchester in 2020 after researching laser spectroscopy for nuclear forensics applications through the Materials for Demanding Environments center for doctoral training. He completed a postdoc in Manchester until 2021, investigating laser-induced breakdown spectroscopy of molten salts for next generation small modular reactors. He then worked at the Central Laser Facility in Rutherford Appleton Laboratory, Oxford, UK, as a target area scientist studying high powered laser plasmas. He joined LANL as a postdoc in August 2022 in the Nuclear and Radiochemistry group and has since helped facilitate the new capability of femtosecond laser-ablation inductively coupled plasma mass spectrometry. His work at LANL has included projects analyzing uranium particles and solids for nuclear forensics and safeguards, as well as other projects in earth science, human biology, biotechnology and materials science.*

Here we present results from femtosecond laser ablation analysis of four distinct uranium oxide powders, with the aim of developing the technique for nuclear forensics. The four samples showed vastly different colors, morphologies and densities during initial microscopy and non-destructive analysis. We analyzed individual uranium oxide particles of each sample to measure actinide isotope ratios and some trace elements of interest. The different sample morphologies, with grain sizes ranging from <5 µm to >750 µm, presented interesting challenges and opportunities for laser ablation analysis which we will cover in this talk. We validated our actinide isotope ratio results with bulk destructive analyses, which revealed that we had calculated a precise but erroneously high 235U:238U isotope ratio. Calibration using standard reference materials corrected our results and validated the laser ablation technique for future work programs.

LA-UR-24-28404

Feasibility of using U – Th Isochrons for the Assessment of 230Th – 234U Model Age Data from Uranium Metals

Jeremy Inglis[1], Anthony Pollington[1], Natalie Rice[1], Allison Wende[1], Stephen LaMont[1], and Robert Steiner[1]
[1]Los Alamos National Laboratory, USA

Biography: *Dr Jeremy Inglis is an isotope geochemist with a jointly awarded PhD degree from Oxford Brookes University, Oxford, England and Syracuse University, New York, USA. He has over 20 years of experience in the field of mass spectrometry and has performed isotope measurements on a wide array of*

analytes during his career. Dr. Inglis joined Los Alamos National Laboratory in 2016, where he leads a team specializing in ultra-low level isotope measurements using thermal ionization mass spectrometry (TIMS). Inglis currently coordinates isotope measurements and material characterization at LANL in support of a number of international safeguards programs.

Determining the age of a nuclear material remains one of the key goals in nuclear forensic investigations. Chronometry techniques can determine the age of a material by exploiting the decay of a radioactive isotope to a daughter progeny, to provide a model-age. Most model-ages are interpreted to correspond to the time passed since the last chemical purification, but this interpretation rests upon (1) the assumption that the material has remained closed with respect to the parent/daughter isotopes and (2) that the decay products were completely purified from the material. Complete purification of the daughter isotope from a material represents a problematic assumption that can result in misinterpretation of model-age data. Incomplete purification will result in an excess of the daughter progeny and consequently model-ages that are older than the actual age of purification. Indeed, several recent chronometry studies of uranium metals, using the now widely employed 230Th/234U chronometer, have shown varying levels of purification. This leads to questions regarding the confidence with which we can correlate calculated 230Th-234U model-ages with actual uranium process history. A potential solution to this problem with 230Th-234U model-ages is the isochron method, which eliminates the need for any assumptions about the initial amount of the daughter nuclide in the sample. Here we present results from a pilot study assessing the feasibility of using U-Th isochrons to assess chronometry data in U materials. We introduce the basic theoretical concepts of the isochron, as applied to U-Th chronometry, including the conditions required to produce a meaningful isochron. Then, using examples from previous characterizations of uranium metals, show that plotting U-Th data on isochrons can aid in both understanding the initial Th isotope composition of a material and provide additional information for the interpretation of chronometry data.

LA-UR-24-28191

Advances on a field-deployable mass spectrometer for its application in nuclear forensics and emergency response.

Mayra Martinez[1], Ankur Chaudhuri[1], David Thompson[1], Bett Kimutai[1], Thomas Domingo[1], and David Godin[1]
[1]Canadian Nuclear Laboratories, Canada

Biography: *Dr. Mayra Martinez is an R&D Scientist in the Nuclear Response and Analysis Branch at the Canadian Nuclear Laboratories, CNL. She is part of the team supporting the Nuclear Forensics mission at CNL. Her work includes method development, processes standardization for nuclear forensics, enhancement of nuclear forensics databases, post Radiological Dispersal Device (RDD) forensic analysis*

using SEM/EDS/Raman, and the development of innovative analytical techniques for in-field testing (portable mass spectrometer).

Mass spectrometry is a key destructive technique widely used in nuclear forensics and emergency response to support the identification and attribution (origin of the material, process history, and last legal owner) of nuclear materials. It provides precise data of the elemental and isotopic properties of chemical, biological, radiological, nuclear, and explosives (CBRNE) materials with higher sensitivity than non-destructive techniques. The relative spectral intensity obtained from a mass spectrum can be used to determine the abundance ratios of different isotopes of a particular element present in the measured sample. The isotope ratio measurement plays an important role in forensics application to radiological, nuclear and other materials.

The high resolution for isotopic identification can be accomplished by instruments such as Thermal Ionization Mass Spectrometer (TIMS) and Inductively Coupled Plasma Mass Spectrometer (ICPMS). The analyses are performed by trained personnel in laboratory settings where several time consuming sample preparation steps (i.e. dissolution, purification, derivatization, etc.) are carried out. These characteristics of the technique limits its applicability to in-field deployment, where a rapid and accurate identification of CBRNE threats could guide the course of action to first responders and law enforcement.

Canadian Nuclear Laboratories (CNL) has been advancing the development of a portable mass spectrometer, by using a commercial compact multi-turn time of flight mass spectrometer (multiturn TOF-MS) with an Electron Ionization (EI) source. The multi-turn TOF provides the high resolution needed for isotopic identification while the EI source allows the use of spectral databases for comparison and identification. This approach has been successfully tested on the field for the detection and identification of gases. The current progress towards the analysis of other types of samples (liquid and solid) will be presented.

Session: Data Science & Analysis

Artificial Intelligence within the Nuclear Sector: Establishing a co-ordinated community

Caroline Shenton-Taylor[1]
[1]University of Surrey, UK

Biography: *Dr Caroline Shenton-Taylor is a Senior Lecturer in Applied Nuclear Physics at the University of Surrey. She has led multidisciplinary teams within both industry and academia, addressing research challenges across the civil and defence nuclear communities. Caroline's interests include the use of artificial intelligence and smart data analytics within nuclear security, nuclear decommissioning, nuclear*

forensics, nuclear medicine and health monitoring. Alongside her research and teaching, Caroline is passionate about scientific exchange and runs the YouTube channel Dr CST. She is the co-host of the Surrey Speaks Will AI… ? podcast, and has contributed to Radio 4, local radio, festivals and numerous outreach events.

This community talk seeks to raise awareness of a new ambition to create a framework, dedicated to support the application of Artificial Intelligence (AI) within the defence and civil nuclear industries. With rapid advancements in machine learning, sharing best practice will support and inform nuclear related AI development, policy and regulation. Included within this initiative is the generation and curation of central and accessible databases, allowing researchers to train, validate, share and assess machine learning (ML) approaches. The developed infrastructure will support AI use within Nuclear Decommissioning, Nuclear Forensics, Nuclear Health Monitoring, Nuclear Medicine, Nuclear Security, Nuclear Structure and Nuclear Theory. Through communicating educational and career opportunities, the community will play a role in supporting the next generation of AI nuclear specialists.

Use of Neural Networks to Deconflict Peaks in Gamma Spectra Analysis

Jay Wroe-Brown[1,2], Caroline Shenton-Taylor[2], and Luke Lee-Brewin[2]
[1]AWE, Aldermaston, UK, [2]University of Surrey, UK

Biography: *Jay is a physicist working in the RADI team at AWE for the past 5 years. Since graduating from the University of Southampton his research to date has revolved around the NTR mission and has spanned Radiological analysis, Blast damage assessment and Radiometrics. His current focus is on gamma spectroscopy and spectrometry.*

Jay's main area of interest is developing bespoke software for analysis and data management in the field of radiochemistry and spectroscopy. He recently began a PhD at the University of Surrey investigating the possibilities and practicalities of applying machine learning techniques to conflict resolution in gamma spectra analysis.

Within the field of nuclear forensics, assessing the radionuclide content of radioactive materials via gamma spectroscopy typically follows a process requiring human intervention. This regularly necessitates deconflicting a gamma spectrum peak where multiple isotopic fingerprints offer a possible nuclide identification. The field of machine learning provides an avenue to automate this step. Previous research has demonstrated that a neural network can identify a predetermined set of radioisotopes in gamma spectra [1, 2]. In these cases, the whole spectrum was entered as binned energies into a convolutional neural network and the present nuclides were reported. Practical applications for automated nuclide identification requires an approach capable of identifying the isotopic cause of peaks from an evolving and expanding library.
This work presents a feed forward neural network, trained to resolve individual conflicts in a gamma spectrum without prior knowledge of the nuclides involved. By utilising parameters that

analysts employ when manually deconflicting, the developed neural network reported an accuracy above 80% including conflicts with nuclides not within the training dataset. When retrained on reduced datasets, the neural network maintained accuracy when 60% of nuclides in the spectral library were previously unseen. This implies that a neural network trained in this way could be exposed to an expanded library consisting of twice as many spectral lines as the training library without compromising accuracy.

[1] L. Lee-Brewin, R. D. Read and C. Shenton-Taylor, "A concolutional neural network algorithm developed for shielded multi-isotope identification," Journal of Instruments, pp. 1-15, 2023.

[2] M. Kamuda, J. Zhao and K. Huff, "A Comparison of Machine Learning Methods for Automated Gamma-ray Spectroscopy," Nuclear Instruments and Methods in Physics Research A, pp. 1-6, 2020.

ML-Enhanced Laser Ablation Plasma Spectroscopy for Pre- and Post-Detonation Signatures for Nuclear Forensic Applications

Justin Borrero[1], Janos Braun[2], Paige Anderson[1], Daniel Emrick[3], Eliel Villa-Aleman[4], Ashwin Rao[5], and Kyle Hartig[1]

[1]Nuclear Engineering Program, University of Florida, USA, [2]Department of Chemical and Materials Engineering, New Mexico State University, USA, [3]COSMIAC at the University of New Mexico, USA, [4]Global Security Directorate, Savannah River National Laboratory, USA, [5]Space Vehicles Directorate, Air Force Research Laboratory, USA

Biography: *Justin is a PhD student in the Nuclear Engineering Department at the University of Florida, working under Dr. Kyle Hartig in the Optical Science and Nonproliferation Group (OSN). He completed his bachelor's and master's degrees in chemical engineering at the University of Puerto Rico. With his background in kinetic studies in gas-phase heterogeneous catalysis, he endeavors to study the nuclear fireball chemistry of actinide species, as well as their radial surface deposition patterns, aiming to support nonproliferation and nuclear forensic applications.*

For nuclear forensics applications, qualitative and quantitative analyses of both interdicted nuclear materials and post-detonation environments include identification of major and trace elements via enhanced characterization methods. In pre-detonation scenarios, the purification and extraction of Pu during the PUREX process routinely involves the production of Pu oxalates [Pu(OXA)], which exist in two oxidation states: Pu(III) and Pu(IV) oxalate. Despite significant advancements in the characterization of interdicted PuO_2 samples, little is known about the impact of the oxidation states on the optical signatures of Pu(OXA). For post-detonation nuclear forensic-wide environmental sampling of dispersed radioactive material, it is crucial to develop effective strategies for identifying and quantifying specific elements and their isotopes present

in the surrounding area. Recent efforts have focused on identifying fallout radionuclides within soil using an array of characterization techniques; however, complex optical signatures masked from overlapping soil signatures have been proven to hinder accurate spectral identification. Owing to the hazardous nature of sample preparation, Laser-Induced Breakdown Spectroscopy (LIBS) has emerged as an attractive method for standoff detection of radiological materials by assessing their optical emission signatures to identify their chemical composition. Here, we aimed to enhance the LIBS spectral discrimination and identification capabilities of Fe(II,III) oxalates as surrogates for preprocessed Pu(III) and Pu(IV) oxalate samples and PuO_2 fallout debris surrogates (CeO_2) in soil matrices by improving spectral feature selection using machine learning algorithms. Here, we report the use of clustering analysis and supervised regression techniques to discriminate the spectral signatures of Fe II,III (OXA), and processed (FeO_2) samples as well as to quantify the concentration of Fe(II,III) in mixed Fe(OXA) samples and Ce in soil matrices. By advancing our understanding of optical signatures and employing sophisticated multivariate and machine learning techniques, we strive to bolster non-proliferation efforts and strengthen the forensic capabilities essential for national and global security.

Keynote 6: Detecting Joe-1: How the world became aware of the Soviet Union's first Nuclear Test

Robert Lock
AWE, UK

Biography: *Dr Robert Lock – AWE Chief Scientist Rob joined AWE, in the Design Mathematics Department, in 1995 after studying Physics at Imperial College London. Having arrived shortly after the UK ended nuclear testing in 1992, the focus of Rob's research and career at AWE has been in the field of Comprehensive Testing Ban Treaty (CTBT) compliant science-based stockpile stewardship. In particular, the application of multi-physics computational fluid dynamics (CFD) algorithms and software to study extreme plasma conditions and high-pressure hydrodynamic phenomena. Whilst at AWE Rob studied, part-time, for a PhD in Applied Mathematics, again at Imperial College (2007).*

Since 2011 Rob has held various senior positions within the Physics area at AWE and in 2020 he was appointed to the role of Head of Physics at AWE; being responsible for some of the key capabilities AWE needs to achieve its core missions, realised through the diverse range of physicists, mathematicians, computer scientists and other technical specialists that the UK relies on to provide those capabilities. Rob has been a formally recognised Technical Authority in the Physics area for over a decade and since 2021 has been AWE's Principal Technical Authority for Physics. In his role as Capability Sponsor for Physics he has been a key voice and leader in evolving and governing the programmes of research in key parts of the AWE's technical programme.

Rob has strong relationships with our partners in the United States, particularly with workers at the Los Alamos and Lawrence Livermore National Laboratories. He has been a JOWOG co-chair for over a decade and became JOWOG32 co-chair in 2020. Rob is also currently the Predictive Capability Strategic

Collaboration (PCSC) physics lead for AWE, which provides strategic technical steering of the US/UK collaboration with AWE.

Since June 2023 Rob has been AWE's Chief Scientist

At 7 am on the 29th August 1949 the Soviet Union detonated a nuclear explosive device for the first time. This was both surprising and shocking, for the U.S.A. in particular. It was an event that had far-reaching consequences for the development of the cold-war. The US response was rapid and profound. Much like the Manhattan project's Trinity test of July 1945, JOE-1 (RDS-1) was conducted in secret and was not announced by the Soviet Union. So, how did the western powers at the time know that this momentous event had taken place? In this talk we aim to tell some of this story and the part that the UK played in providing an independent verification.

Getting the balance correct – Considerations of Nuclear Non-Proliferation around Lithium Enrichment for the Fusion Fuel Cycle.

Thomas Scott[1], Norbert Wegrzynowski[1], Richard Pearson[1], and Bill Nutall[1]
[1]University of Bristol, UK

Biography: *Professor Tom Scott, is a Professor of Nuclear Materials and Devices at the University of Bristol, sponsored by the Royal Academy of Engineering, the UKAEA and the AWE. He leads the UK academic network for Nuclear Threat Reduction (NTR-Net) which includes both fission and fusion technologies as part of its remit. He has over 160 peer reviewed research papers and an active interest in all things related to nuclear detection and materials forensics.*

Nuclear non-proliferation aspects of lithium isotopic enrichment are considered in relation to the expected global deployment of nuclear fusion energy and the associated production up-scaling of fuel cycle materials. Lithium – the 6Li isotope in particular – is essentially one of two elemental fuels required by fusion reactors for tritium breeding. The tritium breeding process is intrinsically inefficient, making breeder blanket design a fundamental challenge to almost all fusion power plant concepts. To overcome this tritium inefficiency many breeder concepts, invoke 6Li enrichment levels that are very high, which strays towards potential problems with regards to nuclear non-proliferation.

We argue for establishing distinct upper enrichment levels to enable supply chain monitoring for misuse and examine which analytical methods may best be employed for isotopic nuclear forensic analysis of Li-based materials. Establishing an agreed upper limit for 6Li enrichment may impact tritium breeding capabilities, which calls for an urgent re-assessment of the tritium breeding paradigm. Whatever solution is sought, lithium supply and isotopic enrichment is a mission-critical issue for fusion energy that needs urgently addressing.

Session: Materials & Processing

Plutonium Processing Signature Development at Pacific Northwest National Laboratory

Richard Clark[1], Amanda Casella[1], Matt Edwards[1], Alex Hagen[1], Forrest Heller[1], Gregg Lumetta[1], David Meier[1], Cody Nizinski[1], Luke Sweet[1], and Joel Tingey[1]
[1]Pacific Northwest National Laboratory, USA

Biography: *Richard Clark holds a B.S. in Chemistry from Brigham Young University – Idaho, and a Ph.D. in Chemistry from the University of Missouri – Columbia. As a graduate fellow, post-doctoral fellow, and staff scientist, Dr. Clark has spent the majority of his career performing research and development of processes pertaining to pre-detonation nuclear forensics. This has included experience working as a radiochemist related to gaseous fluorinations and separations, thermoluminescence, nuclear material science, nuclear fuel cycle, microscopy, and spectroscopy. Richard is the lead of several projects spanning a flexible Pu processing capability system at PNNL which includes Pu precipitation, calcination, fluorination, and metal production. Richard is additionally involved in efforts to increase the Pu processing capabilities including pyrochemical processing. At PNNL, Dr. Clark has also been involved with Molten Salt Reactor research at PNNL.*

Pacific Northwest National Laboratory (PNNL) has established flexible plutonium processing capabilities which has been used to perform nuclear forensics research and development from dissolution to metal production. The processing capabilities emulate historical efforts used by the USA. This capability is a flexible system that can follow and monitor a variety of flowsheets and steps along the process. A signature rich step in Pu processing is the nitrate to oxide conversion which has followed several precipitation methods such as the Pu(III) oxalate, Pu(IV) oxalate, and peroxide precipitations. Within each of these flowsheets, parameters can be changed which include the precipitation temperature, reagent concentrations, reagent addition direction, agitation speed, digestion time, and calcination temperatures. Altering the flowsheet parameters produces variations in the final product. At PNNL, a comprehensive suite of analytical capabilities is used to characterize these variations in the product. Inverse models are being created using tools such as machine learning algorithms to further understand the correlation between the physical properties (including morphologies) and the various processes for nuclear forensics applications. In addition, physics-based models are being developed to fundamentally understand the effect of processing parameters on PuO_2 morphology. Material properties, images, and observations from various PuO_2 processing experiments will be presented.

Investigating surface morphology of uranium ore concentrates: does sample preparation impact the results?

Assel Aitkaliyeva[1], Joseph Boro[2], Alize Griffin[3], and Naomi Marks[2]
[1]University of Florida, USA, [2]Lawrence Livermore National Laboratory, USA, [3]University of California - Los Angeles, USA

Biography: Assel Aitkaliyeva is an Associate Professor of Nuclear Engineering and Materials Science and Engineering at the University of Florida (UF). Her research concentrates on mechanistic understanding of material degradation mechanisms and spans nuclear fuels, advanced high-performance materials, and nuclear forensics. Prior to joining UF in Spring 2017, she was a staff scientist at Idaho National Laboratory. Dr. Aitkaliyeva received her PhD in Materials Science & Engineering and MS in Nuclear Engineering at the Texas A&M University.

Over the last several decades, the microstructure and morphology of nuclear materials have been intensely studied as possible indicators of processing parameters and material provenance. Specifically, a large body of work has been done to evaluate the surface morphology of lab-scale and commercially produced uranium ore concentrates (UOC) products, including the development of a lexicon for describing scanning electron microscopy (SEM) data that would enable comparison of the results obtained in different laboratories. Sample preparation is one of the most important steps in characterizing powders using SEM; it is of utmost importance to create a uniform distribution of particles on the sample substrate, both to improve imaging as well as to inhibit the contamination of instruments with loose particles when the sample is exposed to a vacuum. Depending on the laboratory, samples for SEM can be prepared by placing a small amount of material on carbon tape (tapping), dusting with a brush, or dipping SEM stub in powder, which raises the following question: “does sample preparation alter surface morphology?”. Seeing that morphological characteristics of materials can reflect their storage and processing histories; it is critical to access whether and how material handling affects material morphology.

To answer this question, in this study, we systematically examine morphological characteristics of several UOCs with known processing histories, produced on a commercial scale, over the span of decades. We use all three techniques to prepare UOCs for SEM analysis and directly compare their morphological characteristics to conclusively determine the impact of sample preparation on uranium oxide samples. Additionally, we quantify the morphological differences between samples with different provenance such as size and shape distributions and link surface morphology to processing history.

Evaluating Nuclear Forensic Signatures for Molten Salt and Other Advanced Reactors

Megan Schiferl[1,2,3], Dr. Jeffrey McLachlan[1,2], Dr. Appie Peterson[2], Dr. Naomi Marks[3], Dr. Rebecca Abergel[1,2]

[1]Department of Nuclear Engineering, University of California, Berkeley, USA, [2]Chemical Sciences Division, Lawrence Berkeley National Laboratory (LBNL), USA, [3]Nuclear and Radiochemical Sciences Division, Lawrence Livermore National Laboratory (LLNL), USA

Biography: *Megan is a third year Ph.D. student studying nuclear engineering at the University of California, Berkeley. Her research interests are in actinide chemistry, advanced reactors, and pre-detonation nuclear forensics. She recently completed her master's degree in nuclear engineering with a focus on the nuclear forensic signatures of advanced reactor fuels. The focus of her dissertation work is the application of fundamental protactinium chemistry to advanced reactor safeguards and nuclear forensics challenges.*

The development and deployment of next generation nuclear reactors presents an opportunity to evaluate the nuclear forensic signatures used to characterize nuclear materials that may be found out of regulatory control. Advanced fuels proposed for use in these novel reactors present both challenges and new prospects for the nuclear forensic field, especially since many efforts in pre-detonation nuclear forensics have previously focused on the analysis of uranium-based materials from light water reactor (LWR) fuel cycles, e.g. uranium oxide fuel pellets and uranium ore concentrates. The deployment of advanced reactors, and the corresponding use of advanced fuels such as TRISO particles, metal fuels, and molten fuel salts, requires the current suite of nuclear forensic signatures to be reimagined, adapting to new intricacies anticipated in these fuel cycles. Signatures will need to account for changes in several material properties of advanced fuel forms, including physical dimension and chemical composition. This talk evaluates signatures of uranium fuel cycle materials, such as physical dimension, morphology, sample age, and composition, for their applicability in the analysis of advanced fuel materials. Specifically, this talk will focus on proposed signatures of molten salts, since they show greatest change in physical form from the well-known uranium oxide fuel pellet and has not been the subject of many nuclear forensic studies. Where current signatures are found to be lacking in the analysis of molten salts, recommendations are made for further research. (LLNL-ABS-867543)

Session: Sensors & Detection Technologies

A Neutron-Sensitive Detector Based on a 3D Printed Plastic Scintillator

Adam Barr[1], Cinzia Da Via[1,2], Mosst Tasnim Binte Shawkat[1], Michael Taylor[1], Stephen Watts[1], and John Allison[1,3]
[1]University of Manchester, UK, [2]Stony Brook University, USA of America, [3]Geant4 Associates International Ltd, UK

Biography: *Dr Adam Barr is a PDRA at the University of Manchester, working on detector development using 3D-printed materials. He carried out a PhD in radio astronomy, studying the interstellar medium, also at the University of Manchester, but has switched fields following a break from research.*

In this presentation, we will describe the work done to develop a neutron-sensitive detector based on a scintillating material produced using additive manufacturing. A neutron-sensitive scintillator was produced using the Fused-Deposition Modelling (FDM) method. In FDM 3D-printing, a flexible plastic filament is extruded in thin layers to produce a solid object, providing a low-cost method for producing objects in arbitrary shapes. A neutron-sensitive filament was produced, using polystyrene as a base scintillator. This was doped with PTP and POPOP to give visible scintillation, biphenyl to give appropriate mechanical properties for FDM printing and 6LiF for neutron sensitivity. The quantities of these additives were tested, with the greatest light emission found at 2% PTP, 0.05% POPOP and 0.1% 6Li by weight. Geant4 simulations were used to optimize the design of the 3D-printed scintillators, testing the response of the material to neutron emission in a variety of configurations. The 3D-printed scintillators were imaged with a TimePix3-based camera, offering high spatial and temporal resolution. The combination of 3d-printed scintillator and TimePix3 camera allows for the construction of a low-cost, easily customisable detector. We will discuss the results of these tests, including the response of the scintillating material to electrons, X-rays and thermal neutrons, as well as comparisons with Geant4 simulations.

Scintillation Performance of 2D Perovskite Single Crystals

Amy Dickinson[1], S Alanazi[1], J Ghosh[1], C Crean[1], P.J Sellin[1], L Basirico[2], A Ciavatti[2], L Margotti[2], B Fraboni[2], S Choudhary[3], and S Satapathi[3]
[1]University of Surrey, UK, [2]University of Bologna, Italy, [3]Indian Institute of Technology Roorkee, India

Biography: *The recent development of 2D perovskite scintillators marks a significant advancement in radiation detection, due to their high light emission efficiency, fast response times, and tuneable properties. Among these, hybrid organic-inorganic materials such as Ruddlesden-Popper (RP) and Dion-Jacobson (DJ) are particularly promising. The short decay times and high light yields of 2D perovskites are*

especially advantageous for medical and defence applications, as they allow for rapid and precise radiation detection, ensuring timely and accurate diagnostic and surveillance capabilities.

The recent development of 2D perovskite scintillators marks a significant advancement in radiation detection, due to their high light emission efficiency, fast response times, and tuneable properties. Among these, hybrid organic-inorganic materials such as Ruddlesden-Popper (RP) and Dion-Jacobson (DJ) are particularly promising [1,2]. Their layered structures provide durability and flexibility, while cost-effective production methods and the potential for lead-free compositions enhance both their commercial viability and environmental friendliness. Affordable solution-based synthesis and slow-cooling crystallisation methods have proven effective in producing high-quality 2D perovskite scintillators. In RP and DJ perovskites, a single layer of inorganic material is sandwiched between two monovalent layers or one divalent layer of organic spacer cations, respectively. This unique layered structure promotes efficient charge transport and radiative recombination, resulting in high light yields. Additionally, the high atomic number of the metal cations enables effective X-ray absorption. The short decay times of 2D perovskites are especially advantageous for medical and defence applications, as they allow for rapid and precise radiation detection, ensuring timely and accurate diagnostic and surveillance capabilities.

In this study we report the scintillation performance of 2D single crystal samples of the RP perovskites BA2PbI4, BA2PbBr4 and PEA2PbBr4 along with the DJ perovskite TMPDAPbBr4. Crystal synthesis was carried out by slow cooling (BA2PbI4) and controlled evaporation (BA2PbBr4, PEA2PbBr4 and TMPDAPbBr4) methods [3]. The scintillation light yield compared to a standard sample of BGO was measured using a 50 kVp X-ray beam. Of the perovskite materials studied, PEA2PbBr4 showed 2.5x the effective brightness of BGO.

Other RP and DJ perovskite materials potentially offer similar or improved performance [4]. We will show a systematic comparison of the scintillation performance of a range of 2D perovskite crystals, and discuss their light yield, decay time and their potential for use as X-ray, gamma and alpha spectroscopy detectors.

Boron-loaded opaque scintillator as a low-cost pseudo-segmented neutron detector

Rob Foster[1], and Patrick Stowell[1]
[1]University of Sheffield, UK

Biography: *I am a postdoctoral research associate at the University of Sheffield currently investigating novel scintillating neutron sensors for nuclear security applications.*

The detection of concealed neutron sources is imperative for nuclear security as neutrons can signify the presence of fissile material. Neutron sensors with positional and directional

sensitivity can greatly improve detection capabilities through source localisation. However, the cost and fragility of existing detection systems has limited their widespread use. We are proposing a new, low-cost type of scintillating neutron sensor based on the idea of an opaque scintillator that offers positional and directional sensitivity. Opaque scintillators have recently gained interest in the neutrino physics community where they are being proposed to greatly improve position resolution when imaging neutrino interactions in large-scale detectors. By using an "opaque" medium with a short scattering length but long attenuation length, scintillation light can be confined to within a small region around its emission location, effectively segmenting the detector. The light can then be extracted from the medium using an array of optical fibres coupled to photosensors located outside of the medium. We intend to augment this technique using a boron-loaded opaque scintillator comprising a low-cost mixture of BN:ZnS(Ag) suspended in a base liquid, providing implicit sensitivity to thermal neutrons through neutron capture interactions. In this talk, we will discuss the detector concept as well as the progress made towards realising a first prototype of this novel neutron sensor and plans for the future.

Session: Exercise & Assessment

Conventional Forensic Data Recovery from High Activity Items

Craig Holliday[1], and Stephanie Evans[1]
[1]National Nuclear Laboratory, UK

Biography: *I joined NNL in 2020, following previous experience as an Analytical Specialist in the polymer industry, focusing on microscopic (SEM, AFM) and spectroscopic (FTIR) characterisation of materials.*

My initial work in the nuclear industry was with the In-Situ Analysis (IIA) team, developing an understanding of analytical and instrumentation requirements across a range of challenging environments.

Building on this and my analytical background, my current work now focuses on microscopy for Post Irradiation Examination (PIE) of reactor materials.

NNL alongside the Atomic Weapons Establishment is currently supporting the Home Office and Couter Terrorism Police (CTP) and to develop the UKs response to radioactive materials found outside of regulatory control. By including the UK's civil nuclear assets in responding to a radio nuclear incident, the capability of managing a larger and wider range of radiologically hazardous exhibits is increased.

The Windscale Active Handling Facility on the Sellafield site in Cumbria offers a unique capability that can receive, process and dispose of a wide range of high activity items. The

facility comprises of 13 large, heavily shielded hot cells designed to examine fuel and other heavily irradiated materials. NNL are working with the CTP to establish whether conventional forensic information can be obtained from highly active exhibits.
Each cell is viewed through 1.5 metres of lead glass. Material within the hot cell is handled using Master Slave Manipulators (MSMs) that replicate operator movements inside the cell. However, the dexterity of these manipulators combined with limited visibility means that conventional forensic capability, for example dusting and photographing fingerprints, could be limited.

NNL, with CTP in attendance, carried out a non-active trial using a replica hot cell including MSMs and a leaded glass window. A deactivated smartphone and small tablet device were successfully dusted for fingerprints using aluminium powder. Measurement labels were applied to each, and high-resolution images of resulting fingerprints were successfully captured through a lead glass window using standard DSLR camera equipment. All work was carried out remotely, mimicking how an active exhibit would be analysed in a hot cell. The project will look to develop and practice these techniques in an active hot cell environment.

Lessons learned running full-scale NF exercises at CNL

Thomas Domingo[1], Marina Totland[1], and Ike Dimayuga[1]
[1]Canadian Nuclear Laboratories, Canada

Biography: Thomas Domingo is an R&D Scientist in the Nuclear Forensics Section at Canadian Nuclear Laboratories. His previous experience with gamma-ray spectroscopy include trace element analysis for environmental monitoring, neutron activation analysis using a D-T neutron generator, supporting beamline experiments for nuclear structure studies at TRIUMF, as well as both analogue and digital DAQ development to upgrade existing HPGe counting systems for time-resolved gamma-ray spectroscopy and ultra-high counting rate experiments respectively.

Nuclear Forensics (NF) provides the analysis of radioactive and nuclear (RN) materials, or evidence contaminated with RN materials, in support of the broader investigation of a nuclear security event. A crucial step in NF investigations is the integration of the NF laboratory processes with law enforcement. This includes transfer of exhibit(s) to the NF laboratory, analysis of exhibit(s), reporting of results (including potential implications) to law enforcement, and either storage of exhibit(s) or transfer back to law enforcement. All these processes must be performed while maintaining chain of custody of the exhibit(s) to ensure results will be defensible in court.

Canadian Nuclear Laboratories (CNL) is well positioned to provide nuclear forensics support to law enforcement, utilizing its long history in nuclear research and development and has been working closely with Canadian government departments to implement the required quality assurance and chain of custody specific to law enforcement requirements. Exercises are a well-

established method to evaluate processes and to aid this effort. CNL recently hosted and participated in a multi-day regional exercise for the Royal Canadian Mounted Police's Chemical, Biological, Radiological, Nuclear, and Explosive (CBRNe) National Team. During this full-scale exercise, the CBRNe National Team ran through varying scenarios with members of their response and forensics teams while including participation from the Canadian Nuclear Safety Commission, the Department of National Defense, and CNL for scientific reach back, and concluded with transfer of samples into CNL's secure site. This multi-agency exercise, utilizing RN material helped all participants understand the expectations and requirements involved during a NF investigation and motivated the refinement of multiple procedures.

This presentation will provide an overview of the exercise and many of the lessons learned while hosting and participating in a nuclear forensics exercise with law enforcement.

Posters

P1: Organic Semiconductor Detectors for Alpha and Neutron Detection

Aled Horner[1], Fani Eirini Taifakou[1], Choudhry Zahaab Amjad[1], Filip Aniés[3,4], Chris Allwork[2], Adrian Bevan[1], and Martin Heeney[3,4]
[1]Queen Mary University of London, UK, [2]AWE, UK, [3]Imperial College London, UK, [4]KAUST, Saudi Arabia

Biography: Aled Horner is a fourth-year combined particle physics/condensed matter physics PhD student at Queen Mary University of London. He received an integrated master's degree in physics with particle physics from Royal Holloway University of London. His current research is in organic radiation detectors for national security purposes with a focus on scalability and increasing efficiency of existing in-house detectors.

In recent decades organic electronics have entered mainstream use in consumer electronics found in households around the world. This technology is an area of active scientific interest due to its tuneable, scalable, and cost-effective nature. I will present radiation sensors based on organic semiconductor technology, and in particular applications related to detection of hadronic radiation consisting of α radiation as well as thermal and fast neutrons. Neutron detection is useful in a range of fields from fundamental particle and atomic physics research to the medical field and portal monitors for nuclear security.

These organic sensors focus on NDI-type organic polymers including a novel material with carborane, a polyhedral cluster of carbon, boron, and hydrogen, directly incorporated in the molecular backbone (oCbT2-NDI), sensitising to thermal neutrons via the boron neutron capture process. A comparison will be made with a similar NDI-type polymer (PNDI(2OD)2T)

with homogenously dispersed boron carbide (B4C) nanoparticles, as well as a control sensor without any boron which in of itself is sensitive to more energetic fast neutrons.

Beyond this topic I will present work I am doing on the expansion of this technology in two modes: scaling up the size of the sensors and creating an array system synchronising multiple detectors to work together. These modes are specifically being probed for the application of making portal radiation detectors at strategic locations such as ports, airports and areas of high pedestrian traffic such as the London Underground system to identify illicit materials such as weapons grade plutonium and uranium.

P2: Remote imaging of Alpha Emitters in Various Environments Including Sunlight

Lingteng Kong[1], David Megson-Smith[1], Tom Scott[1], and John Day[1]
[1]University of Bristol, UK

Biography: *Lingteng Kong is a final-year PhD student at the University of Bristol, holding a BSc in Physics and an MSc in Nuclear Science and Engineering. Specializing in optical design, environmental sensing, and 3D modeling, he has dedicated four years to developing a long-range imaging system for detecting alpha emitters. His innovative work has resulted in a technology with unparalleled sensitivity. Currently, Lingteng is focused on commercializing this groundbreaking technology, aiming to enhance safety and efficiency in nuclear environments.*

Alpha particles, with a travel limit of just a few centimeters in air, pose severe health risks if ingested or inhaled, potentially leading to cancer or death. Effective detection of these alpha emitters is essential for both industrial and public safety. Current alpha particle detection methods, such as hand-held ionization chambers, require close proximity to contaminated sites, making these techniques labor-intensive, risky, and costly due to increased contamination risks and the need for frequent decontamination of equipment.

Our development of an alpha-imaging camera represents a significant technological advancement in this area. This prototype camera can detect alpha emitters from meters away by capturing UV light produced when alpha particles interact with nitrogen molecules in the air, a phenomenon known as radioluminescence. The system features a CCD camera and specialized lens system, complemented by a novel filter system to minimize ambient interference and a background subtraction algorithm that enhances sensitivity. The camera's design and processing algorithm are patented.

This user-friendly device is lightweight, portable, and can be set up in under 10 minutes by a single operator. It integrates UV fluorescence with RGB imaging for precise source identification and operates effectively under various environmental conditions. The camera offers

unparalleled sensitivity, detecting down to kBq levels from 1 meter away in 10 minutes in low UV environments, and MBq levels under sunlight.

Our alpha-imaging technology significantly advances nuclear safety and environmental monitoring. It reduces health risks for workers, mitigates nuclear threats, and alleviates public concerns about nuclear power pollution. Economically, it decreases operational costs and improves time efficiency at nuclear facilities. Socially, it contributes to the sustainable development of nuclear energy, promoting societal acceptance and trust in this low-carbon energy source.

P3: Developing the Application of High-Resolution Gamma-Gamma Coincidence Spectroscopy for Complex Nuclear Forensic Samples

Tom Stokes[1,2]
[1]AWE, Reading, UK, [2]The University of Liverpool, UK

Biography: *After graduating with a master's degree in chemistry from The University of York in 2018, I joined AWE's Materials & Analytical Science graduate programme where I gradually found my way to gamma spectroscopy and the Nuclear Forensics programme in September 2019. Since then, I have been primarily reasonable for operating and developing the capability of one the laboratories that contribute to nuclear forensics analysis at AWE Aldermaston. As well as regularly participating in intercomparison exercises with UK and international laboratories, our laboratory has also recently published work aiming to improve the nuclear data for 91Y, a radionuclide of particular interest to Nuclear Forensics and the Comprehensive Test Ban Treaty Organisation (CTBTO) (https://doi.org/10.1016/j.apradiso.2023.111172). My work has also seen me contribute to optimising the collection of nuclear forensics samples and develop tools for effective exhibit management whilst samples are analysed at AWE.*

In April 2024, I embarked on a PhD in Nuclear Physics with The University of Liverpool, seeking to develop and optimise the use of gamma-gamma coincidence spectroscopy for Nuclear Forensics. Gamma-gamma coincidence as a technique has been used for decades, predominantly in nuclear structure research and measurements of low-level cosmological samples; however, there are far fewer examples in the open literature of coincidence spectroscopy being used for the radiometric assay of high activity, complex composition samples. Through improved understanding the performance of high-purity germanium detectors, advanced modelling of detector systems, and sophisticated data processing, it is envisaged that the PhD will culminate in the operational use of gamma-gamma coincidence spectroscopy at AWE, reducing detection limits and spectral interferences and improving analytical timelines for a number of key nuclear forensic signatures.

Germanium-based detectors were first developed in the 1960s and have since become the standard for performing gamma spectroscopy measurements due to their excellent energy resolution. Outside of progress in the manufacture of larger and varied-shape crystals and the introduction of digital electronics, progress in the field of gamma spectroscopy has been largely driven by work into crystal segmentation and the construction of multi-detector arrays. The

introduction of more than one detector allows for the detection of multiple gamma photons emitted from a sample pseudo-simultaneously ("in coincidence"). Through reconstructing which detector absorbed what photon energy and when, it is possible to filter gamma spectroscopy data by time (removing non-coincident signatures) and by photon energy. In other words, a traditional (single detector) gamma spectrum comprises every registered detection within the measurement window; in coincidence spectroscopy, a spectrum can be produced showing only detections measured in coincidence with a photon of a specified energy.

The highly specific nature of this analysis has been shown to reduce by 3-5 orders of magnitude. This not only allows for the identification of previously unobservable signatures, but also benefits the analysis of signatures seen via traditional means by removing spectral interferences. Current work looking at developing the application of high-resolution gamma-gamma coincidence is the subject of a PhD funded by AWE and in partnership with The University of Liverpool to develop these systems for the radiometric assay of complex, high activity nuclear forensic samples.

P4: Nuclear Forensics Transformational Innovation (NFTI) Initiative

Lori Metz[1]
[1]PNNL, USA

Biography: Dr. Lori A. Metz has been working on operational and research programs in the area of nuclear nonproliferation at PNNL for over 20 years, first as a postdoctoral research associate and currently as a staff chemist and nuclear forensics program manager. With expertise in radioanalytical and nuclear chemistry her research interest at PNNL have primarily focused on developing rapid methods to measure various short-lived radionuclides in different environmental matrices. She also actively works to communicate internationally the effects of medical isotope production and other man-made isotope production on nuclear explosion monitoring and determines technical solutions to solve these measurement challenges.

Nuclear material analysis for nuclear forensics is an extremely challenging science as it can involve quantitating 70+ isotopes spanning almost the entire periodic table rapidly from multiple precious samples with high confidence in results (and the samples can be highly radioactive too!). Due to these challenges, current nuclear forensics laboratory methods are very robust and involve analyzing the entire bulk samples as received. A new 5-year PNNL laboratory directed research and development initiative is investigating a new process that rapidly selects microsamples within a bulk sample to reduce unwanted background material potentially greatly speeding up processing. Research is also focused on developing a chemistry model that can learn from early time data to autonomously optimize processing steps and utilizing AI/ML assisted data analysis to reduce the need for expert involvement and signal when data are ready to be reviewed and reported. An overview of the work addressing

challenges in both pre- and post-detonation planned for the new PNNL initiative, Nuclear Forensics Transformation Innovation (NFTI) Initiative, will be presented.

P5: Changepoint theory methods for finding radiation anomalies in large data signals

Kes Ward[1]
[1]Lancaster University, UK

Biography: *Kes is a mathematics researcher at Lancaster University. His research involves developing statistical anomaly detection methods for time series data under conditions of computational constraint, intended for use in a wide variety of applications such as telecommunications and astrostatistics. Recently he has become involved with the Nuclear Threat Reduction Network, NTR-Net, to apply newly developed methods to the problem of detecting unusual events in radiation count data.*

Anomalies in radiation count data do not represent individual time points. Instead, they represent intervals of time, usually when there is more radiation than expected in various different spectral bands indicating the presence of our isotopes of interest. This means that any anomaly detection method aiming to locate them suffers from the interval search problem: adding one new point to a signal creates a lot of new intervals that must be checked before the next point arrives. This is a large computational bottleneck that slows down any algorithm intended to be run on large volumes of data.

Here, we present methods derived from changepoint theory that get around the interval search problem by using recursive computations and statistical pruning: while the outcome they report is identical to having tested all the intervals, they avoid actually doing so, and run much faster as a result. We work on adapting such methods to detect the radiation signatures of specific isotope combinations while ignoring others, giving a method able to intelligently scan a radiation signal very quickly using a small amount of power and memory.

These methods have applications in any area of radiation monitoring where only a small amount of computation is available, such as individual sensors monitoring a live signal with a fixed battery life. They are also useful more generally as first-pass methods run using low significance thresholds where positive results are passed for checking by more expensive computational algorithms and can hugely speed up the checking of very large radiation count datasets while giving no loss of accuracy.

P6: Developments in the use of Glove Bags for Conventional and Nuclear Forensic Analysis in Gloveboxes

Sarah Crooks[1], and Stuart Dunn
[1]AWE, UK

Biography: *AWE possesses bulk actinide handling facilities to aid law enforcement in nuclear forensic investigations. The actinides analysis facility is responsible for the chemical analysis of bulk actinide samples in support of all key programmes at AWE and its therefore important to ensure the integrity of all samples is maintained. Current processes for this involve the segregation of work areas, samples, and exhibits, in addition to thorough cleaning and decontamination before and after analysis. To improve the workflow in a forensics investigation the introduction of glove bag technologies for exhibit handling within gloveboxes and fume cupboards has been developed. The addition of this would expand the capability and allow additional work areas and improve exhibit processing efficiencies, while maintaining the integrity of forensic samples and exhibits.*

This work focuses on the introduction of glove bag technologies to the actinides analysis facility and the recent developments to enhance the capability. Glove bags were initially introduced for basic sample and exhibit unpacking; however, this has since been expanded to include further processing and maintaining sample integrity, through tasks such as size reduction, sample preparation for Non-Destructive Analysis, and dissolution for Destructive Analysis. More recently, development work has been carried out to integrate conventional and nuclear forensics on the most challenging samples. Conducting basic conventional forensic analysis techniques within the glove bags, mostly focused on exhibit and fingerprint photography. Future work will continue in this area to look at additional fingerprint recovery options and enhanced photography.

P7: Precise measurement of trace actinides using Phoenix TIMS

Stephen Guilfoyle
Isotopx Ltd, UK

Biography: *Stephen's education is in material physics, and he has spent the majority of his life working in analytical instrumentation, with particular focus on inorganic mass spectrometry. He has had a range of roles, from engineering to sales and marketing. His particular love is high precision isotope ratio mass spectrometry, and he is always looking to further his knowledge and understanding of these techniques and their applications.*

High precision determination of trace actinides is important in a range of applications, including nuclear forensics, nuclear non-proliferation and Earth science applications. In nuclear forensics applications, the abundance of these actinides is likely to be at the ultra-trace level, creating analytical challenges.

When measuring sub picogram samples of actinides by thermal ionisation mass spectrometry (TIMS), ion counting detectors are necessary due to their low noise compared to that of a Faraday detector. Ion counters however, still have a non-zero noise associated with them, known as the dark noise, which is typically several counts per minute. Additionally, there are sources of measurement error present that are not of concern with Faraday detectors, such as deadtime/linearity, peak flatness, and gain stability.

In this presentation, the performance characteristics of the Isotopx Phoenix TIMS equipped with 10 ion counting channels is evaluated. Furthermore, the performance of the Isotopx ATONA Faraday system for these small samples is also considered. Ultimately, we describe the ideal ion signal value at which it would be benefit the measurement precision to change from using ATONA Faraday detectors to the Phoenix multiple ion counting system.

P8: Automated Sort and Segregation of Legacy Nuclear Waste Using Combined Sensor Systems Delivered By Robotic Manipulator Arm

Alex Carpenter[1], David Megson-Smith[1], and Thomas Scott[1]
[1]University of Bristol, UK

Biography: *I am a first-year physics PhD student at the University of Bristol with a background in software engineering and youth leading. My research is largely regarding sensor fusion of different detector technologies such as machine learning object detection, range finding, gamma spectrometry, x-ray fluorescence and raman spectroscopy. I work with collaborative robotic manipulator arms with these sensor devices attached for the purpose of automated nuclear waste processing.*

I have a particular interest in machine learning tools and addressing actual waste problems. I am also interested in finding uses for techniques hitherto underused in nuclear waste processing.

I am keen on demistifying nuclear science to help more people get on board with nuclear power. I think helping to reduce waste problems is a really important step along that road.

One of the UK's largest legacy nuclear waste problems is Magnox fuel element debris (FED) discarded in the mid-20th century into piles of waste consisting of broken up parts of fuel elements amongst corroded steel strips, swarf and thermocoupled wiring. The highest activity objects in these waste piles are steel nimonic springs containing activated cobalt-60 and nickel-63 from neutron absorption inside the reactor core. These intermediate level waste objects must be characterised in terms of activity level and material composition, and then extracted and appropriately disposed of. This process of sort and segregation has applications beyond just nuclear waste management as remote identification and manipulation is necessary for safe interaction with suspicious radioactive objects.

Machine learning object detection, particularly using neural networks and convolutional methods, identifies patterns in images. The Yolo (You Only Look Once) algorithm, designed by Ultralytics, efficiently detects objects it is trained to look for by drawing bounding boxes over images with coordinates that can then be used to provide spatial information relative to the camera.

An instance of the YoloV8 object detection model, pre-trained on google's OpenImagesV7 dataset, was trained on images of mock FED waste. This was combined with an intel realsense D415 camera attached to a commercially available seven-axis robotic manipulator arm to predict bounding boxes identifying objects of interest from the camera image and video stream. Depth values were determined using the centre point of the drawn bounding boxes alligned with the D415's stereo camera depth image. The Depth values and bounding box locations were used to determine the spatial locations of the objects in the robot's workspace and a cartesian move was performed by the robot arm to a defined vertical standoff distance from an identified object. The standoff position was then a platform for further automated characterisation.

P9: Nondestructive Applications of a Compact Neutron Source Based on the Inertial Electrostatic Confinement Fusion

Mahmoud Bakr[1], and Thomas Scott[1]
[1]University of Bristol, Bristol, UK, [2]Astral System, UK

Biography: Generations and applications of neutrons, protons and X-rays. Detection of special nuclear materials, landmines, radiography, and mining based on active interrogation techniques using a fusion neutron source. Currently, the chief scientist at Astral neutronics (Neutron sources fabrications and applications)

Neutrons are indispensable in various critical functions, from controlling nuclear fuel critically to detecting atomic materials and explosives—essential aspects of CBRNE (Chemical, Biological, Radiological, Nuclear, and Explosive) threats. Traditionally, radioisotope neutron sources have been the standard for these tasks. However, they have significant drawbacks, such as high costs, short lifespans, and stringent radiation control requirements. On the other hand, active neutron sources, like reactors and accelerators, are bulky and unsuitable for field operations. This has led to the development of compact, portable neutron generators, notably the Inertial Electrostatic Confinement Fusion (IECF) neutron source. With their superior controllability and longer lifespans, these generators offer a promising alternative to conventional sources.

IECF neutron generators, as practical tools that produce neutrons through nuclear reactions, are significantly enhancing safety and security. Their applications in nuclear security, such as the interrogation of special nuclear materials like U235, as discussed at NUFOR 2022, and in

homeland security, particularly in detecting landmines and explosives, a topic presented at NUFOR 2023, are testament to their crucial role in safeguarding against potential threats. The fusion team at the University of Bristol is developing novel nondestructive radiography and infrastructure inspection techniques for quality assurance of products, mining of water and minerals, and bridges and heritage buildings for corrosion. The neutron source and the proposal for the inspection technique will be introduced at the event alongside simultaneous neutron and X-ray radiography based on the IECF neutron source. In addition, a preliminary radiography test will be presented.

P10: Thinking small: Identifying heterogeneity in commercial uranium ore concentrates using microanalytical techniques

Christine F. Chan[1], Joseph R. Boro[1], Amy M. Gaffney[1], and Naomi E. Marks[1]
[1]Lawrence Livermore National Laboratory, USA

Biography: *Christine F. Chan is Postdoctoral Researcher at Lawrence Livermore National Laboratory (LLNL). She joined LLNL in 2023. Her research focuses on isotope geochemistry, actinide chemistry, and geochronology. At LLNL, her postdoctoral research focuses on particle-scale heterogeneity in uranium compounds, developing novel techniques for radiochronometry and broader nuclear forensics applications.*

Uranium ore concentrates (UOCs) are produced when uranium ore has been mined, milled, and chemically processed; they represent the first step in the nuclear fuel cycle. These materials contain approximately 60-80% uranium, are a fungible commodity, and are produced in large quantities (tons); thus, UOCs are susceptible to illicit use and trafficking. Documenting the physical, chemical, and isotopic characteristics of bulk UOC powders for the purposes of identifying diagnostic forensic signatures has been a major priority in the nuclear forensic community. Impurities within UOCs can be useful for identifying sample provenance. This study aims to understand the range and degrees of heterogeneity within commercial UOCs so that workers can fully exploit all forensic signatures.

To better quantify the degree of heterogeneity in UOCs, we applied microanalytical techniques, including scanning electron microscopy, electron microprobe, and micro-Raman spectrometry, to individual uranium particles from two commercially produced UOC powders. Preliminary particle analysis indicates that (1) compositional heterogeneity is discernable on the particle-scale, (2) distinct populations of uranium particles can be identified by particle size, texture, shape, brightness in backscattered electron (BSE) imaging, and chemical impurities (e.g., Ni, Fe, Cu, S), and (3) spatially-resolved analytical techniques can reveal the presence of multiple phases that are not apparent through bulk analytical approaches (i.e. XRD, MC-ICPMS).

Understanding the degree of heterogeneity in UOCs has important implications for bulk elemental and isotopic characterization of UOCs, as well as the application of model age

radiochronometry that assumes homogeneity. Additionally, if we can correlate impurities at the particle scale in UOCs with known process histories, we can better comprehend the processes that cause these impurities and make them useful for forensic purposes.

Prepared by LLNL under Contract DE-AC52-07NA27344.

P11: AWE: Nuclear Security Technologies Variable Geometry Gamma Spectrometry Method for Nuclear Forensics

Nathan Harrison
AWE, UK

Biography: *In 2023, I graduated from the University of Bristol with an MSci in Chemical Physics. During my studies, I concentrated primarily on physical chemistry and specialised in solid-state physics in my final year. Currently, I am employed at AWE – Nuclear Security Technologies as a Material & Analytical Scientist within the Radiometric Analysis & Data Interpretation (RADI) team, which serves as one of AWE's primary laboratories for nuclear forensics radiometric analysis.*

Over the past eight months with the team, I have gained experience in various analytical techniques, including alpha spectroscopy and Mirion's iMatic system for gross alpha/beta counting. My primary focus has been on gamma spectroscopy, specifically the UKAS variable geometry gamma spectroscopy method, for which I am the process owner for. This method is fundamental to AWE's nuclear forensics analysis regarding gamma spectroscopy and is very unique which is why I intend to present and share this method in my upcoming poster presentation.

Have you ever wondered how radioactive samples of peculiar geometry can be accurately characterised? Look no further! This poster delves into AWE's UKAS-accredited variable geometry gamma spectroscopy method for nuclear forensics. Let us explore why we use this technique, how we measure radioactive samples, and the quality aspects of this unique approach.

Nuclear Forensics

Nuclear Forensics is a multidisciplinary field providing methodologies and techniques for collection, analysis and provenance of radioactive/nuclear materials suspected to be outside of regulatory control. AWE is tasked with providing the technical capability and expertise required to support UK police investigations by classifying and characterising radioactive materials to an evidential standard suitable for the police. Clearly, AWE cannot dictate the shape and size of all potential police exhibits, necessitating the development of an analytical method capable of analysing any object, whether qualitatively or quantitatively - even your shoe….and so the variable geometry gamma spectrometry method was born.

Variable Geometry Gamma Spectrometry

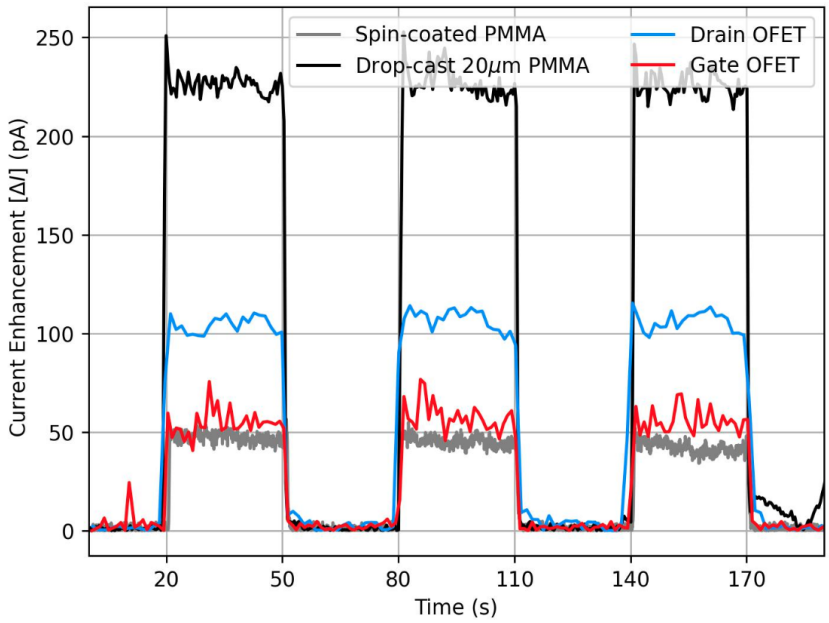
One of the cornerstone methods developed at AWE is our Nuclear Forensics variable geometry gamma spectrometry method, which has been granted ISO17025 accreditation by UKAS, the UK's national organisation which accredits laboratory methods against defined standards. What makes this method truly exceptional is its ability to provide accurate and reliable data while accommodating a wide range of potential live police scenarios.

In summary, AWE's gamma spectroscopy method empowers investigators, instils confidence in the data, and ensures compliance with rigorous standards. It is a fascinating journey into the world of nuclear forensics!

P12: PMMA dielectric driven α particle and neutron detection in DPP-DTT OFETs

Choudhry Amjad[1], Aled Horner[1], Albanik Gashi[1], Adrian Bevan[1], and Chris Allwork[2]
[1]Queen Mary University of London, UK, [2]AWE, UK

For the first time, we present α particle detection at 108 pA current enhancement using DPP-DTT as a semiconductor along with Poly(methyl methacrylate) (PMMA) as a dielectric in an organic field effect transistor (OFET). Output characteristics, transfer characteristics, and current-time measurements were obtained under 4 MeV α particle irradiation and in its absence, in addition to repeatable time-dependent (dynamic) α particle OFET responses. Due to the known α particle Bragg curve in organic materials and the thin DPP-DTT layers being deposited via floating film transfer, we assert that the radiation-induced current in the PMMA dielectric layer is the dominant driver of α particle response in these OFET devices. Supporting this assertion, an investigation into PMMA capacitor structures through current-voltage characteristics, current–time measurements, and time-dependent α particle responses was conducted. We report that the α response in the drain current of the OFET is twice as large as that of a capacitor made with the same active PMMA layer, and we describe two novel mechanisms that could drive this disproportionate current enhancement.



P13: Seismic coupling of surface waves in clay sediments from subsurface and subaerial explosions

Evie Read[1], David Green[2], Stuart Nippress[2], James Wookey[1], and Nick Teanby[1]
[1]University of Bristol, UK, [2]AWE, UK

Biography: *I'm a 1st year PhD student at the university of Bristol in the Earth Sciences Department. My research focus is forensic seismology, currency I'm looking at optimising deep learning to advance forensic seismology analysis capabilities.*

Chemical explosions close to the surface generate waves that travel through the atmosphere as blast waves and through the ground as seismic waves. The amount of energy converted into seismic energy is determined by the height-of-burst (or depth-of-burial) as well as the geological medium beneath (or surrounding) the explosion. Near surface explosions can be better characterised by understanding the wavefields produced and the corresponding variations in seismic coupling induced by different geological media. Forensic evaluations of unknown explosions depend on understanding this seismic coupling.

Particularly little is known about seismoacoustic coupling for near-surface explosions above and within saturated sediments, which are common environments in coastal and estuary settings. To fill in this knowledge gap, five 100kg charged TNT-equivalent explosions (between 1.39m above and 2.32m below) were carried out and recorded at four stations at 1.2–3.3km distance. Here, we analyse the surface wave portion of the resulting waveforms. We identify three

distinct components: the expected Rayleigh wave, an inversely-dispersed wave and an air-to-ground coupled wave.

To understand the propagation pattern observed, and gain an insight into the velocity structure, we apply a range of forward modelling approaches to model different characteristics of the surface wave packet. We use the wavenumber integration method to generate synthetic seismograms, which we compare with analytically-predicted group velocity curves. This is supplemented with horizontal vertical spectral ratio (HVSR) modelling. Together, these approaches converge on a 1D velocity model which reproduces the features observed in the real data. Additional work has explored the ability to predict explosive charge weight (and/or yield) from surface wave amplitudes, and that the surface waves may be less influenced by multi-pathing when compared to the initial P-wave amplitudes that are commonly used in current procedures.

P14: Informing Actinide Signature Prediction Through Computational Modelling.

Moli Smith[1], Simon Middleburgh[1], and Matthew Gilbert[2]
[1]Bangor University, UK, [2]AWE, UK

Use of computational models and simulations have become increasingly useful within the field of nuclear forensics due to the difficulties handling radioactive materials in experimental studies. Further, modelling methods can test and provide a mechanistic understanding of materials' phenomena that will allow some degree of extrapolation from empirical data and will in turn highlight new areas for experimental exploration. The focus of this work is to use density functional theory (DFT) coupled with other computational methods to investigate the changes in magnetic ordering and morphology of both bulk UO_2 and PuO_2 as well as their surfaces to assess the nuclear forensics signatures associated with the oxides and predict how these signatures will change with time due to ageing effects. This work will then be compared and validated with experimental work on UO_2.

P15: Using Machine Learning to Understand the Effects of Process History on Particle Morphology of Uranium Ore Concentrates

Alize Griffin[1,2], Joe Boro[2], Assel Aitkaliyeva[3,2], and Naomi Marks[2]
[1]University of California - Los Angeles, USA, [2]Lawrence Livermore National Laboratory, USA, [3]University of Florida, USA

Biography: *Alize Griffin is a second-year undergraduate in chemistry and physics at UCLA. Her research at LLNL has included efforts focused on Intentional Forensics and machine learning approaches for powder morphology image analysis.*

The morphology of uranium ore concentrate (UOC) particles can be strongly influenced by the production pathway and storage conditions to which the material has been subjected. With this in mind, we leverage morphology characteristics and a machine learning approach to identify provenance signatures for commercial U3O8 samples with different processing histories and provenance.

We have used machine learning (ML) and deep learning convolutional neural networks (CNNs) to identify processing history from powder morphology characteristics. Secondary electron (SE) images of UOC's were taken, randomly cropped to 111x111 pxl, and normalized to create a training set of 10,000 images per class and reserve testing set of 2,000 images per class. We explored a variety of CNN architectures and preprocessing to find a best suited workflow for these types of materials. We optimized model parameters including structure, learning rate, batch size, and number of nodes to improve the CNN's image recognition.
The model was trained on 14 distinct U_3O_8 powders with known processing history. With optimized preprocessing techniques, we have achieved >70% positive ID on reserved testing data. These findings will inform future models and strategies for ML-based approaches for understanding powder morphology and provide new quantitative tools for morphology-based nuclear forensics signatures.

P16: Trace elemental and isotopic analysis of actinide materials with an automated microfluidic system

Shuang Yu Han[1], Bernard Treves Brown, Matthew Higginson, Philip Kaye, and Clint Sharrad
[1]The University of Manchester, UK

Biography: *Shuang Yu Han is a PhD student studying at The University of Manchester. Working on the development of small, modular microfluidic systems for radiochemical separation and analytical applications in restrictive environments such as gloveboxes or fume hoods. With several prototypes that are developed for different applications, such as trace element purification, isotopic analysis of actinides, and miniature recycling systems for automated recovery of actinides.*

Shuang is very interested in future developments in new laboratory technology, analytical techniques and further miniaturisation and automation efforts in development of new, novel sensors for qualitative and quantitative determination of elements in difficult matrices.

Advancement in analytical device miniaturisation through microfluidic technology offers an alternative approach towards radiochemical analysis. When compared to traditional macroscale analytical process, microfluidics devices manipulate and process fluid samples typically in the microlitre range, which provides benefits in terms of more efficient mixing and precise conditions control that are not feasible in macroscopic systems while reducing waste generation.

Microfluidic extraction devices are fabricated using poly (methyl methacrylate). Recovery and separation of uranium and plutonium from trace elements relevant to the nuclear fuel cycle are demonstrated using extraction chromatographic resins packed within the microdevice in concentrated mineral acids. Enabling analysis of nuclear materials with a drastic volume reduction to ≤ 2 ml per analysis.

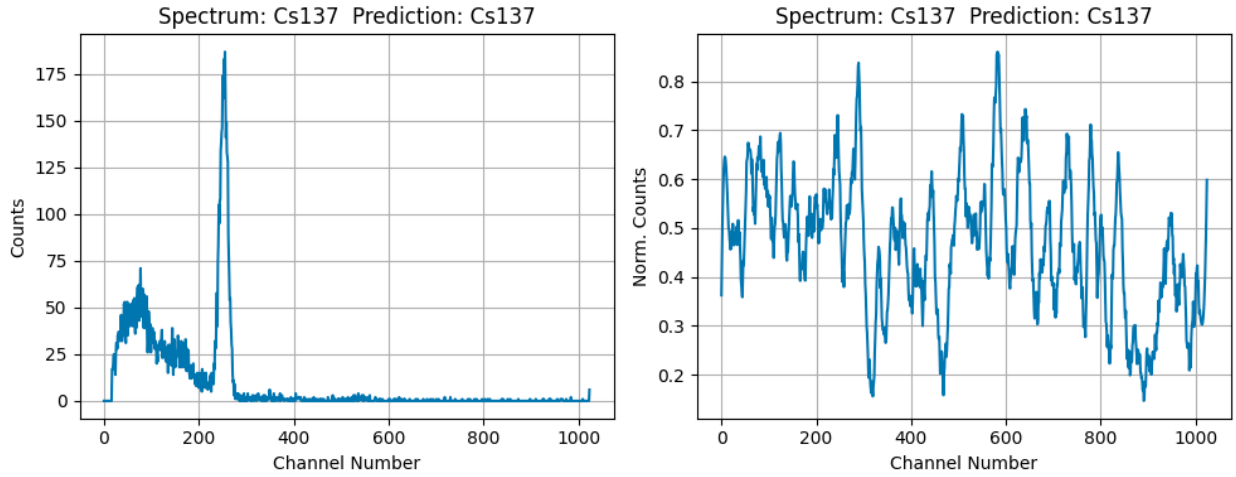
A novel online analytical system was also developed in parallel. Where flows from the microfluidic separation system are redirected towards a coupled ICP-MS and MC-ICP-MS systems, enabling online analysis of trace elements and precise analysis of actinide isotopic ratios as it is separated within the microdevice with minimal operator - sample interaction. Such an online microdevice – Mass spectrometry system enables automated separation-detection of radioactive samples within 2 hours of sample uptake while generates less radioactive waste, satisfying the As Low As Reasonably Achievable (ALARA) principle.

P17: An evolutional generative attack algorithm designed to fool neuralnetwork isotope identifiers

Jasmine Ghamsari[1], Luke Lee-Brewin[1], and Caroline Shenton-Taylor[1]
[1]University of Surrey, UK

Biography: *The SIGMA data team at the University of Surrey has been exploring applying machine learning algorithms to real time isotope identification in urban environments. The SIGMA dataset is a large dataset of gamma spectra collected in London throughout 2018 by AWE. Neural network isotope identifiers are capable of rapidly predicting isotopes present within a spectrum. Recent research from the group has been focused on trying to understand which features of a gamma spectrum these models use when making predictions. This work focusses on a generative attack algorithm which creates fake spectra a model predicts to be a certain isotope. These fake spectra contain no features typically associated with a gamma spectrum yet the model still predicts them to be certain isotopes. This raises interesting considerations for the deployment of neural network isotope identifiers in safety critical applications.*

Real time isotope identification can aid law enforcement in the interdiction of illicit radiological material. In 2018 AWE Nuclear Security Technologies collected a large dataset of gamma spectra from detectors placed in key areas around London, known as the SIGMA dataset. This dataset has presented an exciting opportunity to develop machine learning algorithms, such as neural networks, designed to identify isotopes in urban environments. Neural network isotope identifiers are an area of active research and show potential in analysing spectral data quickly and accurately, even when presented with short acquisition time spectra. The design of a neural network is originally based off the human brain with nodes and synapses connected together in a large network. A common misconception is that a trained model learns to make decisions in the same way as a human. If a model is not understood properly, but presents a high prediction accuracy, it is likely to be relied upon too heavily. When making safety critical decisions, such as isotope identification in an urban environment, this could have serious consequences. In this work, an evolutionary generative attack algorithm is used to demonstrate that a neural network isotope identifier, tested on the Sigma dataset with high prediction accuracy, can be fooled. This algorithm iteratively optimises, fake spectra which maximise the output prediction of the neural network. Comparison between these fake spectra and real gamma spectra shed light on the differences between neural networks and human cognition. Figure 1 shows a comparison of a real Cs137 spectrum (left), and a fake spectrum generated by the genetic algorithm (right). No features typically associated with a Cs137 are present within the fake spectrum, however the model predicts both spectra to be Cs137. This raises interesting considerations for the deployment of neural network isotope identifiers in safety critical applications.



P18: Laboratory validation of simulated gamma-spectra for the purpose of training a convolutional neural network

James Biggs[1], Luke Lee-Brewin[1], and Caroline Shenton-Taylor[1]
[1]University of Surrey, UK

Biography: The SIGMA data team at the University of Surrey has been exploring applying machine learning algorithms for real time isotope identification in urban environments. This work forms part of a research project undertaken by James Biggs over a one-year Master of Physics project.

The timely and accurate identification of legal and illicit radiological materials within an urban environment is a topic of national security. Convolutional neural networks have proven effective in gamma-spectra isotope identification, across a variety of shielding conditions [1]. There is a need to reflect real-world scenarios within a laboratory environment, providing information supporting the simulation of machine learning training datasets. This work presents a laboratory environment designed to support neural network development applied to the SIGMA dataset. The SIGMA campaign recorded 1.5 billion one-second gamma spectra from detectors across London, with the data made available to the academic community via nuclear security science network (NuSec) [2]. In this project, representative gamma spectra were simulated in Geant4 and compared to laboratory and SIGMA obtained measurements. The discrepancies between the real-world, simulated and theoretical spectral count numbers were then compared. A framework was developed, allowing simulated spectra to be corrected for static source-detector distance and shielding. This approach provides a route to inform future simulated spectra, improving the quality of training data supplied to a neural network and aiding the evaluation of the SIGMA network performance. Simulating training data containing isotopes unseen by the original SIGMA trial will benefit from this approach. This work can now be adapted to encompass moving radiological materials within the scene

[1] L. Lee-Brewin, D. Read and C. Shenton-Taylor, “A convolutional neural network algorithm developed for shielded multi-isotope identification,” Journal of Instrumentation, vol. 18, May 2023.
[2] www.nusec.uk/news/2022/10/18/sigma-data-challenge/Accessed Aug 2024

P19: Gamma-Ray Microcalorimeters using Superconducting materials and Technologies for Nuclear Forensics.

Rhys Turner[1]
[1]Loughborough University, UK

Biography: *I'm a PhD student at Loughborough University focusing on superconducting cryogenic detectors for improved performance in gamma spectroscopy that far surpass the performance of current gold standard gamma detectors. These can be used for nuclear forensics for decommissioning nuclear reactor fuel rods and to identify the ages and abundance of complex radioactive samples.*

Gamma spectroscopy for nuclear forensics requires accurate non-destructive analysis of complex radioactive material. Use of the current 'gold standard' detectors such as High Purity Germanium (HPGe) can result in mass ratio errors. Such inaccuracies hinder the characterization of fissile materials like Plutonium (Pu), making it difficult to accurately measure the abundance of complex samples. In the case of Pu, this measurement is crucial for determining the type of reactor where the sample was produced and its intended use as reactor fuel. Given these challenges, a new type and architecture of detector is required for more precise measurements. This need has spurred rapid advancements in superconducting gamma-ray detectors, particularly microcalorimeters and the fast-maturing Transition-Edge Sensor (TES). These devices are proving essential for the next generation of gamma detectors due to their superior energy resolution and lower statistical and systematic errors compared to HPGe, enabling mass ratio analysis with errors below 1%, allowing for accurate identification of material abundance in complex samples.

With further development, TES technology can enable precise identification of parent nuclei, the age of samples (or reactor fuel), and the mining location. This advancement has significant implications for safeguarding and border control, enhancing global safety and security. However, there are limitations to TES sensors that will be discussed further, along with their functionality and the measurement cycle from photon detection to energy readout.

P20: Long-range Detection of Alpha Radiation

Talha Shameem[1], Peter Hobson, Linda Cremonesci, and Antonio DiBuono
[1]Queen Mary University of London, UK

Biography: *Talha Shameem is a third-year particle physics/detector physics PhD student at Queen Mary University of London. He received a research master's degree in accelerator physics and a BSc in physics with particle physics from Royal Holloway University of London. His current research is in long-range alpha detection with the intent for nuclear decommissioning, nuclear forensics, and more.*

With alpha detection solutions requiring PPE and taking up significant amounts of time and effort, a stand-off alpha detector has a global interest. The requirements of this technology are not trivial to accomplish and include (but are not limited to): sensitivity to 250 kBq point source and 50 kBq $m^{(-2)}$ plane source, a minimum detection distance of 2 m, and the ability to use the detector in daylight. Since alpha particles of 5 MeV in air travel approximately 40 mm they may be detected indirectly by the radioluminescence phenomenon. The most intense emission band is at 337.1 nm, which is within the ultraviolet range. The signal produced by this process from the source is well documented to be far weaker (irradiance magnitude of 10 fW/m^2 at 337.1 nm for the 50 kBq $m^{(-2)}$ plane source) than sunlight (irradiance magnitude of 1 W/m^2 at 337.1 nm) and is a critical hindering factor in detection. As such, experimentation and simulation work in FLUKA has been undertaken to model and create a viable solution.

P21: Automated Capture of Extensive Micrographic Libraries for Training AI Models for Nuclear Forensics

Thomas Scott[1], Matt Gilbert[2], and Michael Rushton[1]
[1]Bangor University, UK, [2]NTR-Net, AWE, UK

Biography: *Mr. Tom Scott is a first year PhD student at Bangor Univeristy in North Wales. His current research is in the field of Nuclear Forensics specifical looking at the use of image classification for finding the provenance of material.*

With prior work with digital twins in the modelling of the THOR Facility on Anglesey.

Image classification and object detection employing artificial intelligence (AI) and machine learning (ML) has improved significantly in recent years. They now provide a useful set of tools for the nuclear forensics' community, allowing key properties for material provenance assessment to be established rapidly from micrographs. AI and ML algorithms rely on training data which is often derived experimentally. A key challenge to their adoption is the significant size of these training databases, the production of which often require a large investment in time and money as thousands of images can be required for image classifiers to work effectively. To address this challenge, this project has developed an automated robotic system to aid in the generation of large micrographic datasets.

A robotised optical microscope has been created allowing for automated sampling across a large 214x214mm bed. Automation greatly reduces the need for human intervention which has clear advantages when working with nuclear materials. Computational micrography techniques, including focus-stacking and image stitching, have been incorporated to allow high quality images to be captured with a much larger field of view than any single micrograph at similar magnification, further aiding the range of applicability of the datasets produced.

The system has initially been tested using non-active simulant material, namely ceria as an analogue for plutonia. The development of the system and the results of these initial experiments are reported here.

P22: Development of a novel neutron detector using trapped 3He

Toby W. Bird[1], Andrew Pratt[1], Alison Laird[1], and Charles Barton[1]
[1]University of York, Heslington, UK

Biography: Senior Lecturer in the School of Physics, Engineering, and Technology at the University of York. Research area is nuclear physics, including nuclear structure, reactions, nuclear astrophysics, and detector development.

The global demand for portable neutron detection is on the rise for security, monitoring and scientific investigations [1]. Practical uses could include deploying advanced radiological and nuclear detection capabilities at border points, as monitors around small modular reactors for energy or centres for medical radioisotope production, or directly as part of a scientific analysis package. Portable neutron detectors add flexibility and utility and are crucial for various current purposes and planned future uses. Helium-3 (3He) based detectors have been the standard for thermal neutron detection due to their high efficiency and excellent radiation discrimination, however, these detectors tend to be large and obtrusive and require high voltages to operate. [2] Therefore, the development of a compact 3He neutron radiation detector is critical. Utilising our proprietary adaptation to known fabrication methods, we show how He can be embedded in high quantities. These 3He-embedded materials are then used as converter media, exploiting the reaction between 3He and a thermal neutron to produce tritium and a proton. This release of energy can then be detected using a photodiode. In this work, we will show how we produce these novel materials as well as how we characterise them. We have also incorporated these materials into a detector and shown a neutron response from our converter media.

This work was supported by NuSec FEA 429056 Barton

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[2] Richard T. Kouzes, et al. Neutron detection alternatives to 3He for national security applications, NIM A, Volume 623, Issue 3, 2010. ISSN 0168-9002 https://doi.org/10.1016/j.nima.2010.08.021

P23: Flexible Polymer Semiconductor Radiation Sensors for in-situ Characterisation of Nuclear Sites

Albanik Gashi[1], Alan Drew[1], Adrian Bevan[1], and Antonio Di Buono[2]
[1]Queen Mary University of London, UK, [2]National Nuclear Laboratory, UK

Biography: Albanik Gashi is a postgraduate research student with Queen Mary University of London (QMUL), funded under the Nuclear Decommissioning Authority's (NDA) PhD bursary scheme. He is currently working on the development of flexible polymer radiation sensors. He has research interests which include organic electronics, radiation detection and instrumentation, as well as nuclear security/threat reduction.

Nuclear decommissioning demands a complete understanding of the radiological hazard present, which is often achieved through the combination of in-situ detection and the complementary radiochemistry. Current challenges with in-situ detection arise from the various functions present at nuclear installations. These place constraints on the detector geometry, precision, chemical and environmental resistance of the characterisation technology employed, frequently requiring tailored solutions. We investigate organic (polymer, oligomer, and small molecule) semiconductors deposited on flexible substrates as a conformal and tuneable solution to this challenge. Organic semiconductors in general have made headway in consumer electronics, such as OLED displays in mobile phones, as well as IR photodiodes, and flexible photovoltaics. In the last 20 years, organic semiconductors have been investigated as cheaper alternatives (compared to their inorganic counterparts) in the field of radiation detection, with all radiation types being reported in the literature with end-goal applications in medical dosimetry, nuclear security, and high energy physics. We aim to fabricate flexible alpha particle sensors to be used for in-situ characterisation of buried structures (pipelines) and scaffolding present on Nuclear Decommissioning Authority (NDA) sites. Characterisation in this context includes: 1. Contamination location. 2. Radioactivity. 3. Radioisotope identification. Investigations into the alpha detection capabilities of these diode-style organic sensors are undertaken in laboratory conditions utilising 241-Am sources, with an initial interest in understanding the detection capabilities of the sensor element alone, with respect to minimum detectable activity and sensitivity to particle energy. The end goal of this project will be to combine our sensors with an eversion robot and perform in-situ characterisation at an NDA site.

P24: Investigating the Potential of Raman Spectroscopy for an OLED Commercial Display

Charlotte Odlin[1], and Adrian Bevan[1]
[1]Queen Mary University of London, UK

Biography: Charlotte began her MSci Physics degree at Queen Mary University of London in 2020, and graduated 2024. For her final year research project, she researched the potential use of Raman spectroscopy for an OLED commercial display. She then continued this research from July-August 2024 as part of a summer student internship within the School of Physical and Chemical Sciences at Queen Mary. Her interests lie in organic electronics, radiation detection and nuclear security.

This poster presents the potential use of Raman spectroscopy on OLED devices within nuclear forensics. OLED displays contain conjugated organic compounds which have characteristic Raman spectroscopic signatures. These spectra can change as a result of radiation exposure. We present results of studies of iPhone 14 OLED displays that have been irradiated using ^{60}Co and other organic semiconductor material.

P25: Development of Small-Scale Separation Methods for the Rapid Analysis of Post-Detonation Nuclear Debris

Anastasia Baltes[1,2], and Artem Gelis[1]
[1]University of Nevada-Las Vegas, USA, [2]Los Alamos National Laboratory, USA

Biography: Anastasia Baltes is a Glenn T. Seaborg Graduate Research Fellow in the Nuclear and Radiochemistry Group at Los Alamos National Laboratory (LANL) and a second-year PhD student in the Radiochemistry Program at the University of Nevada-Las Vegas (UNLV). At LANL, she focuses on accelerated pre-detonation nuclear forensics. Her focus at UNLV is the analysis, dissolution, and separation of nuclear debris.

Analyzing nuclear debris is vital for identifying forensic signatures in a post-detonation environment. While established methods exist for obtaining signatures from debris, ongoing efforts in nuclear forensics aim to shorten the analysis timeline. This project explores innovative approaches by integrating materials chemistry with radionuclide separation techniques to deliver actionable signatures more quickly than traditional methods. By leveraging the phase distribution of radionuclides in debris, we develop targeted dissolution methods combined with a microfluidic system, effectively reducing analytical timelines. Phases of uranium/plutonium-based debris collected from the Trinity test site were evaluated to identify novel dissolution and small-scale separation methods that can be implemented in the field. Synthesized surrogate debris is also leveraged within the project, as well as the ability to incorporate actinides and treat the debris with fast neutrons. After separating the mineral phases based on selective dissolution and sequential extraction methods, the correlation of radionuclides with specific

mineral phases and the constituents impacting the performance of radioanalytical procedures is ascertained. Then, a microfluidic system that manipulates small amounts of fluids is utilized to perform multiple solvent extraction steps and purify the radionuclides of interest. The system's known interfacial areas and rapidly mixed regime allow for the measurement of kinetic rate constants for interfacial mass transfer during extraction. Entire separation protocols are performed inside a glass microfluidic cartridge, confining radiation, reducing exposure, and making radioactive waste disposal safer/simpler. Speciation data obtained from these studies will offer new methods for the specific and rapid separation of radionuclides, addressing a key challenge in ongoing forensic research. This advancement will facilitate the development of analytical techniques that eliminate the need for complete sample digestion and reduce the time required for isotopic ratio determination by solution methods. Our findings are directly applicable to real-world nuclear forensic scenarios, providing practical solutions for improving analysis efficiency.

NuFor
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