

ENABLING TECHNOLOGIES & INNOVATION CONSORTIUM

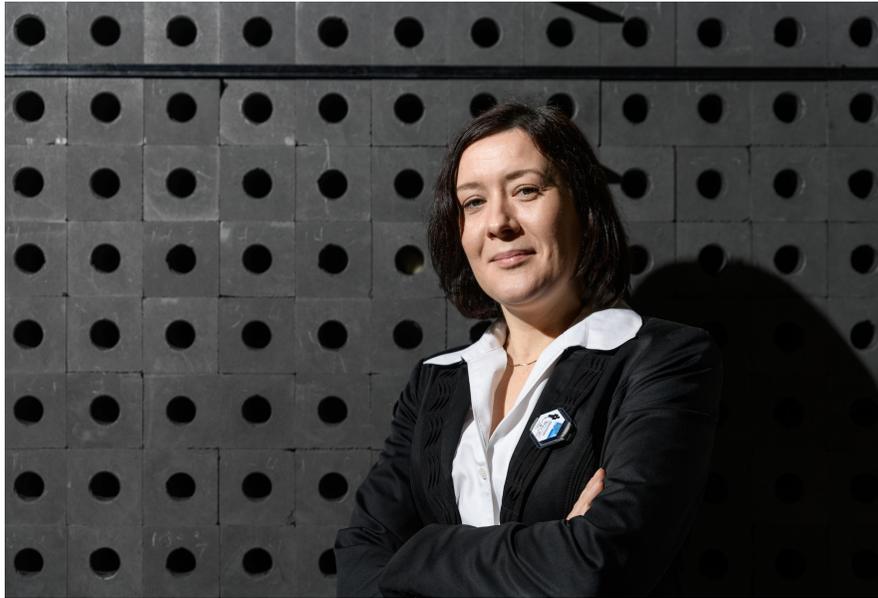
2022 Newsletter



WELCOME TO ETI'S ANNUAL WORKSHOP 2022

March 29 - 30, 2022





MESSAGE FROM THE DIRECTOR

Dr. Anna Erickson, Consortium Director

“Innovation is exploration of uncertain and unfamiliar space,” I wrote last year as we were adapting to challenges that were brought by COVID-19. I think we became quite good and flexible in our handling of remote work, “meta” meetings, and virtual dissertation defenses. In this letter, I planned to talk about the achievements that were at the center of last year’s successes—and there were a lot of them—but recent events in Ukraine brought back the uncertain and unfamiliar space, now in nuclear domain.

Let me begin with expressing the support of and solidarity with Ukraine, a nation with a long history of nuclear legacy. Following the dissolution of Soviet Union, Ukraine became the third largest nuclear arms nation, holding about a third of the Soviet nuclear arsenal.

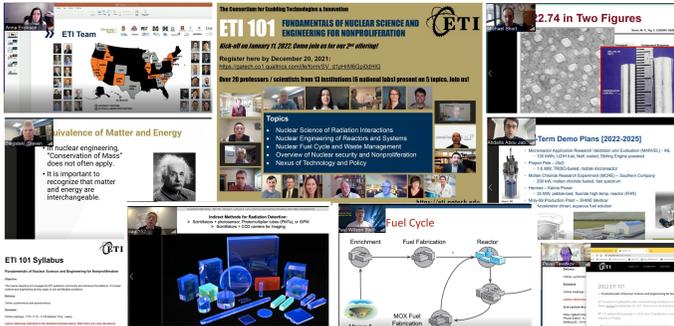
In 1994, Ukraine along with Belarus and Kazakhstan signed an agreement with Russia, the United Kingdom, and the United States, as part of the Budapest Memorandum on Security Assurances. The Memorandum prohibited the signatory states from using threats or economic coercion against Ukraine, Belarus, and Kazakhstan in exchange for return of

nuclear weapons to Russia. Today, Ukraine remains an NPT state with civilian nuclear reactors.

The recent events in Ukraine raised several concerns regarding Russia using nuclear weapons in a conflict. While there is quite a bit of debate whether Russia will escalate to nuclear weapon use, it highlights the importance of diplomacy, disarmament, and nonproliferation work. Chaos around nuclear power plants in Ukraine, in particular Russian military seizing decommissioned Chernobyl nuclear power plant still containing spent fuel, also highlights the danger of radioactive and nuclear material misuse and displacement. Safety and security of nuclear materials and personnel are of utmost importance, and we as the ETI community should keep in mind these unfamiliar events as we develop our technology and innovation.

To our ETI community: thank you for your hard work in enabling nonproliferation efforts! I am looking forward to seeing you this week and discuss the latest accomplishments by our students and colleagues.

ETI 101: FUNDAMENTALS OF NUCLEAR SCIENCE AND ENGINEERING FOR NONPROLIFERATION



As a result, the 2022 version of the ETI 101 consists of five modules:

- Nuclear Science of Radiation Interactions and Applications
- Engineering of Reactors and Systems
- Nuclear Fuel Cycle and Waste Management
- Overview of Nuclear security and Nonproliferation
- Nexus of Technology and Policy

The objective is to engage the ETI community at large and beyond the consortium, including universities and national laboratories, to introduce foundations of nuclear science and engineering as they apply in nonproliferation applications.

ETI101 lectures are offered via distance delivery methods and include conventional style lectures covering various topics of science and technology as well as demonstrations focusing on applications and elements of the overall framework of nonproliferation and safeguards.

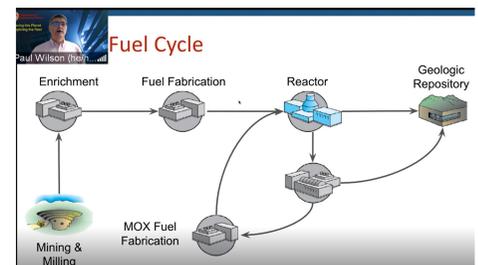
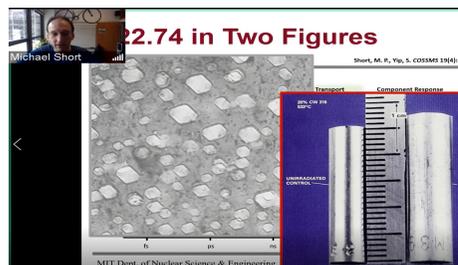
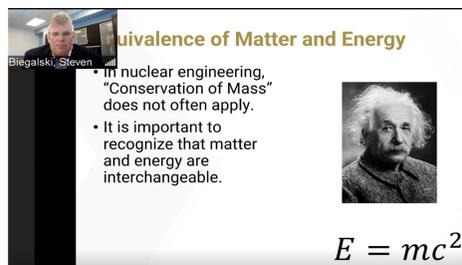
All course materials, presentations and video recordings are contributed by faculty and national laboratory experts for general use and are posted on the ETI 101 website, <https://eti.gatech.edu/2022-eti-101/>. Online availability of the ETI 101 materials facilitates both synchronous and asynchronous modes of the course delivery.

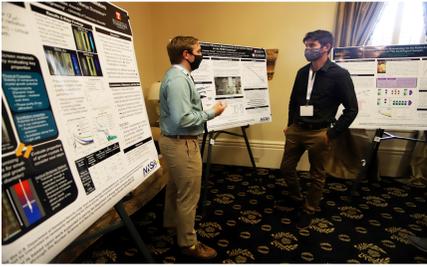
Plans are in the works to deliver ETI 101 again in Spring 2023.

The transformational possibilities associated with the multidisciplinary nature of the ETI consortium cannot be achieved without strong academic activities. Our semester-long introductory course on fundamentals of nuclear science and engineering, ETI 101, returned in January of 2022. It is our second offering of the course. We build on the success of its first offering in spring of 2021.

This time ETI 101 kicked-off on January 11, 2022. Similarly to the first offering, most of the lectures are being delivered in a twice-per-week format although some of the weeks provided three lectures. The course is concluding on May 19.

Original four modules returned expanding their content. In addition, the fifth module has been added to conclude the course emphasizing the synergy between technology and policy aspects.





UNIVERSITY PROGRAM REVIEW 2021



ETI PRINCIPAL INVESTIGATOR SPOTLIGHTS

Something else here

Andrea Johnson (SC): Exploring the Effects of Industry Standard Tools on Computational Thinking in the Classroom

While preparing students for careers beyond graduation, HBCU faculty often must balance the priorities of bridging the gap between the level of student preparation and the expected level of preparedness as influenced by industry and discipline standards. Prioritization of these standards does not always align with the experience of students at Historically Black College and Universities (HBCU) and Minority Serving Institutions (MSI). The Association of Computing Machinery (ACM) 2013 Computer Science Curricula guidelines highlight version control as one of many core tools in the Social Issues and Professional Practice (SP) Knowledge Area students should experience in their upper-level software engineering courses. Research has demonstrated that at this level, students receive exposure to the tool but are not able to gain sufficient mastery. Other researchers have advocated for version control being introduced earlier in the computer science curricula. There is limited research that indicates that this tool improves the learning outcomes for students or significantly complements the other ACM Knowledge Areas. Dr. Johnson's work explores the challenges experienced by an HBCU faculty member while integrating GitHub and various other tools into programming classes at Spelman College. It is important to note, there is no research that directly addresses the use of version control in predominately African American classrooms. This research also extends a larger agenda of understanding how computational thinking is developed in students from historically marginalized classroom settings.



Spelman College®

A Choice to Change the World

Milton Garces (UH): The Tonga Blast Wave

There always something blowing up somewhere. However, massive blasts are rare. In an ideal world, we see disaster looming and take preemptive measures; isolate, evacuate, mitigate. In the case of the Hunga Tonga eruptive sequence, in hindsight one could argue there was some advance warning. However, nobody was prepared for the massive explosion at ~04:15 UTC of 15 January 2022, with an equivalent explosive yield that rivals the 1883 eruption of Krakatoa volcano.

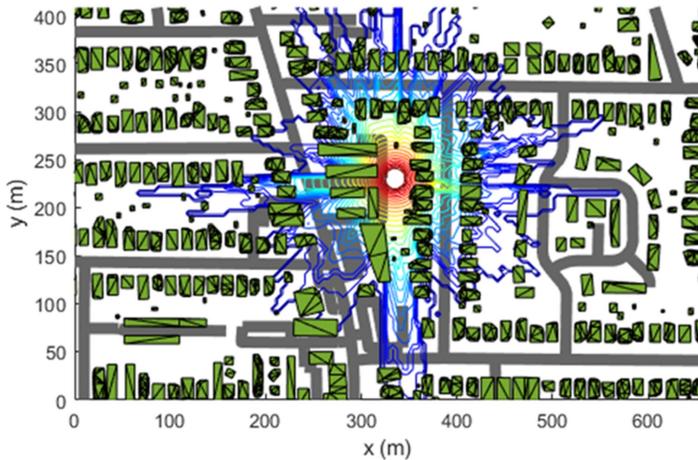
It was early Friday evening in Hawaii when the news started rolling in, before ash and tsunami damage cut off communications from Tonga. Reports of the blast wave being heard in Samoa and Fiji started coming in. The first atmospheric wave hit Hawaii - 5,000 km away - around 11:30 PM local time. This first arrival was recorded by our local infrasound stations, barometers, sea-level sensors, and smartphones; this was the first of multiple circumglobal transits of an exotic surface guided air wave known as a Lamb wave. An unexpected tsunami surge caused some damage in Kona, Big Island.

There is a cadence and method to approaching blasts on the right side of the boom, a term often used to convey forensic analyses of destructive explosions. Was it natural or man-made? The answer leads to different approaches and reporting paths. In this case, the blast was clearly volcanic, and international relief efforts were set in motion. How big was it? We have standard methods for equivalent yield estimated, but nobody in my generation had worked with anything beyond a few hundred tons of TNT equivalent. After reviewing the acoustics literature from the Cold War, by Monday afternoon I had a yield estimate many megatons larger than the nominal 50 MT yield of Tsar Bomba. But I was incredulous; such an intensity sounded preposterous. By the time the fifth arrival of the Lamb wave around the world, the remaining question was if the Tonga blast was bigger than the 200 MT blast from the 1883 Krakatoa eruption.

In the last weeks we've aggregated, processed, and fused data from hundreds of recording stations on Earth, and teamed up with US and international teams to interpret the complex wavefield captured by multiple sensor modalities. Various papers have already been submitted, and many more are in progress. This emerging body of literature will upgrade take our understanding of our Earth's response to extreme events, as seen through the high-resolution lens of the digital era.

ETI RESEARCH SPOTLIGHTS

Thrust Area 1



1. Samuel Kemp (GT): Radiological Multi-Source Search Using Heterogeneous Vehicle Array in Urban Environments

This work presents a system of UAVs coordinating ground vehicle to quickly locate the source of radioactive emissions in an urban environment. The objective is to get the ground vehicle to do high fidelity scans of the radioactive sources in an environment with an unknown number, distribution, and strength of radioactive sources. The UAVs are equipped with low-cost radiation detectors, GPS, and visual cameras.

The ground vehicle carries more advanced sensors, GPS, lidar, and visual cameras. The UAVs can take off and land on the ground vehicle for recharging. The UAVs are there to get as much information as quickly as possible to guide the path of the slower, but more sensitive ground vehicle. Various algorithms are used for estimating the radiation source parameters, guiding the UAVs and ground vehicle, and modelling radiation attenuation through buildings.

Publication:

S. Kemp and J. Rogers, "UAV-UGV Teaming for Rapid Radiological Mapping," 2021 IEEE International Symposium on Safety, Security, and Rescue Robotics (SSRR), 2021, pp. 92-97, doi: 10.1109/SSRR53300.2021.9597870.

2. Jacob Tellez, Will Smith, and Nicole Hege (CSM): Evaluation of Chemical Speciation to Enable Online Monitoring of Molten Salt Reactors

Characterization of chloride molten salts with high f-element loading remains limited in literature despite relevance to nonproliferation and online monitoring of molten salt reactors and pyroprocessing separation schemes. Coupled spectroscopic and computational investigations provide certain benefits, as experimental information can validate simulation, while simulations can provide atomistic resolution. Raman and IR spectroscopy investigations of the LiCl-KCl eutectic containing trivalent metal chlorides are being pursued by classical and ab initio molecular dynamics (MD), as well as experimental investigations. Classical simulations employ a polarizable potential to evaluate nanoscale coordination and thermophysical properties of the salt. Early investigations of pure metal chloride systems reveal highly coordinated complexes coinciding with cations sharing one, two, and three chlorides. Evaluation of speciation and thermophysical properties at lower concentrations in the eutectic remains ongoing. Ab initio simulations utilizes density functional theory (DFT) based wavefunctions to model UCl₃ and CeCl₃ in a LiCl-KCl eutectic over increasing Ln/An concentration (16-80% BW) to determine changes in local coordination environments

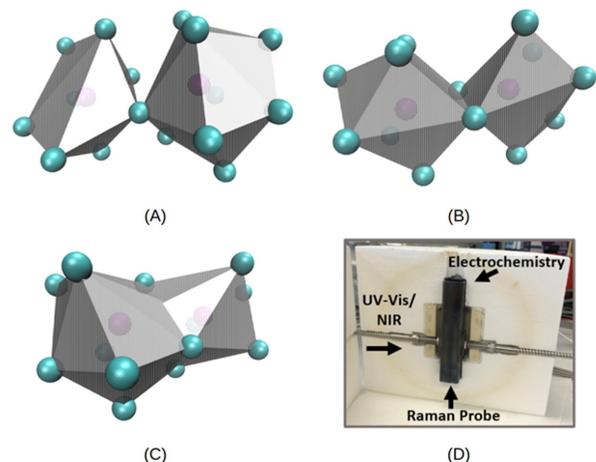
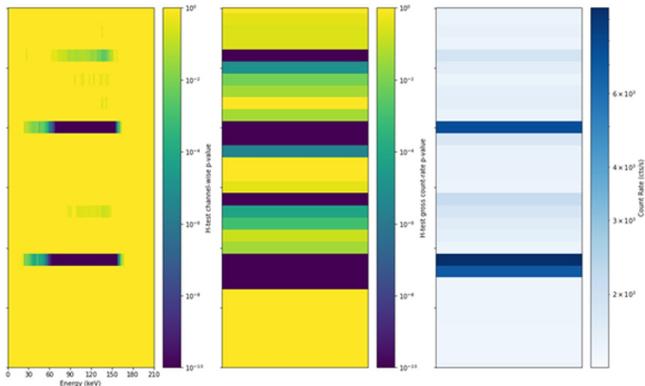


Figure: (A) Corner, (B) Edge, and (C) Face-sharing uranium chloride complexes found in pure UCl₃. (D) Image of the 3-D molten salt furnace developed in this project.

through applied graph theory. The Raman and IR spectroscopy of the systems are predicted to determine if shifts in the local environment led to distinguishing chemical signatures that may be used to identify the unique molten salt composition. A 3-D high temperature furnace has been constructed which enables simultaneous measurements using Raman and UV-Vis Spectroscopy with electrochemical techniques. After initial studies indicated careful temperature ramping is necessary to preserve the quartz spectrophotometric cell, further studies will employ a slower temperature ramp and more protection of the Raman probe seated at the bottom of the furnace.

3. Jordan Stomps (UW): SNM Radiation Signature Classification Using Semi-Supervised Machine Learning

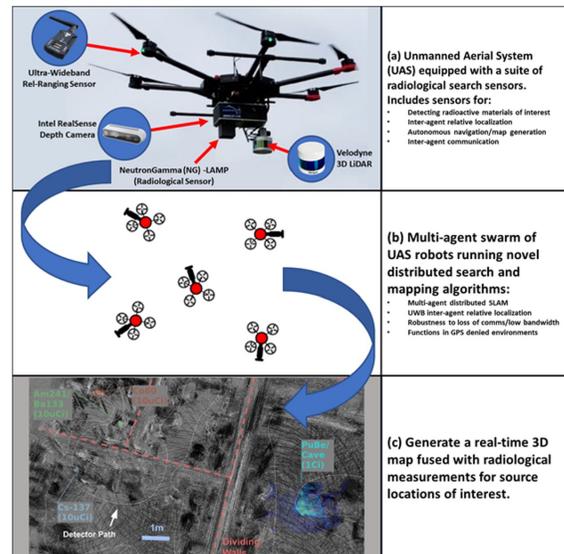


Identifying underlying patterns in data distributions can be discovered with machine learning with potential application in nuclear nonproliferation. However, preparing a dataset appropriate for training a machine learning model by carefully labeling each data sample can be costly, time-consuming, or imperfect. Therefore, this work is developing a machine learning model built on semi-supervised learning to utilize both labeled and unlabeled data. Even though the unlabeled data does not provide formally classified instances, it can help identify an underlying distribution or pattern relevant to classification. This can be used for identifying special nuclear material (SNM) transfers and characterizing the materials present via their radiation signatures. Radiation measurements from sodium iodide (NaI) detectors are provided by the Multi-Informatics for Nuclear Operations Scenarios (MINOS) venture at Oak Ridge National Laboratory (ORNL) as sample data. First,

anomalous measurements are identified with statistical analysis, classified, and labeled. Then, after background estimation, energy dependent features can be used to train a semi-supervised model. Once trained, this model could potentially classify anomalous measurements associated with SNM scenarios. Performance is compared to a traditional baseline, a purely supervised method, to understand the value of unlabeled data. Future work includes more formal quantification of the tradeoffs between labeled and unlabeled data, feature importance, etc. An implementation of this model could be coupled to other detection analyses, including data fusion and spatially dependent methods.

4. Andrew Fishberg (MIT): Collaborative SLAM for Facilitating Radiological Search and Mapping on a UWB Enabled Multi-Agent Aerial Platform

Our project is working to advance the state-of-the-art of radiological search, the task of deploying one or more autonomous agents to search a region for dangerous radioactive materials. To these ends, robots must be integrated with delicate radiation sensors and be capable of navigating a range of challenging mission environments. A typical radiological search scenario may have GPS being jammed or unreliable, non-existent or outdated prior maps, and a dangerous time-critical nature. To hasten the search process, we parallelize through intelligent multi-agent coordinated search approaches. In other words, our robot swarm must autonomously divide the region into individual search tasks, intelligently assign them to specific agents, and



This algorithm, a form of distributed simultaneous localization and mapping (SLAM), must be robust to real-world working conditions; our algorithms must be resilient to loss of connectivity between agents, low communication bandwidth (i.e. cannot rely on sharing all data between agents), and potential permanent catastrophic loss of individual agents. In service to these research goals, our latest work has focused on the use of multiple ultra-wideband (UWB) sensors to perform relative localization between agents, without need for external infrastructure. This localization system will then be integrated into the larger distributed SLAM pipeline.

Publication:

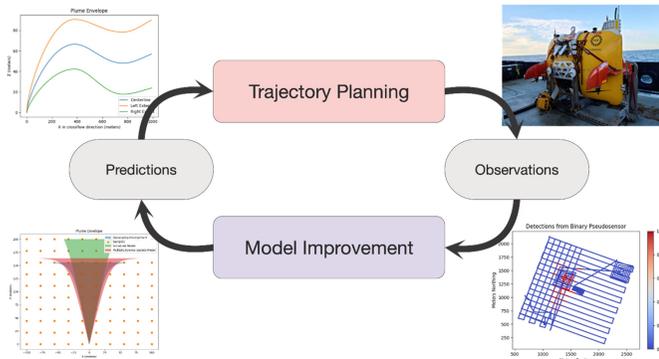
Andrew Fishberg, "Collaborative SLAM for facilitating radiological search and mapping on a UWB enabled multi-agent aerial platform", DOE NNSA University Program Review (UPR2021), September 8 – 10, 2021, Historical Academy of Medicine, Midtown Atlanta, GA.

5. Samuel Kei Takazawa (UH) : Explosion Detection using Transfer Learning via YAMNet



Detecting explosions as quickly as possible is important in the context of non-proliferation monitoring. A method to achieve this prompt detection is using an array of recording smartphones installed with a trained model to detect explosions. To make such a machine learning model specializing in explosions, we used explosion data collected on smartphones and a trained machine learning model (YAMNet). The explosion data was collected in collaboration with INL and NNSS over a two-year period with data ranging in yield from 7 grams to 1.8 kilotons TNT equivalent yield over a distance ranging from 160 meters to 140 kilometers. YAMNet (Yet Another Mobile Network) is a trained model specializing in classifying ~1 second audio clips into 521 categories. This method of using a trained model's result to train for a new task is called transfer learning. The newly trained model performed with 90% accuracy with false positive rate (mistakenly classifying noise as explosion) of 3% using a test data set. The models will be further tested with other environmental signals and their accuracies will be broken down by other factors such as distance from the source of explosion.

6. Genevieve Flaspohler (MIT): Autonomous Trajectory Planning for Mapping Deep Sea Hydrothermal Plumes



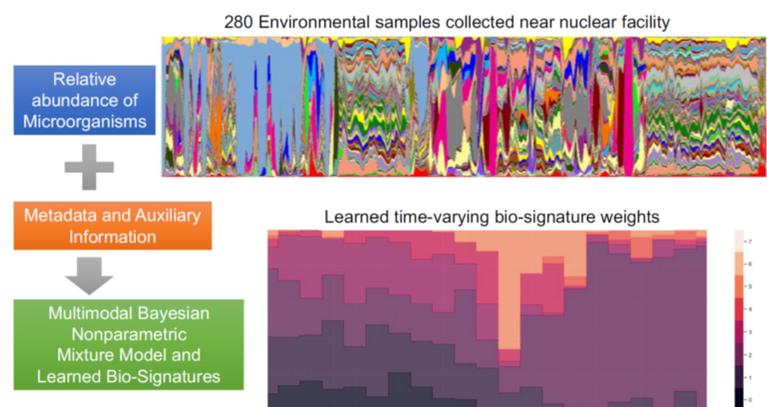
We develop and deploy an autonomous robot planning for hydrothermal plume localization and characterization. We present results on a real-world application – mapping deep sea hydro-thermal plumes. Deep sea hydrothermal plumes act as heat, nutrient, and chemical pumps in the deep ocean, supporting unique ecosystems. However, localization and direct observation are challenging due to their variable spatiotemporal nature. Plumes are influenced by tidal advection and turbulent mixing on both short (sub-hour) and long (seasonal) timescales. Plume structures span multiple spatial scales, from kilometers in the non-buoyant layer to tens of meters in the buoyant stem. Key plume drivers such as entrainment, currents, and buoyancy flux are inherently challenging to measure. These elements have analogs in similar autonomous monitoring and mapping problems applications. The approach combines complementary

sensing modalities – autonomous underwater vehicles (AUVs), remotely operated vehicles (ROVs), CTD casts, and bottle samples – to map deep sea hydrothermal plumes. CTD casts resolve vertical plume structure at large scales; dense and repeated horizontal AUV surveys enable spatiotemporal mapping; targeted ROV deployments can characterize plume source parameters; and finally, bottle samples provide deeper understanding of biogeochemical cycling in plume waters. The resulting algorithm for generating deployment plans consists of three components: 1) a trajectory optimization method, which chains canonical “lawnmower” AUV surveys to track a probabilistic plume forecast, 2) a high-level task planner that quantifies uncertainty in the plume model and targets CTD and ROV surveys to reduce this uncertainty, and 3) an opportunistic sampling algorithm that collects scientifically useful bottle samples. Results from a November 2021 Guaymas Basin research cruise utilizing the AUV Sentry and ROV Jason demonstrate that autonomous decision-making can advance the efficiency and robustness of operational mapping and localization.

7. Christopher Dean (MIT): Discovering Genomic Bio-Signatures for Monitoring and Verification with Bayesian Nonparametric Inference

Radiological events impact local bacterial and fungal communities. Metagenomic data analysis offers the ability to detect radiological processing or events by a bio-signature: particular patterns in these bacterial or fungal communities. Modeling bacterial and fungal communities pose significant data analysis challenges, for example, samples may contain over 15,000 distinct species and the fewer than 100 disjoint measurement sets; additional conflating factors are abundant, as weather and chemical events also significantly impact these populations. Probabilistic models provide a natural way to address these challenges, allowing for both dimensionality reduction and jointly modeling data from different sources to identify effects. In particular, a popular class of models called Hierarchical Dirichlet processes (HDPs) express data (species abundance counts)

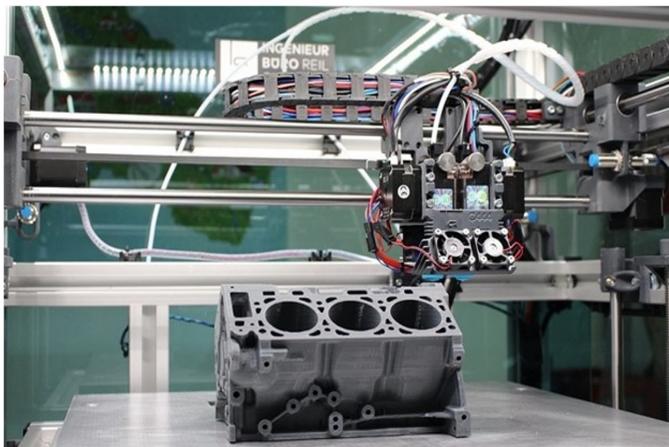
as arising from a weighted combination of shared bio-signature contributors, or distributions over species. This approach enables statistical strength to be pooled across groups of data, while still allowing groups of data to have different models due to the effect of idiosyncratic mixture weights. Further, HDPs do not specify the model complexity—the number of bio-signature contributors—a priori, allowing this to be determined by the data. We develop multi-modal HDPs (mmHDPs), an extension of HDPs that accommodate multiple types of data. In doing so, we present a model and inference method that can learn joint topics amongst both base data (relative abundance counts for bacteria and fungi) and metadata, for example, weather data that



ETI RESEARCH SPOTLIGHTS

Thrust Area 2

1. Natalie Cannon (GT): Additive Manufacturing: A Challenge to Nuclear Nonproliferation



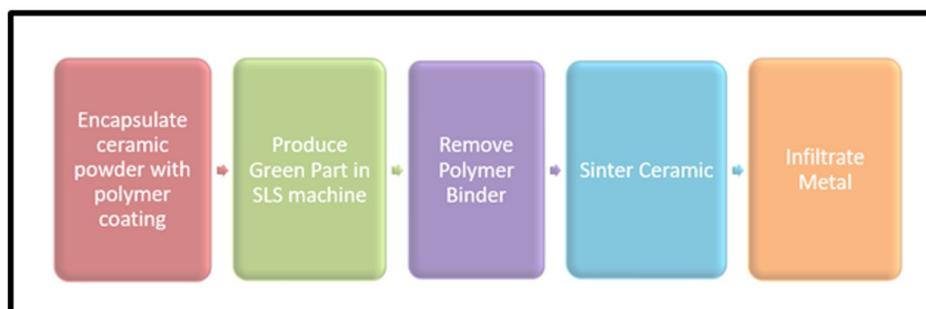
Additive manufacturing (AM) is a fast-evolving technology that allows businesses to automate and simplify the creation of complex objects. In the realms of nuclear weapons and nuclear enrichment technologies, AM methods have recently been applied. There are currently little international or domestic export regulations in place for AM's involvement in the nuclear sector, resulting in an unregulated proliferation pathway. Existing export regulations are based on broad concepts and procedures and do not consider the individual subtleties of various additive manufacturing techniques. It is necessary to examine and describe AM methods and their nuclear applications to create regulations and restrictions that

will be successful in monitoring proliferation routes. This project involves identifying and ranking 32 AM approaches based on their potential influence on the nuclear fuel cycle. Export controls would target AM nuclear proliferation threats using this type of identification and categorization without affecting the whole industry and fuel cycle. Furthermore, due of its comprehensive approach to regulating and monitoring proliferation channels, legislation using this strategy would discover gaps in export regulations.

Publication:

To be presented at: 2022 ETI Workshop, the 2022 International Conference on Methods and Applications of Radioanalytical Chemistry (MARC), DOE NNSA University Program Review (UPR2022), the 2022 Institute of Nuclear Materials Management (INMM) Conference

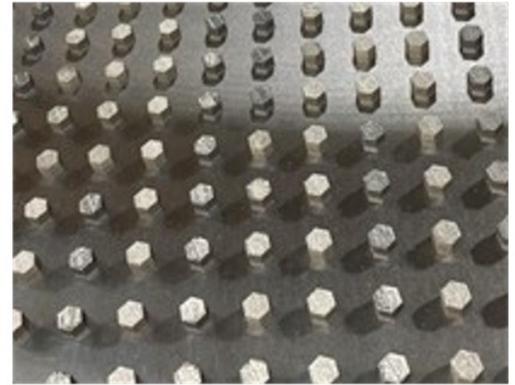
2. Patrick Snarr (UT): Indirect Selective Laser Sintering of Nuclear Cermets



Cermets, ceramic/metal composites, are an interesting material for the nuclear industry as they are capable of combining the strengths of metals (structural integrity) and ceramics (able to operate in harsh environments). Furthermore, additive manufacturing of cermets could allow for this unique material to be fabricated in highly complex geometries. The University of Texas at Austin is developing an oxygen-sensitive, indirect selective laser sintering process capable of printing nuclear cermets. The mechanical properties of these cermets will be studied to develop design guidelines and the geometrical capabilities of the process studied. The objective of the project is to bring the developed indirect selective laser sintering process to a place where nuclear applications of the printed cermets can be explored.

3. Alec Mangan (UW): Acoustic Signatures of Additive Manufacturing

I am studying the signatures associated with Laser Powder Bed Fusion (LPBF) additive manufacturing. LPBF is a process where a laser melts metal powder to build a 3-D part layer by layer. The advantages of LPBF are that it can produce complex geometries, and the high cooling rates associated with the process enable unique material properties. I am using acoustics (sound) to characterize signatures of this process. By using commercial off-the-shelf microphones to listen to the LPBF process, I aim to use sound to identify defects in the final parts. Ultimately these experiments will enable the verification of 3-D printed parts while potentially reducing the qualification time for other materials testing requirements. In addition, acoustic signatures may be able to quantify the process conditions.



Presentation:

D. J., Thoma, A. S., Mangan, A. K., Agrawal, B. Rankhoui, Z. Islam, Design of HEAs for Additive Manufacturing Using High-Throughput Method, 2nd World Congress on High Entropy Alloys, Charlotte NC, December 6, 2021, (Oral Presentation)

4. Scott Snarr (UT): Multiple-Material Selective Laser Melting: Minimizing Material Contamination and Interface Scanning Strategy Development

Advanced manufacturing methods such as multiple-material selective laser melting (SLM) facilitate new levels of design freedom for part fabrication but also potentially enable nuclear proliferation. This project aims to further develop and explore the multiple-material SLM process to better understand the threat it poses to nuclear proliferation in the future. A nozzle-based powder deposition system and novel leveling device were designed and tested to create uniform-height, contamination-free, multiple-material powder beds, as seen in the figure below. This allows for the exploration of scanning strategies for creating strong, high-quality multiple-material parts. The produced multiple-material parts will be analyzed to characterize the quality of bonding at the multiple-material interface and to quantify the bond strength. Relevant signatures of the advanced manufacturing process will then be identified and documented.

Presentation:

Snarr, S., Najera, A., Beaman Jr., J., & Haas, D. (2021). Multiple-material powder bed fusion machine development: reducing cross-contamination between materials. Presented at the 2021 Solid Freeform Fabrication Symposium – An Additive Manufacturing Conference, Austin, TX

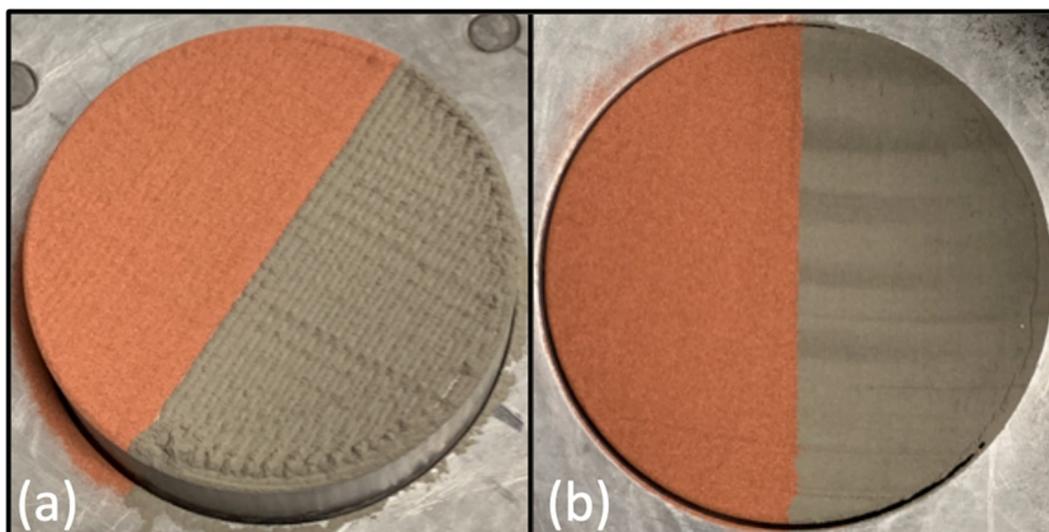
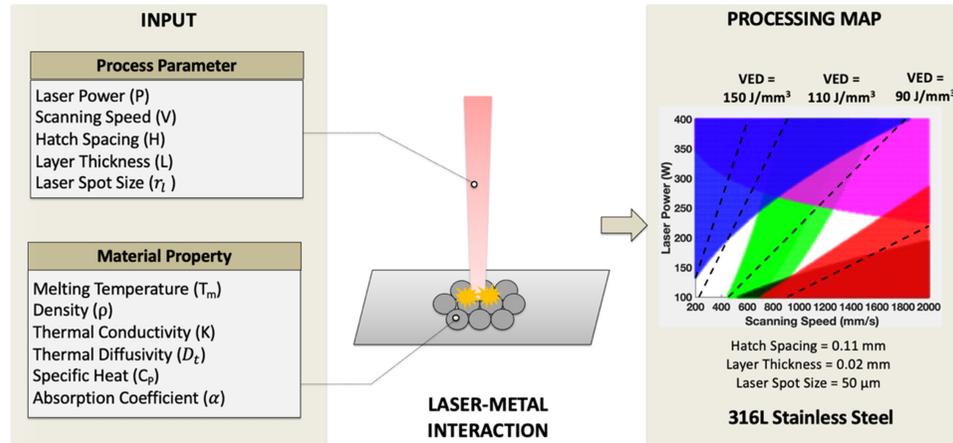


Figure 1. Multiple-material powder bed before and after leveling,
(a) Multiple-material powder bed as deposited via nozzle, (b) Leveled, contamination free multiple-material powder bed

5. Ankur Kumar Agrawal (UW): High throughput process mapping of additively manufactured materials



One of the challenges in additive manufacturing (AM) is to make dense defect-free components. A large number of independently controlled variables make process optimization a time-consuming task. A novel high-throughput (HT) experimental methodology allowed fabrication and analysis of 200+ samples within a week. This approach has three benefits. First, it enables rapid interrogation of samples over a large processing space providing a better understanding of how processing variables affect print quality. Second, the physical and surface signatures permit direct linkages with the internal porosity defects. Samples from different processing regimes can be mapped for easy visualization of the processing window for an alloy. Third, accelerate the generation of high-quality data, particularly when guided with a fundamental premise. Large datasets obtained from the HT approach can be combined with the statistical learning models to predict the optimal processing conditions for an alloy.

Awards:

Turnbull award for best graduate research paper at University of Wisconsin-Madison, 2020

Publications:

- A.K. Agrawal, GM de Bellefon, D.J. Thoma, "High-throughput experimentation for microstructural design in additively manufactured 316L stainless steel", *Material Science and Engineering A*, 793 (2020), 139841
- B. Rankouhi, A.K. Agrawal, F.E. Pfefferkorn, D. Thoma, "A dimensionless number for predicting universal processing parameter boundaries in metal powder bed additive manufacturing", *Manufacturing Letters*, 27 (2021), 12-17
- A.K. Agrawal, D.J. Thoma, "Influence of process parameters on the microstructure evolution and mechanical properties of additively manufactured 316L stainless steel", TMS Annual Meeting 2021, Orlando, USA
- A.K. Agrawal, D.J. Thoma, "High-throughput process mapping and microstructural control in additively manufactured 316L stainless steel", ETI Annual Workshop 2020, Atlanta, USA
- A.K. Agrawal, GM de Bellefon, D.J. Thoma, "High throughput process mapping of metal additive manufacturing applied to austenitic stainless steel and Ni-based superalloys", MS&T 2019, Portland, USA

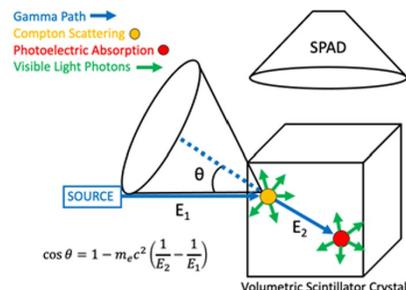
ETI RESEARCH SPOTLIGHTS

Thrust Area 3

1. Alex Bocchieri (UW): Scintillation-Based Gamma Imaging with SPAD Camera

This project is on developing a new gamma ray imager, conventionally known as a "Compton camera", by imaging interactions in a scintillator detector.

The objective of the gamma ray imager is to determine the direction to the radiation source. We use a high speed photon counting camera to estimate interaction locations and energy depositions in the scintillator. Based on these estimates, Compton scattering kinematics are used to backproject a cone representing the direction from where the gamma ray could have originated. Backprojecting many cones from many incident gamma rays results in a heatmap of where the gamma source could exist. The main advantage of our proposed setup is that interactions are observed in a single, thick scintillator volume. Conventional Compton cameras use two thin scintillator planes coupled with silicon photomultipliers. Interactions are more likely to occur in a thick detector than a thin one. Therefore, our method will observe more interactions in a shorter amount of time and locate the radiation source faster. The entire process of imaging gamma interactions and backprojecting cones is simulated with Geant4. Heatmaps from 100,000 incident gamma rays show that our method can determine the direction to the radiation source.



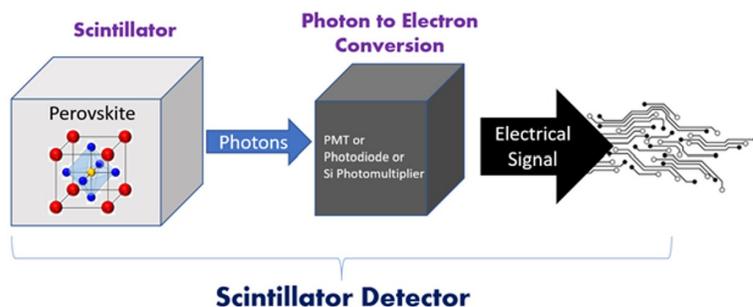
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Publication:

Alex Bocchieri, "Scintillator camera for gamma ray detection and imaging", DOE NNSA University Program Review (UPR2021), September 8 – 10, 2021, Historical Academy of Medicine, Midtown Atlanta, GA.

2. Allen Challie Wood (UNC): Perovskites as Scintillators for Competitive Indirect Radiation Detectors

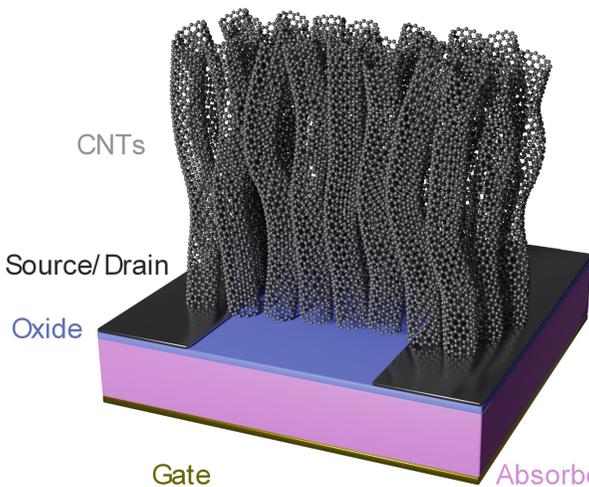
This project aims to use materials with a perovskite crystal structure to create better indirect radiation detectors. The detectors work by taking in radiation of high energy and down converting the radiation to that of lower energy. This detector stage is performed by the scintillator, which the perovskite crystal can be used to create. There are many types of perovskites in single crystal form, with different bandgaps, quantum efficiencies and emission properties that need to be considered to create a good scintillator. The scintillator must also behave in certain ways when subject to high energy incident radiation in order to get good luminescence for the photodiode, or other method of photon to electron conversion, to create a reliable electrical signal. This conversion of the radiation to an electrical signal is then performed by a second stage which can be isolated from the optimization desired for the scintillator stage. There has been a lot of research on Si photomultipliers which can be utilized to create the best detector possible. The goal of this project is to utilize the high light yield that perovskites have already demonstrated



to have to create scintillators with great energy resolutions and perform on par with, or better than, commercially available scintillators like CsI. The wide range of different types of perovskites makes the class of crystal an attractive candidate for creating scintillators sensitive to a wide range of photon energies which can be used to detect radioactive isotopes among other uses.

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3. Arith Rajapakse (GT): Vertically aligned carbon nanotube (CNT) based detector



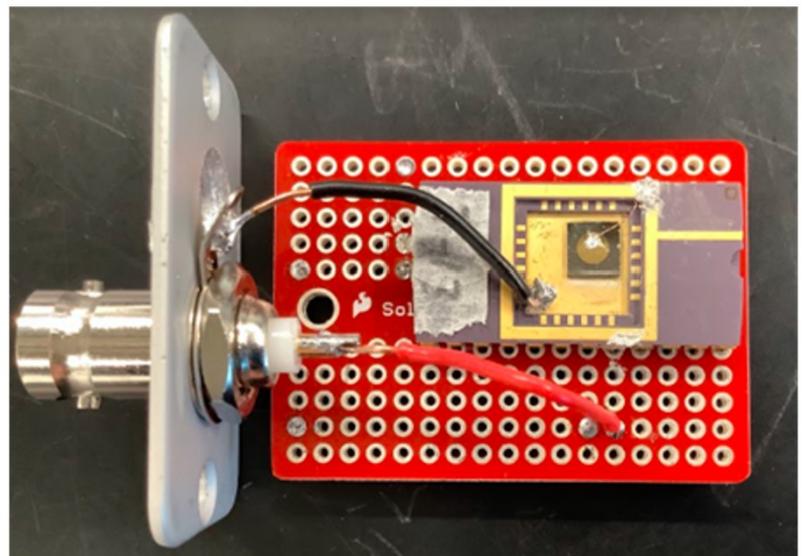
The goal of this project is to design, fabricate, and test a vertically aligned carbon nanotube (CNT) based detector that senses the charge generated by ionizing radiation in a traditional semiconductor detection volume. As charge is produced in the semiconductor, the resulting electric field alters the device conductance. Therefore, ionizing radiation is detected as a change in the device current. The CNT-based detector prototype responds to x-rays and can discriminate between x-ray pulses of varying energy and flux. In addition to indirectly ionizing x-rays, it also responds to directly ionizing radiation such as high energy protons. Aside from radiation detection, the device also demonstrates broadband (near ultraviolet to infrared) photoconductive absorption; enabling it to behave as a photo sensor on its own.

Publications:

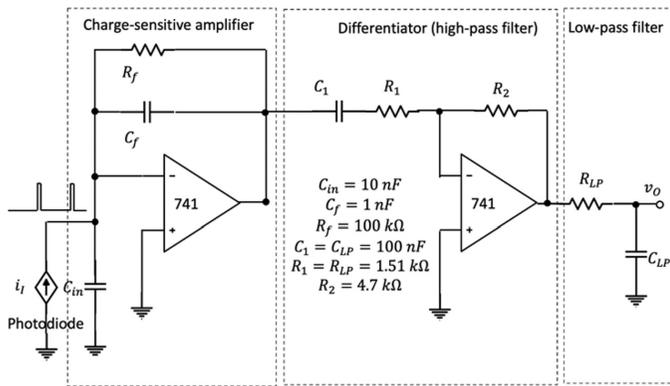
- Arith Rajapakse, Anna Erickson, "Exploring the Photoconductive Nature of Carbon Nanotube Ionizing Radiation Detectors", IEEE Nuclear Science Symposium and Medical Imaging Conference, Yokohama, Japan, October 2021.
- Rajapakse, A. Erickson, "Improving the Device Response of Carbon Nanotube Radiation Detectors through the Fine Tuning of Chemical Vapor Deposition Processes", IEEE Nuclear Science Symposium and Medical Imaging Conference, Boston, Massachusetts, USA, November 2020.
- Arith Rajapakse, Anna Erickson, "Improving the Ionizing Radiation Response of Carbon Nanotube Field Effect Transistor Detectors", IEEE Nuclear Science Symposium and Medical Imaging Conference, Manchester, United Kingdom, November 2019.
- Paul B. Rose Jr., Arith Rajapakse, Anna Erickson, "Ionizing Radiation Detection Using Vertically Aligned Carbon Nanotube Array Transistors", IEEE Nuclear Science Symposium and Medical Imaging Conference, Sydney, New South Wales, Australia, November 2018

4. Jarod Remy (OSU): Evaluation of GaN Schottky diodes for radiation detection and performance under high neutron fluence

Gallium Nitride (GaN) is a wide bandgap and radiation hard semiconductor material that is being explored for use in radiation detection and spectrometry. We are studying Schottky diodes comprised of a thin GaN epitaxial layer deposited on a thicker GaN substrate. The Schottky behavior was formed between the epitaxial GaN and Ni/Au contact and an ohmic contact is made between the GaN substrate and Ti/Al/Ni/Au. We are studying the electrical properties using current-voltage and capacitance-voltage characterization. To test the device's radiation sensing properties, we have measured an alpha spectrum from an Am-241 button source, where a distinguished peak can be discerned. The alpha particles only deposit part of their total energy, so SRIM/TRIM simulations are being performed to help correlate the experimentally acquired peak shift with the simulated energy deposition. X-ray irradiation is also being performed on the devices to show the detectors transient current response. Lastly, the radiation hardness of the devices is being tested by near core irradiation performed at the 500-kW research reactor at the OSU Nuclear Reactor Laboratory.



5. Michael Jin (OSU): Silicon Carbide (SiC) Neutron Detector



Lutz, Gerhard. *Semiconductor Radiation Detectors: Device Physics*. 1999.

Franco, Sergio. *Electric Circuits Fundamentals*. 1994.

The goal of this project is to design, fabricate, and test a vertically aligned carbon nanotube (CNT) based detector that senses the charge generated by ionizing radiation in a traditional semiconductor detection volume. As charge is produced in the semiconductor, the resulting electric field alters the device conductance. Therefore, ionizing radiation is detected as a change in the device current. The CNT-based detector prototype responds to x-rays and can discriminate between x-ray pulses of varying energy and flux. In addition to indirectly ionizing x-rays, it also responds to directly ionizing radiation such as high energy protons. Aside from radiation detection, the device also demonstrates broadband (near ultraviolet to infrared) photoconductive absorption; enabling it to behave as a photo sensor on its own.

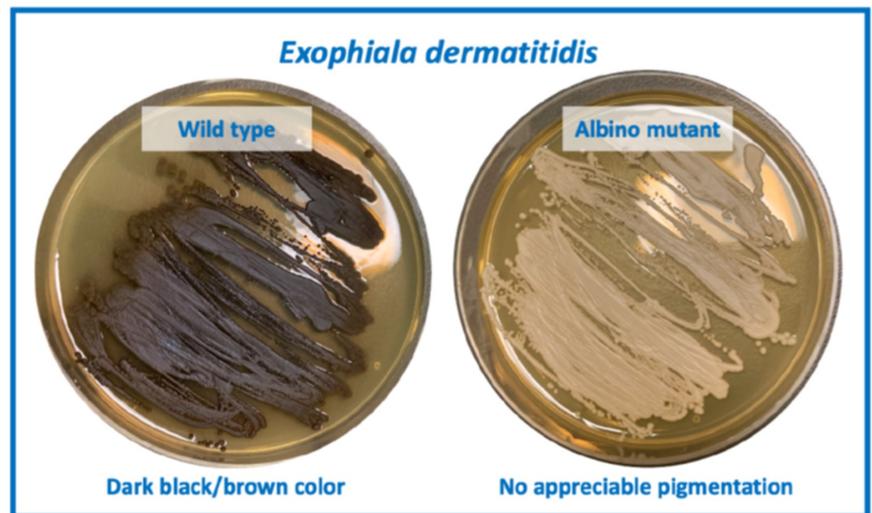
Publications:

- Arith Rajapakse, Anna Erickson, "Exploring the Photoconductive Nature of Carbon Nanotube Ionizing Radiation Detectors", IEEE Nuclear Science Symposium and Medical Imaging Conference, Yokohama, Japan, October 2021.
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6. Haley Schramm (WSU): Passive fungal sensors for radiation

While radiation is commonly used as a method to kill cells, there are unique microorganisms that demonstrate enhanced growth after radiation exposure. Though this characteristic trait called radiotrophism has been studied for decades, its molecular origins remain unclear. The black yeast *Exophiala dermatitidis* exhibits the radiotrophic behavior and has been the main study system. Melanin is made by the fungus and was initially thought to be the cause of the high resistance to radiological stress. An albino mutant was made by genetically altering the black yeast which did not possess the radioresistant behavior. However, subsequent studies comparing the black

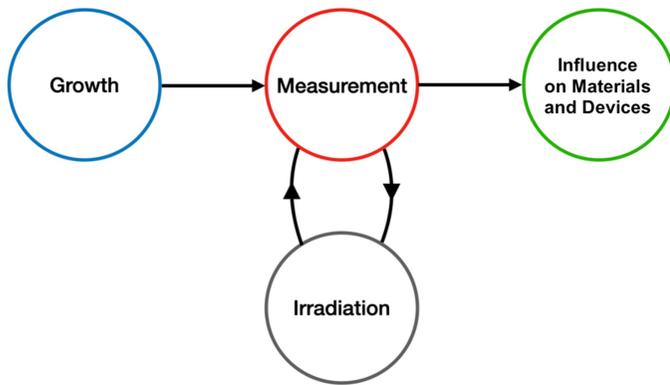
yeast and its albino mutant failed to identify a molecular origin linked to the difference in pigmentation. The proteome, which describes a protein complement, expressed by *E. dermatitidis* has not been thoroughly explored. Since proteins are the chemical components that execute functions within a cell, proteins responsible for a trait of radioresistance would give insights into the molecular mechanisms that enable radiotrophic behavior. The identified molecular mechanisms can be exploited to develop a low-cost, passive radiological biosensor. Genetic modifications that alter the pigmentation expression will be made to create an array of pigmentation intensity that can be used to infer radiation exposure.



7. Evan Cornuelle (OSU): Radiation effects in ultra-wide bandgap gallium oxide

Even though ultra-wide bandgap semiconductors such as GaN and β -Ga₂O₃ are far more radiation-tolerant than conventional Si,

high energy particles still cause atomic damage, which alters electronic properties, device characteristics and circuit performance, none of which are well understood in these newer technologies at present. This work considers β -Ga₂O₃ synthesized using various growth methods, highly sensitive (parts per billion) thermal and light-based measurements, and deliberate radiation of materials and devices, allowing for the fundamental understanding of defects and their impact on device performance and reliability. Such work can enable the production of robust ultra-wide bandgap semiconductor radiation sensors and rad-hard electronics that operate in harsh radiation environments.

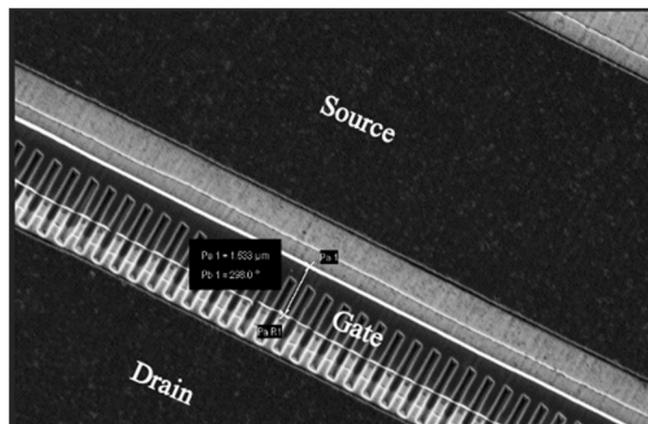


Publications:

- H. Ghadi, J. F. McGlone, C. M. Jackson, E. Farzana, Z. Feng, A. F. M. A. U. Bhuiyan, H. Zhao, A. R. Arehart, and S. A. Ringel, "Full bandgap defect state characterization of β -Ga₂O₃ grown by metal organic chemical vapor deposition," APL Materials, 8 (2), 021111 (2020) <https://doi.org/10.1063/1.5142313>
- E. Farzana, A. Mauzi, J. B. Varley, T.E. Blue, J. S. Speck, A. R. Arehart, and S. A. Ringel, "Influence of Neutron Irradiation on Deep Levels in Ge-doped (010) β -Ga₂O₃ layers grown by plasma-assisted molecular beam epitaxy," APL Materials 7 (12), 121102 (2019) <https://doi.org/10.1063/1.5126463>
- J. M. Johnson, Z. Chen, J. B. Varley, C. M. Jackson, E. Farzana, Z. Zhang, A. R. Arehart, H. Huang, A. Genc, S. A. Ringel, C. G. Van de Walle, D. A. Muller, and J. Hwang, "Unusual Formation of Point Defect Complexes in the Ultra-wide Band Gap Semiconductor β -Ga₂O₃," Phys. Rev. X, 9 (4), 041027 (2019) <https://doi.org/10.1103/PhysRevX.9.041027>

8. Ashok Dheenana (OSU): Radiation Tolerant Wide Bandgap Microelectronics

Solid-state electronics for sensing, communication and computation are essential in enabling technologies for nuclear nonproliferation. When compared to standard Silicon microelectronics, semiconductor electronic devices implemented using wide bandgap materials such as Gallium nitride (GaN) and beta-phase Gallium oxide (β -Ga₂O₃) are less susceptible to degradation in electrical performance in harsh environments with radiation and high-temperatures. Using these materials, we are investigating novel electronic device designs and developing cleanroom fabrication processes that could enable radiation sensors and radiation-tolerant microelectronic circuits.



Presentation:

A. Dheenana et al., "High Current-Density β -Ga₂O₃ Lateral FinFETs". Lester Eastman Conference on High Performance Devices. University of Notre Dame, Notre Dame, Indiana, USA. Aug. 2021.

ETI SUMMER SCHOOL: ADVANCED MANUFACTURING

Date: May 23-27, 2022

The Consortium for Enabling Technologies and Innovation (ETI) is pleased to announce the third ETI Annual Summer School that will be held in-person on the campus of Georgia Institute of Technology, Atlanta, Georgia, on May 23 – 27, 2022. In this 5-day program, advanced manufacturing for nonproliferation will be explored. In-person lab demonstrations and tours will be conducted, including traveling to the Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Limited financial support from ETI Consortium will be available, including lunch, dormitory, and bus travel to Oak Ridge National Laboratory. Students and researchers of all academic levels are invited to participate.

This third ETI summer school will provide an introduction to advanced manufacturing. Initially students will learn about additive manufacturing, micro-manufacturing, and maker-communities. Hands-on learning will include student projects utilizing additive manufacturing technologies at the Flowers Invention Studio (Figure 1) (<https://inventionstudio.gatech.edu/>). Technologies available include a fleet of FDM and SLA printers, along with conventional advanced manufacturing technologies like CNC machining, laser cutters, and waterjet. Tours will introduce students to advanced metal-based additive manufacturing technologies located at the Advanced Manufacturing Pilot Facility (<https://research.gatech.edu/manufacturing/ampf>). Discussions will cover how advanced manufacturing may be utilized within the nuclear fuel cycle. In addition to learning the fundamentals of the technologies, summer school modules will also cover physical signatures, digital and electronic signatures, and side channel signatures from advanced manufacturing. ETI has hosted two successful summer schools.



The Consortium for Enabling Technologies & Innovation (ETI)

Annual Summer School

Advanced Manufacturing for Nonproliferation

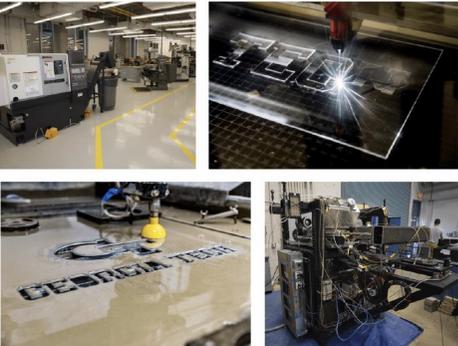
May 23 – 27, 2022 (in-person)

Summer school will be held on the campus of Georgia Institute of Technology

Register by April 8, 2022:
<https://forms.gle/eVCxkLGda345DpKu7>

Documents required for registration:

- CV (1 - 2 pages).
- Half-page statement about why you want to attend this ETI Summer School.



Eligibility requirements: U.S. citizen or permanent resident.

Join us! Here's what you'll get:

- Advanced manufacturing for nonproliferation will be explored.
- In-person lab demonstrations and tours will be conducted.
- Limited financial support from ETI Consortium will be available, including lunch, dormitory, and bus travel to Oak Ridge National Laboratory.

Topic Areas:

- ❖ Day 1 – Introduction to Design Engineering
- ❖ Day 2 – Manufacturing Processes
- ❖ Day 3 – Advanced 3D Printing
- ❖ Day 4 – Predictive Analytics
- ❖ Day 5 – Visit Oak Ridge National Laboratory

More details will be updated on the Summer School website:
<https://eti.gatech.edu/eti-annual-summer-school-2022>

Please contact Kierra Payne for any questions: kierra.payne@me.gatech.edu.



ETI Achievements by the Numbers

3

Students Receiving
B.Sc. Equivalent Degree

9

Students Receiving
M.Sc. Equivalent Degree

7

Students Receiving
Ph.D. Equivalent Degree

3

Students Accepting
a Job in the Field

6

Internships

2

Postdocs Transitioning to
National Labs

33

Peer-Reviewed Publications Accepted

5

Book Chapters Accepted

1

Other Publication Accepted

28

Oral Presentations by Students

1

Oral Presentation by Postdocs

33

Oral Presentations by Professors/Faculty

16

Poster Presentations by Students

3

Poster Presentation by Faculty

33

Conference Papers/Reports

7

Keynote Speaker/Invited Talks

6

Outreach Programs

28

Courses Designed by ETI

AWARDS & HONORS

for ETI Faculty Members/Students



Alfred Hero was named a Life Fellow by the Institute of Electrical and Electronics Engineers (IEEE), July 2021



Aurora Clark was named a fellow of the American Physical Society, the nation's leading association for physicists..



Jinsong Huang was named a 2021 Highly Cited Researchers™ in Materials and Chemistry on Publons.



Atul Ingle was awarded Best Poster award at the University Program Review, Atlanta 2021.



Alan Sellinger was named a Highly Cited Author Award as one of the top 1% most cited authors in Royal Society of Chemistry journals, 2020



Kate Thompson's, poster was awarded Best National Laboratory Collaboration at the University Program Review, Atlanta 2021.

SCHOLARSHIP RECIPIENTS SPOTLIGHT

Fellowship and Scholarship Recipients Update



Sarah Mantell

Sarah Mantell is a Ph.D. student at the University of California, Santa Barbara. Sarah has spent the majority of her time during the last few months preparing a conference paper for her work in developing computer vision based detection methods for melt pool defects. Sarah will get the chance to present her work at a machine learning conference in July 2022. Additionally, Sarah has been working with her mentors at Los Alamos National Laboratory to create a research plan for Summer 2022. The remainder of time has been dedicated to studying for my qualifying exams which I will take at the end of the school year.

Alexandra (Lexie) Schueller

Alexandra (Lexie) Schueller is a third-year graduate student at the Georgia Institute of Technology studying mechanical engineering. Previously, she graduated from The University of Texas at Austin with a B.S. in mechanical engineering and a certificate in manufacturing and design. She also has past experience working at 3M, General Electric, and IBM on measurement system design, thermal systems design, design for manufacturing, and manufacturing process optimization.



Jordan Parker-Ashe

Jordan Parker-Ashe is a Massachusetts Institute of Technology freshman from Virginia Beach, VA. She has been focusing on advancing her technical skills. Last semester, under her PI's supervision, Joran built a Geiger Counter from scratch (except for the Geiger tube). She states, "Learning the circuitry involved really helped me grow as a nuclear engineer." This semester, with another researcher from MIT's Plasma Science and Fusion program, Jordan is building a LED Peltier-cooled cloud chamber to detect and visually show ionizations. She has learned that she really enjoys working with her hands, and having a thorough foundation in electronics, machining, designing, and building has made her a better researcher.



Nick Folino

Nick graduated with his B.S. in Computer Engineering at The Ohio State University in December 2021. Since graduating in December, I accepted a full-time position as a Hardware Engineer at CAS (Chemical Abstracts Service), a division of the American Chemical Society in Columbus, Ohio. In this position, I maintain the computer hardware and monitoring systems in CAS's main data center. This position will allow me to further my knowledge of hardware technologies and could lead me to attending graduate school for a masters degree in Computer Engineering.



Alexander Greenhalgh

Alex is currently an undergraduate material science and engineering major with a minor in mathematics at the University of Tennessee, Knoxville. His hobbies include trail running and 3D printing. Alex has always had a fascination with computer science, so he wants to go into a field like computational science that combines his domain knowledge of materials with his interest in mathematics and coding.





eti.gatech.edu