Pacific Northwest
NATIONAL LABORATORY

PNNL-35306

Summary Report for the 2023 Radiation Detection for Nuclear Security Summer School

November 2023

BS McDonald
ML Woodring
JE Baciak, University of Florida

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Pacific Northwest National Laboratory
Richland, Washington 99354

Summary

The Pacific Northwest National Laboratory (PNNL) hosted the 9th Radiation Detection for Nuclear Security Summer School 20-30 June 2023 in Richland, WA. The school provided students with an understanding of nuclear security challenges faced in the field and exposed them to the technical foundations and insight needed to contribute to this applied research and development area.

Acknowledgments

We thank the National Nuclear Security Administration's (NNSA's) Defense Nuclear Nonproliferation Office of Research and Development for supporting the summer school. We thank the people who gave guest lectures and helped with activities and tours. This included: Brian Archambault, Becky LaMastus, Bob Runkle, Cindy Henderson, Ches Simpson, Fiona Kroontje, Dustin Kasparek, Paul Johns, Eric Becker, Brittany Robertson, David Meier, Andrew Puyleart, Stephanie Lyons, Angela Moore, Eric Smith, Nicole Lahaye, Todd Hossbach, Emily Mace, Angela Moore, David Springfels, Glen Warren, Matt Cooper, Lance Lidey, Mital Zalavadia, Hank Zhu (NNSA), and Andy Karam (DHS). We especially thank Kathy Roberts, Erin Kinney, Kevin Damrell, Mary Bliss, and Claudia Romero for their logistical and programmatic efforts behind the scenes that helped make the summer school a success.

Figures

Tables

1.0 Introduction

The Pacific Northwest National Laboratory (PNNL) hosted students from across the United States at the 9th Radiation Detection for Nuclear Security Summer School 21-30 June 2023 at the Richland, WA campus. The course featured technology demonstrations, tours of operational facilities, and interactive instruction with detection equipment and methods. Students interacted with PNNL experts and external leaders in nuclear security.

The course is designed for graduate students in science and engineering programs with interest in careers within the US national laboratory system or federal government agencies responsible for nuclear security. Undergraduate students are also considered. Priority is given to students whose research is funded by the NNSA's Office of Defense Nuclear Nonproliferation R&D and students performing research in fields with potential nuclear security applications. Enrollment is limited to approximately 16 students. It has been held eight times since 2012. A significant number of summer school alumni work at national labs and government agencies, including at least seven currently at PNNL.

Students attended from universities across the country. A group photo is shown below in Figure 1 and details about the students are provided in Table 1. A third of the students were involved with the National Nuclear Security Agency (NNSA) University Consortia programs this year.

Figure 1. Group photo of the 2023 Summer School participants, instructors, and support staff.

Table 1. List of students and some details about their backgrounds.

Name	School	Field of Study	Research Topic
Jace Beavers*	Kansas State University	Nuclear Engineering	Low-power radiation detection systems
Bryana Wattier*	Clemson University	Environmental Engineering & Earth Sciences	Life cycle assessment related to nuclear fuel cycles
Zachary Tobin	Texas A&M University	Chemistry	Nuclear structure
Nicholas Mendez	Michigan State University	Physics	Experimental nuclear physics
Justin Borrero*	University of Florida	Chemical Engineering	Fallout models
Conner Howard	Washington State University	Mechanical Engineering	TBD
Nathan Luu	Oregon State University	Radiation Health Physics	Health physics and nuclear medicine
Andrew Wantz	Michigan State University	Nuclear Physics	Experimental nuclear physics
Adam Hartley*	Michigan State University	Nuclear Chemistry	Neural networks for detector analysis
Hannah Patz*	University of Florida	Nuclear Engineering	Nuclear forensics
Aaliyah St. Louis-Alleyne	Florida A&M University	Physics	TBD
Germany Harris	Alabama A&M University	Chemistry	TBD
Sarah Olocha	Alabama A&M University	Civil Engineering	TBD
Dewayne Maye	Alabama A&M University	Computer Science	TBD
Scott Garner	Florida A&M University	Computer & Electrical Engineering	TBD

*Students doing research as part of NNSA University Consortia

2.0 Course Schedule and 2023 Updates

The detailed, nine-day schedule for the school is provided in the appendix. It included foundational lectures, guest lectures, lab and facility tours, and interactive exercises. Some materials were updated to include recent developments in detector technology and applications to evolving nuclear security missions. The content in 2023 was revised for targeted lectures and activities. New or refined items included:

- Included a lecture by Cindy Henderson to provide initial motivation for course topics: “Why do we care? Proliferation and the state of the world.”
- Included a new guest lecture on nuclear arms control research by Dr. Glen Warren.
- Included new (to the course) introductory lecture on international safeguards and a hands-on safeguards activity as part of the B reactor tour (led by David Springfels).
- Made significant updates to a lecture on Radiation Imaging Applications.
- Revised the “Who caught the bad guy?” exercise to use a radiation portal monitor re-play tool to train the students on how to set energy thresholds to discriminate among sources.

Measurements were collected at the 3440 test track and analyzed as part of a team-based competition ("The Megabowl").

- Hosted Dr. Andy Karam from the Department of Homeland Security, National Urban Security Technology Laboratory (NUSTL), who shared about work in radiological emergency response and working with first responders.
- Hosted Dr. Hank Zhu from NNSA/Defense Nuclear Nonproliferation Research & Development, who shared an overview of his career and his research portfolio with students.
- New lab tours at PNNL included tours of labs focused on CCDs, X-ray imaging, and general-purpose radiation detection research and development.
- Updated a hands-on machine learning activity where students worked through two Python Jupyter notebooks with PNNL staff guiding.
- Revived an older activity from earlier summer school called "Nuclear in the News," where students find recent news stories from reputable sources, and they are discussed and categorized into various nuclear security mission areas explored in the course.

The activities and laboratory tours provided students with insight and examples of how radiation detectors are used in research and operational settings. These included a visit to a laboratory containing a Swedish Automatic Unit for Noble Gas Acquisition (SAUNA) system which is designed for low-level measurement of radioxenon. These systems are used as part of the International Monitoring System network of the Comprehensive Test Ban Treaty Organization. Students toured the Radiochemical Processing Laboratory (RPL) used for research in cleanup of radiological wastes, processing and disposal of nuclear fuels, and production and delivery of medical isotopes occurs. Additional, students received training at the HAMMER facility and toured a local nuclear fuel fabrication facility. An example thermal image of reactor- and weapons-grade plutonium sources at the HAMMER facility is shown in Figure 2

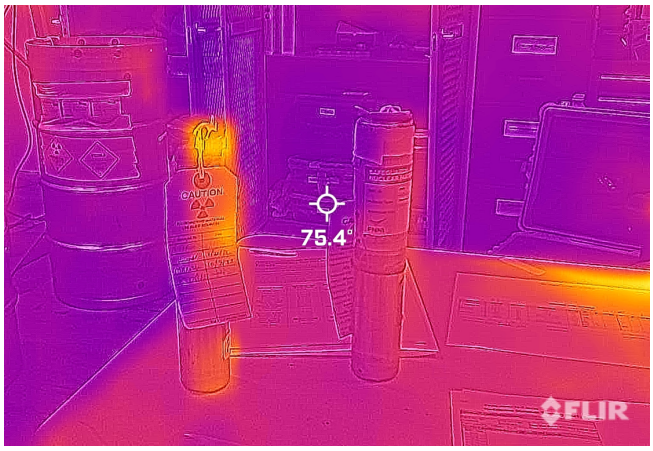

Figure 2. Thermal image of reactor-grade (left) and weapons grade (right) plutonium sources at the HAMMER facility.

Students donned Tyvek suits and toured of the shallow underground laboratory (SUL, Figure 3) where low-background detectors are assembled, tested, and used for national security, environmental, and fundamental science applications.

Figure 3. Photograph of students during the Shallow Underground Laboratory hold ultrapure copper samples.

Figure 4. Students and PNNL staff during a ‘speed mentoring’ networking session.

Table 2. Summary of activities and tours. Students viewed locations via Zoom interface.

ACTIVITY/TOUR	PURPOSE	LOCATION
Lost Source Exercise	Demonstrate how radiation detectors can be used to detect, locate, and characterize radiation material in various situations	PNNL 3440 Test Track
SNM Overview	Learn from experts about the types of material encountered in the nuclear fuel cycle. Demonstration of shielding for neutron and gamma sources.	Volpentest HAMMER Training and Education Center
Who Caught the Bad Guy?	Students form teams and develop energy windowing algorithms for an RPM to maximum detection sensitivity and reduce false alarms	PNNL 3440 Test Track
Laboratory tours	Expose students to some research and development laboratories and some operational facilities	PNNL Shallow Underground Laboratory, Radiochemical Processing Laboratory, 361 Building (SAUNA)

3.0 Findings and Feedback

Students completed a form at the end of the course that included quantitative feedback to prescribed questions and qualitative written feedback. Results from the student surveys are provide in Table 3 and Table 4. Most students thought the length of the school was 'just right,' and overall provided positive feedback about the content and structure of the program.

Table 3. Student survey results regarding the length of the school.

	Too short	Just Right	Too long
The length of the summer school was:	2	10	3

Table 4. Student evaluation survey results.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I found the Radiation Detection for Nuclear Security Summer School to be informative and engaging.				
13	2			
The Radiation Detection for Nuclear Security Summer School improved my understanding of the nuclear security mission.				
10	5			
I believe the Radiation Detection for Nuclear Security Summer School enhanced my understanding of radiation detection as applied to nuclear security.				
9	6			
The activities/experiments performed within the Summer School were useful.				
5	10			
The facility tours were engaging and enhanced your understanding of the nuclear security mission.				
6	9			
The guest lectures provided improved understanding of the challenges associated with the wide scope of nuclear security.				

7	7	1	
Having student participants present on their research is an important part of the summer school agenda.			
5	5	2	3
I would recommend the Radiation Detection for Nuclear Security Summer School to other students.			
10	3	2	
Participation in the Radiation Detection for Nuclear Security Summer School has increased my interest working within the nuclear security mission at national laboratories, or for the federal government.			
8	4	3	

My favorite part of the summer school was:

- The different people that were able to give us talks, also I liked the daily tours.
- The tours and the forensics lecture
- B Reactor, SUL, many tours of practical applications. Activities (namely hands-on) were greatly enjoyable (Mega bowl).
- B Reactor tour, underground lab
- The shallow underground lab tour!!!
- Visiting the labs/fields.
- Hanford B Reactor Tour!
- Facility tours
- Guest lectures, lab tours, group activities, hands-on coding
- I liked meeting the radiation detector scientists and engineers. I really appreciated the opportunity to collaborate and work with other students, as well.
- All the tours and activities that show how rad detection is applied to national security.
- All the tours!
- Tours were great along with the real-world activities.
- The tours were amazing. HAMMER and the underground lab were amazing.

I would make improvements to the RDNS Summer School by:

- By cutting the hours back just a little bit.
- The first four lectures are every informative and should be emailed of the students by the end of the week. That would have helped the students can review the material and ask questions for the following week.
- Disperse lectures more and/or lecture mornings, activities after lunch.
- Put the “Clean room” lab tours before the fuel fabrication facility tour.
- In general, it seems like there is so much information given, in such a short time frame. Also, I feel like lectures first thing in the morning are a little(sp). I found it hard to focus when I was just waking up.
- Having the lecturers be prepared to tally/engage with students who have no knowledge of nuclear power as some of this information went over a lot of people’s head.
- Overall, there was a good mix of activities and lectures, and generation there was a good distribution between them. However, at times it would have been nice to intersperse them more (avoids being tired on your feet or a little zoned out in lecture).
- Needs more one-on-one meetings with faculty to discuss prospects working for the lab.
- Would be nice to have a group social event or dinner. Would’ve liked to have respected the designated time for student presentations rather than squishing them around.
- 1) I think the class should be more widely advertised. 2) I think the application process should be more selective. I like the diversity in background, but I also think the less advanced students weren’t quite as incisive. 3) It would be nice to collect presentation topics prior to the summer school, so relevant scientists at the lab could attend if available.
- When presenting student research, more PNNL staff members should be present, so they are more opportunities for students to talk to researchers that are doing research that the student wants to do.

- Student presentations: more scientists/engineers should be present (particularly those working on relevant work). There was only one present for mine and it was unrelated to my research, so I got no questions or feedback.
- More specialized (smaller groups) for networking. Maybe a career fair of some sort?
- Syllabus delivered sooner.
- More networking opportunities would have been nice.
- Have the presentations on hand before speakers give their talks.
- The student presentation should be in the presence of staff scientist or post-docs. It would be good networking. In front of the students alone is useless.

Other comments:

- Diversity of activities was great. As an undergrad in an unrelated field, I was able to follow along on most of the high-level science-y talks.
- Dancing palm trees next year, please.
- I feel like the course isn't very beginner friendly. For those who have some background, it is a really great course.
- Thank you for this opportunity!
- I felt that the career event (speaking w/ people from PNNL) was really short and career opportunities felt crammed in at the end.
- Thank you! The Megabowl training dataset could be expanded, even if they are unknown sources.
- The lab tours being in the morning meant we were exhausted after lunch and had a hard time with paying attention to the lectures after lunch.
- If we could get some slides before the classes started that would be great.
- The Megabowl activity was a tad disorganized since the method we were told about didn't follow the information we were given. Also, a narrower list of potential material options would be helpful to narrow scope.
- The machine learning activity was chaotic due to multiple conversations being held at once, would prefer if it was able to be done in groups.
- Excellent snacks.
- Thank you so much

The key findings of the summer school are provided in Table 5.

Table 5. Key Summer School Findings.

ATTENDANCE	
Number	PNNL hosted 15 students
Backgrounds	Consistent with previous years, the students possessed diverse academic backgrounds that included nuclear engineering, physics, chemistry, computer science, and other engineering disciplines.
Schools	Students from the following schools participated: Washington State University, University of Florida, Alabama A&M University, Florida A&M University, Texas A&M University, Kansas State University, Michigan State University, Oregon State University, Clemson University
CURRICULUM	
Lectures	A set of core lectures covered topics spanning nuclear security missions, special nuclear material signatures accessible via radiation detection, gamma-ray and neutron detector systems, charged particle detection, radiation imaging applications, and test and evaluation.
Guest Lectures	Guest lectures allowed students to interact in a small group setting with national experts on a range of relevant topics that included treaty verification, defense nuclear nonproliferation, nuclear material interdiction, triage, nuclear forensics, and emergency response.
Activities & Tours	The most unique aspect of the summer school was the hands-on activities and focus on missions and applications. These activities gave students an appreciation for field environments encountered by technology users and exposure to the challenges faced by technology developers. Activities included a lost source search exercise, energy windowing algorithm testing with a radiation portal monitor, in-class discussion of recent events, and machine learning exercises. Laboratory tours provided students with insight into facilities and instruments used for cutting edge research and development, including PNNL's shallow underground laboratory, Radiochemical Processing Laboratory, and radiation detector development laboratories.
Student Lectures	Students shared their current research with the class in 5–10-minute presentations throughout the nine days of the course.
FEEDBACK & LESSONS LEARNED	
Student Evaluations	Feedback overall indicated that the summer school was informative and engaging, and that it improved their understanding of the nuclear security mission and how radiation detection relates to nuclear security. Most feedback providers agreed that they would recommend the summer school to their peers. Their written comments showed, consistent with past years, that the tours, activities, and professional interactions were the favorite parts of the school. Students also provided constructive feedback, such as how to better load the balance of lectures and activities.
Key lessons learned	• Students suggested that student presentations be presented in front of PNNL technical staff kind of like speed mentoring. That way our staff could see what students are working on and help guide them. • Prepare a student web site, Teams site, or Wiki page with presentations, agenda, maps, and as a potential collaboration space for team activities. • Try to schedule more activities after lunch or intersperse lectures and activities more homogeneously, if possible, to keep students better engaged. • Students requested to have presentations ahead of time or during presentation that are printed out so they can write notes on them and follow along.

4.0 Conclusions and Future Plans

Student evaluations indicate that the summer school again achieved its objectives of exposing students to nuclear security applications and operational challenges, articulating the connection of student research into broader applied mission areas, and growing student interest in careers in at national labs and government agencies.

Fiscal year 2024 will be an off year for the summer school. We plan to improve the content and layout of the summer school based on student feedback and emerging topics. We also will promote school and share outcomes at a conference such as the Institute for Nuclear Materials Management annual meeting, which includes section on workforce development in nuclear security and other areas.

Appendix A Summer School Schedule

DAY 1 – Tuesday, June 20, 2023

TIME	TOPIC	PARTICIPANTS
7:30 am	Badging Office	Badging at 650 Horn Rapids Rd
8:00 am	Welcome: Introductions, Logistics, and overview	Ben McDonald
8:30 am	Lecture 1: The Nuclear Security Mission (Discovery Hall)	Bob Runkle
9:30 am	Walk to 3440, Safety Video	
9:45 am	Activity 1: Team building Exercise 3440 test Track	Mitch Woodring, Jim Baciak
11:30 am	Discuss student presentations	Mitch Woodring, Jim Baciak
12:00 pm	Lunch Break (Summer on the Sidewalk)	
1:00 pm	Lecture 2: The Physics of Fission, Nuclear Fuel, Enrichment, Reactors	Prof. Jim Baciak
2:00 pm	Group photo	
2:30 pm	Lecture 3: Fundamentals of Radiation Detection: γ Rays	Prof. Jim Baciak
3:30 pm	Guest Lecture 1: Radiological ER	Eric Becker

DAY 2 – Wednesday, June 21, 2023

TIME	TOPIC	PARTICIPANTS
7:45 am	Meet at ESC parking lot, Vans leave at 7:50 am	Erin Kinney, Jim Baciak, Kevin Damrell
8:00 am	Activity 2: HAMMER tour and training	
12:15 pm	Vans back to campus	
12:30 pm	Lunch Break	
1:30 pm	Lecture 4: Fundamentals of Radiation Detection: Neutrons	Jim Baciak
2:30 pm	Student presentations	Mitch Woodring, Jim Baciak
3:00 pm	Guest Lecture 2: DHS NUSTL	Andy Karam
4:00 pm	Activity 3A: Intro to “Who Caught the Bad Guy?”	Mitch Woodring

DAY 3 – Thursday, June 22, 2023

TIME	TOPIC	PARTICIPANTS
8:00 am	Guest Lecture 3: Why do we care? Proliferation & the state of the world	Cindy Henderson
9:00 am	Vans to Fuel Fabrication Facility (ESC parking lot) Activity 7: Fuel Fabrication Facility Tour	Mital Zalavadia, Mitch Woodring
12:00 pm	Lunch Break	
1:00 pm	Lecture 5: Signatures of Special Nuclear Material, Spent Nuclear Fuel	Jim Baciak
2:00 pm	Guest Lecture 4: NSDD	Paul Johns (virtual)
3:00 pm	Gamma Ray and Neutron Detection Systems	Jim Baciak

4:00 pm	Activity 3A: “Who Caught the Bad Guy?” discussions	Mitch Woodring

DAY 4 – Friday, June 23, 2023

TIME	TOPIC	PARTICIPANTS
8:00 am	Activity 3A: “Who Caught the Bad Guy?” (3440)	Mitch Woodring, Mital Zalavadia
10:00 am	Activity 3B: SUL Tour (3425)/Portal measurements (3440) (split into groups of 8)	Emily Mace
12:15 pm	Lunch Break	
1:00 pm	Activity 3B: SUL Tour/Portal measurements Groups Swap	Emily Mace
3:30 pm	Guest Lecture 5: Radiation Triage	Ches Simpson

DAY 5 – Monday, June 26, 2023

TIME	TOPIC	PARTICIPANTS
8:00 am	Activity 3C: Who Caught the Bad Guy?” Results	Mitch Woodring
9:00 am	Student presentations	Jim Baciak, Mitch Woodring
9:30 am	Guest Lecture 7: Arms Control	Glen Warren
10:30 am	Nuclear in the News	Ben McDonald
12:00 pm	Lunch break	
1:00 pm	Lecture 8: Test Science & Hands-on Example	Mitch Woodring, Angela Moore
2:45 pm	Activity 6: Ask me Anything – Speed Mentoring	
4:00 pm	Student Presentations	Ben McDonald

DAY 6 – Tuesday, June 27, 2023

TIME	TOPIC	PARTICIPANTS
8:00 am	Lecture 7: Charged Particle Detection (3420, Fermi Room) Meet at Discovery Hall at 7:50 am (Kevin)	Todd Hossbach
9:00 am	CCD Lab Tour (3420)	Todd Hossbach
10:05 am	Vans to PSL	Erin Kinney, Kathy Robertson, Kevin Damrell
10:15 am	Tour of Detector Labs (PSL)	Mital Zalavadia
11:05 am	Vans to ESC	Erin Kinney, Kathy Robertson, Kevin Damrell
11:15 am	Guest Lecture 6: Introduction to Safeguards	David Springfels, Fiona Kroontje
12:15 pm	Lunch break (Summer on the Sidewalk)	
1:15 pm	Lecture 8: Radiation Imaging Applications	Erin Miller, Dustin Kasparek
2:15 pm	Vans to 331	Erin Kinney, Kathy Robertson, Kevin Damrell
2:30 pm	Activity 12: Tour of Imaging Lab (331/171)	Ben McDonald, Mital Zalavadia

3:15 pm	Vans back to campus	Erin Kinney, Kathy Robertson, Kevin Damrell
3:30 pm	Activity 13: Introduction to Safeguards & B-Reactor Activity	David Springfels

DAY 7 – Wednesday, June 28, 2023

TIME	TOPIC	PARTICIPANTS
8:00 am	Meet at ESC parking lot, Vans to B-Reactor Visitor Center	David Springfels, Erin Kinney, Claudia Romero, Kevin Damrell
9:00am	B-Reactor Tour	
12:15 pm	Vans back to campus	Erin Kinney, Claudia Romero, Kevin Damrell
12:30 pm	Lunch Break	
1:30 pm	Student Presentations	Jim Baciak, Mital Zalavadia
3:30 pm	Guest Lecture 8: NNSA/DNNR&D	Hank Zhu

DAY 8 – Thursday, June 29, 2023

TIME	TOPIC	PARTICIPANTS
8:00 am	Guest Lecture 9: Rapid Response & International Deployment Capabilities	Matt Cooper
9:00 am	Guest Lecture 10: Nuclear Forensics	David Meier
9:50 am	Vans to 361	Erin Kinney, Kathy Robertson, Kevin Damrell
10:00 am	Activity 10: RASA Tour, 361 Building	Lance Lidey
10:50 am	Vans to RPL	Erin Kinney, Kathy Robertson, Kevin Damrell
11:00 am	Activity 11: RPL Lab Tours	David Meier
12:20 pm	Vans to ESC	Erin Kinney, Kathy Robertson, Kevin Damrell
12:30 pm	Lunch break	
1:15 pm	Activity 8: Hands-On Machine Learning and Detector Applications	Brian Archambault, Andrew Puyleart

DAY 9 – Friday, June 30, 2023

TIME	TOPIC	PARTICIPANTS
8:00 am	Guest Lecture 11: NGFP and internships	Becky LaMastus
9:00 am	Lecture 9: Emerging Trends & Opportunities	Bob Runkle
10:00 am	Awards, Questions & Discussion/Feedback	

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