Pacific Northwest
NATIONAL LABORATORY

PNNL-29646

Summary Report for the 2019 Radiation Detection for Nuclear Security Summer School

January 2020

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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 students from across the United States at the 6th Radiation Detection for Nuclear Security Summer School 17-28 June 2019. The summer school provided students with a unique understanding of nuclear security challenges faced in the field and exposed them to the technical foundations, analyses, and insight that will be required by future leaders in technology development and implementation. The course heavily emphasized laboratory and field demonstrations including measurements of special nuclear material. Student evaluations and feedback from student advisors indicates that the summer school achieved its objectives of 1) exposing students to the range of nuclear security applications for which radiation detection is necessary, 2) articulating the relevance of student research into the broader context, and 3) growing student interest in careers in nuclear security.

Acknowledgments

We thank the National Nuclear Security Agency's Defense Nuclear Nonproliferation Office of Research and Development for supporting the summer school. The tour of the Framatome Fuel Fabrication Facility is always a highlight, and we thank Framatome for their hospitality. We thank the long list of people who gave guest lectures, helped with activities and tours, and provided logistical support, especially Amy Nixon and Kathy Roberts for their efforts behind the scenes that helped make the summer school a success, and Valarie Velasquez for her help preparing this report.

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1.0 Introduction

The Pacific Northwest National Laboratory (PNNL) hosted students from across the United States at the 6th Radiation Detection for Nuclear Security Summer School from 17-28 June 2019. The cohort consisted of one advanced undergraduate student and fourteen graduate students. They were all U.S. citizens and came from universities across the country. All students, but one - International Relations, are in Science, Technology, Engineering, or Math (STEM) programs, and roughly half are currently engaged in DNN R&D University Consortia research. A group photo is shown below in Figure 1 and details about the students are provided in Table 1. This enrollment size enabled hands-on laboratory activities and tours and fostered a collaborative and discussion-rich atmosphere.

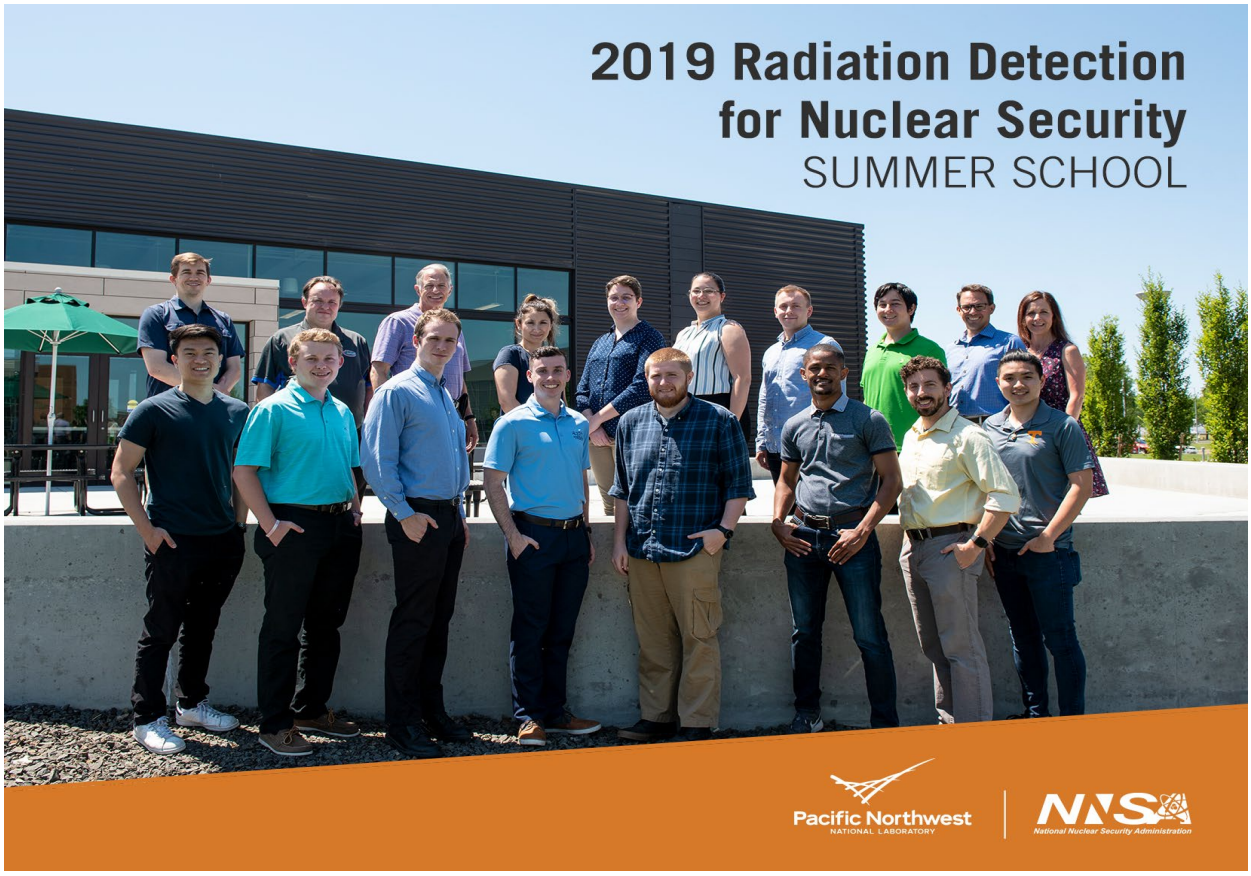

Figure 1. Group photo of the 2019 Summer School participants, instructors, and support staff.

Table 1. List of students, their universities, fields of study, and research topic (as applicable).

STUDENT	UNIVERSITY	FIELD OF STUDY	RESEARCH TOPIC
Ana Arteaga	Oregon State University	Inorganic Chemistry	Intersection of fundamental 4f and 5f chemistry: Solution and structural characterization studies
Robert (Jake) Carter Jr.	University of Tennessee	Energy Science & Engineering	Identification of radiation isotopes, multiple detector modeling, and investigation of close packed detectors for Compton scattering location information.
Katherine Childers	Michigan State	Chemistry	Constraining the cross section of ^{82}Se(n,γ) ^{83}Se to validate the β-Oslo Method.
Brandon Cortino	North Carolina State University	International Relations	Analyzing Russian foreign and missile policy, Pacific allies' grand strategy, and ally responses to statements made by key political figures in US foreign policy.
Wesley Gillis	Georgia Institute of Technology	Nuclear Engineering	Novel techniques in uranium mass verification from fresh nuclear fuel for international safeguards.
Rebecca Krentz-Wee	University of California Berkeley	Nuclear Engineering	Use of a time-encoded radiation imaging system for warhead verification in future arms control treaties.
Mitch Mannino	Oregon State University	Nuclear Engineering	Characterizing SNM with temporal spectroscopy.
Owen Mannion	University of Rochester	Physics	Nuclear fusion research using high energy density plasmas at the University of Rochester's Omega Laser Facility.
Noah McFerran	University of Florida	Nuclear Engineering	Characterize sources of spectral variation of the gamma-ray emissions of a filled uranium hexafluoride (UF_6) cylinder.
Robert Olesen	Air Force Inst. Tech.	Nuclear Engineering	Rotating Scatter Mask (RSM) project, a low-cost radiation detection system capable of determining the direction of a gamma-emitting source over a nearly 4π solid angle field-of-view.
Anthony Papol	Washington State University	Physics & Astronomy	Galaxy merging events and formation histories.
Dustin Scriven	Texas A&M	Physics & Astronomy	Develop highly pixelated neutron detector made of PSD-capable organic scintillator (p-Terphenyl).
Ryan Tan	University of Tennessee	Nuclear Engineering	Development of low-cost semiconductor radiation detectors operable at room temperature.
Surafel Woldegiorgis	University of Florida	Nuclear Engineering	Deep-net assisted neutron CT for future treaty verification and photo-fission yield calculations based on Microscopic Nuclear Fission model.
Wilson Tam Yong	University of California Berkeley	Data Science	Not yet defined (Undergraduate)

2.0 Course Schedule and New Activities

The two-week agenda for the school is provided in Figure 2 and Figure 3, including core lectures, guest lectures, lab and facility tours, and hands-on activities. Overall, it was executed without major issues. As usual, some materials were updated to include recent developments in detector technology and applications to evolving nuclear security missions. New or refined lectures and activities this year included:

- A pulse-shape discrimination lab with a liquid scintillation detector,
- A guest lecture from SGM Gary Mauk (79th Troop Command, 1 CBRN-Task Force, Massachusetts National Guard),
- A lecture on charged particle detection, which was given before the shallow underground lab tour,
- A half-day, hands-on machine learning workshop with PNNL experts and connections to radiation detector data analysis,
- Briefings on some of NA-22's data science and proliferation detection portfolios by Angie Waterworth and Craig Sloan, respectively, and
- A speed mentoring and career discussion session with a range of PNNL staff (Figure 6).

The activities and laboratory tours (Table 2) were again the highlight of the summer school course in several ways, because they provided students with hands-on experience using detectors, such as those in Figure 2 and Figure 3 that are currently deployed in operational environments. The primary goal of the activities was to demonstrate the challenges faced by technology operators, for example the difficulty of carrying heavy instrumentation. A set of laboratory and off-site tours gave students an appreciation of specialized instruments used in various nuclear security settings. These included a visit to the SAUNA (Swedish Automatic Unit for Noble Gas Acquisition) 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 were also given a tour of the shallow underground laboratory (SUL) where low-background detectors are assembled, tested, and used for national security, environmental, and fundamental science applications; 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. Students also experienced a typical detector development lab during the pulse shape discrimination activity.

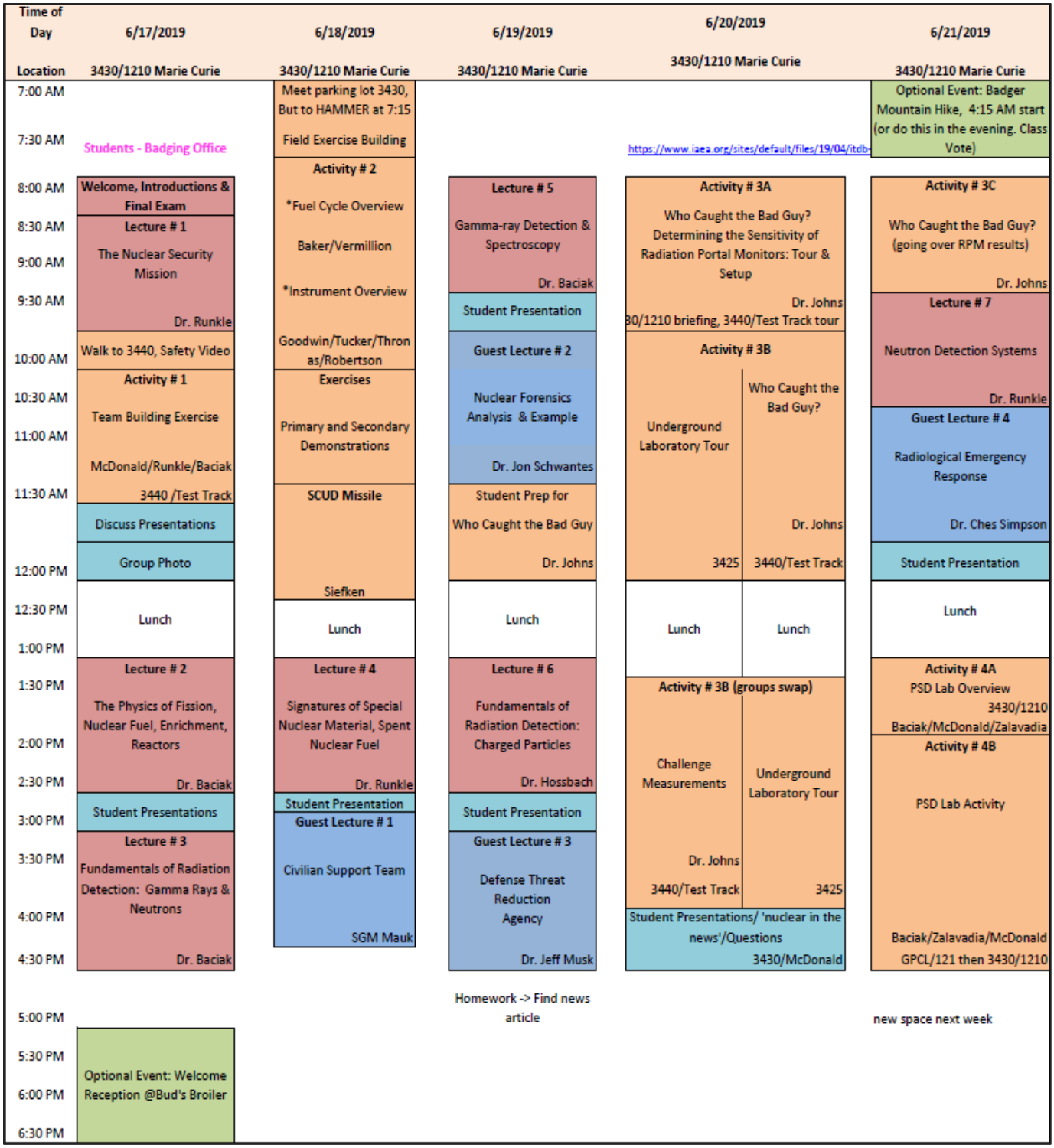

Figure 2. Schedule for the first week of the school.

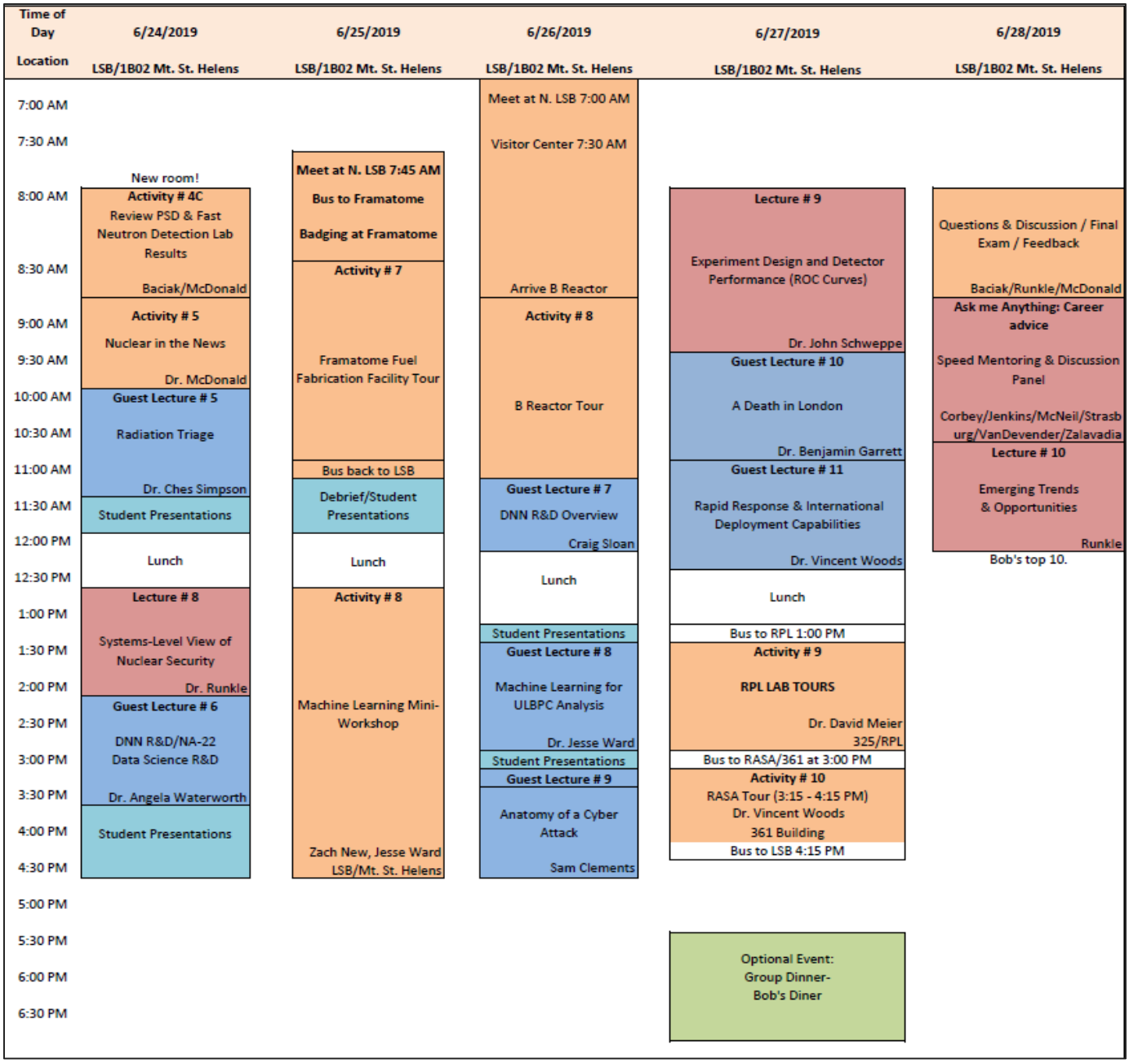

Figure 3. Schedule for the second week of the school.

Figure 4. Students participating in the “Lost Source” exercise at the 3440 Lab with various handheld and backpack radiation detectors.

Figure 5. Photograph of students during the Shallow Underground Laboratory (SUL) tour wearing classroom attire and holding samples of ultrapure copper.

Figure 6. PNNL Staff Members providing Speed Mentoring sessions to Summer School students.

Figure 7. Photograph of the group during the Hanford B Reactor tour.

Figure 8. Photograph of some of the students during an evening hike on Badger Mountain.

Table 2. Summary of activities and tours.

ACTIVITY/TOUR	PURPOSE	LOCATION
“Lost Source” search exercise	Use a variety of radiation detectors with differing efficiencies and energy resolutions to find a “missing” source and gain understanding into operational issues with detectors.	PNNL 3440 Test Track
Fuel Cycle Overview	Learn from experts about the types of material encountered in the nuclear fuel cycle (students see real materials)	Volpentest HAMMER Training and Education Center
Border Guard Training	Participate in a border guard training activity that includes locating and identifying sources in a realistic setting.	Volpentest HAMMER Training and Education Center
Nuclear in the News	Students connect how nuclear security missions are related to publicly reported current events	PNNL
Who Caught the Bad Guy? Activity	Students form teams and develop energy windowing algorithms for an RPM to maximum detection sensitivity and reduce false alarms	PNNL 3440 Test Track
Pulse Shape Discrimination lab activity	Introduce concepts, hardware, and software for pulse shaped discrimination between fast neutrons and gamma rays with a liquid scintillation detector.	PNNL
Framatome Fuel Fabrication Facility Tour	Provide students with a detailed tour that shows how fuel rods are produced (from UF_6 to fuel assemblies).	Richland, WA (near PNNL)
Machine Learning Mini Workshop	Provide students with an overview of machine learning techniques and have them run through several exercises. Also hear from an expert who has used ML to analyze radiation detector data.	PNNL
B Reactor Tour	Visit the site of the world’s first industrial-scale nuclear reactor and learn about its development, construction, and operation during the Manhattan Project.	Hanford Site
Laboratory tours	Expose students to operational facilities and research and development laboratories	PNNL Shallow Underground Laboratory, Radiochemical Processing Laboratory, 361 Building (SAUNA)

3.0 Outcome, Feedback and Findings

The key findings of the summer school in 2019 are provided in Table 3 below.

Table 3. Key Summer School Facts and Findings.

ATTENDANCE	
Number	We hosted 15 students this year because of the limited capacity of activities and tours. These students were all U.S. citizens and came from universities across the country.
Backgrounds	Consistent with previous years, the students possessed diverse academic backgrounds that included nuclear engineering, physics, astronomy, chemistry, inorganic chemistry, energy science, data science, engineering and international relations.
Schools	Students from the following schools participated: University of Tennessee (2), University of Florida (2), Michigan State University (1), North Carolina State University (1) , Washington State University (1), Oregon State University (2), University of California Berkeley (2), Georgia Institute of Technology (1), University of Rochester (1), Air Force Institute of Technology (1), and Texas A&M University (1).
CURRICULUM	
Lectures	The largest element of the summer school was a collection of 10 lectures. These lectures covered topics spanning nuclear security missions, signatures accessible via radiation detection, gamma-ray and neutron detection, charged particles, nuclear security systems, and future opportunities.
Guest Lectures	Guest lectures allowed students to interact in a small group setting with national experts on a range of contemporary topics that included treaty verification, defense nuclear nonproliferation, nuclear material interdiction, nuclear forensics, and nuclear safeguards.
CURRICULUM	
Activities & Tours	The most unique aspect of the summer school was the hands-on activities and focus on missions and applications. Each year we have allocated more and more time to this critical part of the course. 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, pulse-shape discrimination analysis, border-guard training, energy windowing algorithm testing with a radiation portal monitor, and a machine learning workshop. Laboratory tours provided students with insight into facilities and instruments used for cutting edge research and development, including PNNL's shallow underground laboratory and Radiochemical Processing Laboratory. A tour of the Hanford Site B-Reactor and the Framatome Fuel Fabrication Facility gave students a real-world look into the nuclear fuel cycle.
Student Lectures	All students presented their current research to the class. These presentations allowed the instructors to articulate the relevance of student work within nuclear security and to provide guidance on future work and potential collaborations across the national laboratory complex.
FEEDBACK & LESSONS LEARNED	
Student Evaluations	Students completed an evaluation form that provided both quantitative feedback to prescribed questions and qualitative feedback that specifically requested recommendations for course improvement. The students unanimously agreed 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. Students all agreed that they would recommend the summer school to their peers. Their written comments showed, consistent with past years, that the tours, activities, and networking with other students were the favorite parts of the school. For improvement, the key theme was that the machine learning workshop was overwhelming.

Key lessons learned	The machine learning mini workshop was a new addition this year, and we will consider how it can be refined to better fit the target audience and make some of the computing logistics more streamlined. The lectures provide essential core content and are usually not the highlight for students. We will refine these to include at least one interactive component (e.g., group exercise).

Results from the surveys are provide in Table 4 below.

Student Evaluation Survey

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.				
11	2			
The Radiation Detection for Nuclear Security Summer School improved my understanding of the nuclear security mission.				
13				
I believe the Radiation Detection for Nuclear Security Summer School enhanced my understanding of radiation detection as applied to nuclear security.				
9	4			
The activities/experiments performed within the Summer School were useful.				
7	5	1		
The facility tours were engaging and enhanced your understanding of the nuclear security mission.				
9	4			
The guest lectures provided improved understanding of the challenges associated with the wide scope of nuclear security.				
10	3			
Having student participants present on their research is an important part of the summer school agenda.				
7	5	1		
I would recommend the Radiation Detection for Nuclear Security Summer School to other students.				
11	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.				
9	4			

"My favorite part of the summer school was:"
• I was glad to learn about the work that other students and researchers do in this field, especially because my background is fundamental physics. The needs of fundamental science and security have their differences, and I enjoyed exploring them.
• Being able to see some of the lab's capabilities and how those capabilities are used in nuclear security.
• The tours. I did not have any background experience in nuclear sciences, and the tours were very informative and helpful in understanding.
• Visiting the B Reactor and seeing how the field of nuclear engineering has progressed throughout history.
• The breadth of topics that were covered and the hands-on experiments.
• Guest speaker presentations by individuals who have clear understanding of how relevant the field is in the future (?).
• Seeing the B Reactor and the machine learning workshop.
• Hanford + HAMMER.
• My favorite parts were the experiment activities.
• Tours! B Reactor, Shallow Underground Lab, Framatome. Getting to know PNNL staff and hear about their work.
• Networking opportunities and breadth of components of nuclear security I never knew of.
• The B Reactor tour was amazing from a historical and engineering perspective. I also really enjoyed the "Death in London" lecture.
• The B Reactor tour. Soo cool.

"I would make improvements to the Radiation Detection for Nuclear Security Summer School by:"
• Sincerely my only one complaint is that some of the computing requirements were a bit too high. I only had one student in my group who had MATLAB which made the PSD lab difficult.
• Maybe having more tours (like RPL) in the morning rather than after lunch.
• Providing simpler background knowledge for those with little to no experience in nuclear science or data science. I was overwhelmed early on with the complexity of some of the material, which progressed throughout the course.
• Making the ML portion of the course more concise as the information presented covered too many topics and was presented at a level that assumed the entire audience had experience with data science beforehand. It may help to generalize information? The course presented material that would be taught over the course of 1-2 semesters of school.
• Providing slide handouts to facilitate taking notes.
• Some guest speakers seem to have had too much time and use it to go over their office organization (not so relevant). So, maybe more speakers and shorter time slots and have them concentrate on what their office does and not concentrate on which specific part of their office does what.
• Having more time on the details of how detectors work.
• Improving the machine learning workshop. It would be better to have 30-40 minutes before the workshop for troubleshooting to make sure we don't lose time with setting up.
• Increasing the time spent on machine learning and having students write code.
• The machine learning was interesting, but we really needed more time to understand the code. If we could have some backup computers or better internet so everyone could participate that would be great.

- Increasing accessibility for non-STEM explanations of utility were exceptional, but much of the material was daunting.
- I thought the machine learning workshop was useful but could use some improvement. I felt like I was just pressing 'enter' and not fully understanding what I was doing.
- The coding/data science part was very overwhelming.

Other comments:
• I'm hoping that Wednesday's machine learning notebook exercise and data will be made available to us. Other than that, thank you all so much. The experience was amazing and I learned so much. It was very eye opening to see not just the application of detection to national security, but also as to how the world works; both are very important. Thanks.
• The summer school was very eye-opening. Thank you for this unique opportunity.
• The course was a blast, and the interactions with students and staff was fun, informative, and exciting. Thank you so very much!
• With the gamma spectroscopy /detection portion of the lectures, it would be useful to bring in a simple NaI and some button sources as a demo for how spectrum is acquired and how peaks change with different sources. Same with neutron measurements. Include a FPGA portion for digital spectroscopy.
• I know the schedule is tight, but I would have loved more time at B Reactor.
• Keep up the excellent work! This is vital for equipping the next generation of nuke specialists.
• I learned so much. Thank you!

4.0 Conclusions and Future Plans

By all accounts, the 2019 summer school was a success. Some activities that encountered technical hiccups the previous year were a success this year, particularly the PSD lab. Part of the course was updated this year to change some focus from near-field radiation detection to a broader set of areas that are topics of R&D in the nuclear security community (e.g., situational awareness, enabling capabilities, and machine learning). The main example of this was the inclusion of a half-day machine learning workshop. Feedback from the students indicated that the content was somewhat overwhelming, and that more time should have been given for setup and completing the coding activities. The speed mentoring and career discussion panel was very well received and provided students information from staff with varied roles and points in their career who support nuclear security missions. The school continues to be a unique and valuable experience for students because it connects research in radiation detection and other areas to nuclear security missions. The student presentations were also valuable, and instructions helped map their work to how they directly or indirectly support nuclear security missions. For FY20, we plan to host another school and engage the new NNSA University Consortia. We also still plan to conduct a survey of alumni to gauge how the school has impacted their chosen fields and careers (this was not completed in FY19).

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