PNNL-28441

Pacific Northwest
NATIONAL LABORATORY

Summary Report for the Radiation Detection for Nuclear Security Summer School 2018

January 2019

BS McDonald
JE Baciak
RC Runkle
AR Nixon

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 99352

Executive Summary

The Pacific Northwest National Laboratory (PNNL) hosted students from across the United States at the 5th Radiation Detection for Nuclear Security Summer School 18-29 June 2018. 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 direct 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) exciting students about the possibility of future careers in nuclear security. In fact, we have seen previous students enroll in and complete graduate programs (former undergraduates), complete internships at agencies like the National Nuclear Security Administration and become staff members at national laboratories and other government agencies.

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Acknowledgments

The authors would like to thank the National Nuclear Security Agency's Defense Nuclear Nonproliferation Office of Research and Development for supporting this work. Additionally, we would like to thank Framatome Inc.'s Fuel Fabrication Facility in Richland, WA, for allowing us to tour their facility. Furthermore, the authors thank the long list of people who gave guest lectures, helped with activities, and provided logistical support to the school. We heap special gratitude upon Diana Jenno, Amy Nixon, and Kathy Roberts for their efforts behind the scenes and in the execution of the school

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1.0 Introduction

The Pacific Northwest National Laboratory (PNNL) hosted students from across the United States at the 5th Radiation Detection for Nuclear Security Summer School from 18-29 June 2018. The cohort consisted of three advanced undergraduate students and thirteen graduate students. They were all U.S. citizens and came from universities across the country. All are in Science, Technology, Engineering, or Math (STEM) programs, and roughly half are currently engaged in DNN R&D University Consortia research. One student was active duty army. A group photo is shown below in Figure 1 and details about the students are provided in Table 1. This small enrollment enabled hands-on laboratory activities and tours and fostered a collaborative and discussion-rich atmosphere. Both the instructors and the students recommend that the summer school be kept small in future years.

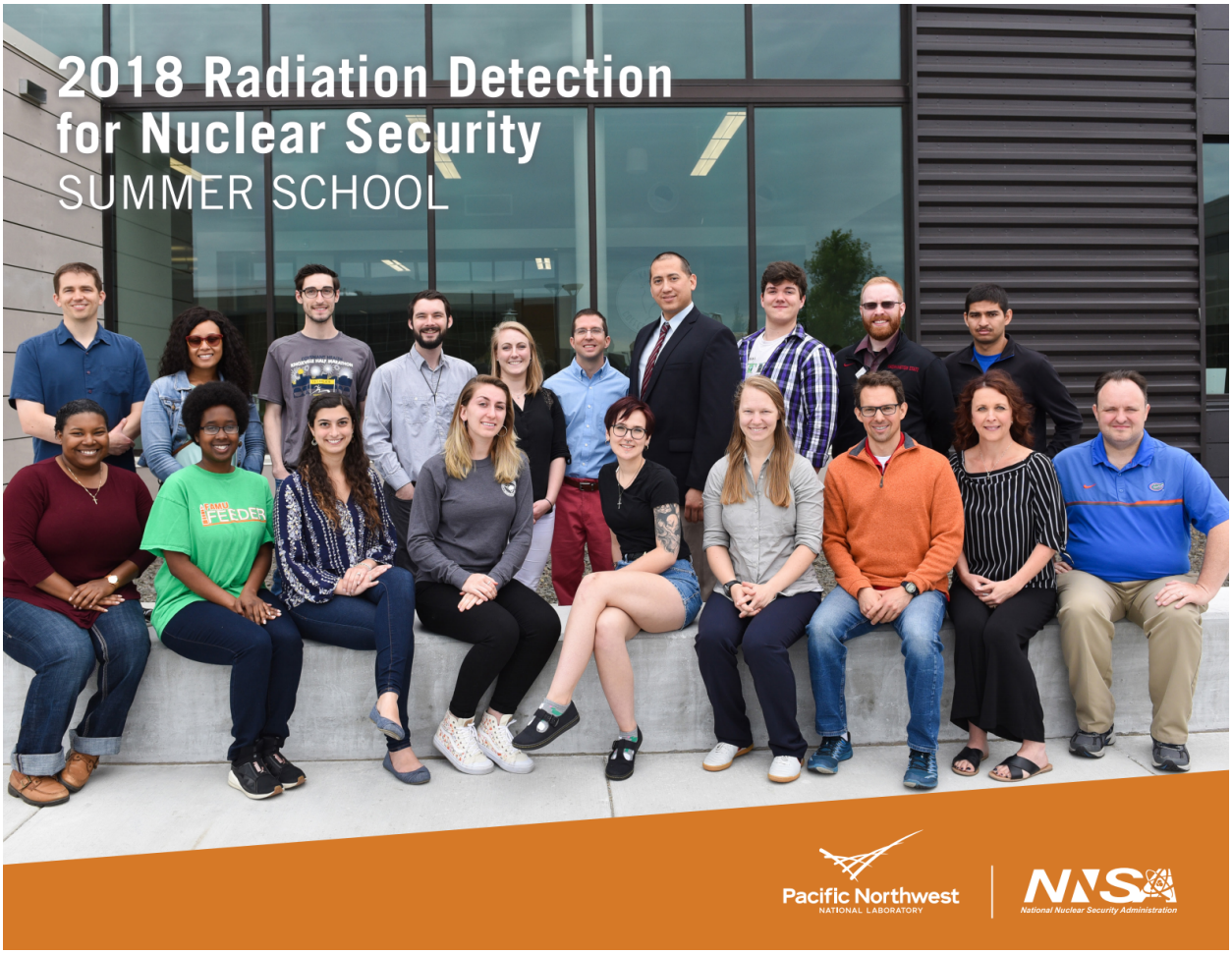

Figure 1. Group photo of the 2018 Summer School participants, instructors, and support staff.

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

STUDENT	UNIVERSITY	FIELD OF STUDY	GRADUATE THESIS/TOPIC
Sean Alcorn	University of Tennessee	Nuclear Engineering	Wearable nuclear detector system
Michael Bojazi	Clemson University	Physics	Galactic Chemical Evolution & Radioactivity in the Early Solar System
Rosendo Borjas Nevarez	University of Nevada, Las Vegas	Radiochemistry	purification of zirconium from radioactive nuclear fuel cladding using a chloride volatility process
Evangelina Brayfindley	North Carolina State University	Computational & Applied Mathematics	Nonproliferation, image analysis and uncertainty quantification
Ashley Brooks	Intern, PNNL	Applied Physics	Not yet defined
Joseph Butterfield	University of Colorado at Boulder	Integrative Physiology	Medical space sources
Ardelia Clark	Vanderbilt University	Radiation Imaging	Crystal growth of inorganic scintillators via vertical Bridgman
Emma Cockram	University of Florida	Nuclear Engineering	Nuclear forensics using laser induced plasma spectroscopy
Bianca Cruz	North Carolina State University	Nuclear Engineering	Applied and theoretical aspects of engineering
Dustin Kasparek	Oregon State University	Applied Physics	Applied physics and nuclear science and engineering
Jedidiah McCoy	Washington State University	Materials Science & Engineering	Implementation of accelerated crucible rotation in electrodynamic gradient freeze method for highly non-stoichiometric melt growth of cadmium zinc telluride
Hannah Patenaude	University of Nevada, Las Vegas	Chemistry	Not yet defined (Undergraduate)
Ali Rafique	Prairie View A&M University	Biology	Not yet defined (Undergraduate)
Daniel Rutstrom	University of Tennessee	Materials Science Engineering	Not yet defined (Undergraduate)
Angela Simone	University of Tennessee	Nuclear Engineering	Safeguards systems
Morgan Smathers	Oregon State University	Medical Health Physics	Not yet defined

2.0 Course Schedule and New Activities

The two-week agenda for the school is provided in Table 2, including core lectures, guest lectures, lab and facility tours, and hands-on activities. Overall, it was executed without major issues. New lectures and activities included 1) a pulse-shape discrimination lab with a liquid scintillation detector, 2) a guest lecture on the ^{210}Po poisoning case, 3) a PNNL lecture on the design of experiments and evaluating detector performance with Receiver Operating Characteristic (ROC) curves, and 4) a guest lecture from two members of the National Guard 9th Civilian Support Team. Some of the other lectures and activities were slightly updated from their original material to include recent developments in detector technology and applications to nuclear security missions.

The activities and laboratory tours (Table 3) 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 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 experience a typical detector development lab during the pulse shape discrimination activity.

Table 2. Schedule for the 2018 Summer School, including core and guest lectures, tours, and activities.

Day 1 (Monday, June 18, 2018)	
7:30	Students Arrive at Badging and Pick Up their Badges
Discovery Hall – Frontier	
8:00	Welcome, Introduction and Safety Video
8:30	**Lecture #1** – "The Nuclear Security Mission," Bob Runkle/PNNL
3440 Building - Test Track	
10:00	(Walk to 3440 Building) View Safety Video
10:15	**Activity #1** – Team Building Lost Source Exercise 3440 & Test Track, Ben McDonald, Bob Runkle/PNNL, Jim Baciak/University of Florida
	Walk back to Discovery Hall
11:45	Group Photo, Discuss Student Presentations
12:00	LUNCH
1:00	**Guest Lecture #1** – "Radiological & Emergency Response," Cari Seifert/PNNL
2:30	**Lecture #2** – "The Physics of Fission, Nuclear Fuel, Enrichment, Reactors," Jim Baciak/UF

4:00	**Activity #2A** – GADRAS Setup, Ben McDonald/PNNL
5:00	Adjourn
5:30	Extracurricular Activity: Welcome Reception @ Buds Broiler with Bob Runkle
Day 2 (Tuesday, June 19, 2018)	
Discovery Hall – Frontier	
8:00	**Lecture #3** – "Fundamentals of Radiation Detection: Gamma Rays," Baciak/UF
9:00	**Activity #2B** – GADRAS Introduction – Modeling Gamma-Ray Source Terms, Ben McDonald and Ches Simpson/PNNL
10:30	**Lecture #4** – "Signatures of Special Nuclear Material, Spent Nuclear Fuel," Runkle/PNNL
12:00	Student Presentations – LUNCH
1:30	**Lecture #5** – "Gamma-Ray Detection & Spectroscopy," Jim Baciak/UF
3:00	**Activity #2C** – Modeling Gamma-Ray and Detector Response, Ben McDonald/Ches Simpson/PNNL
4:30	Adjourn

Day 3 (Wednesday, June 20, 2018)	
Discovery Hall – Frontier	
8:00	**Lecture #6** – "Fundamentals of Radiation Detection: Neutrons," Baciak/UF
9:00	**Activity #3A** – Pulse Shape Discrimination & Fast Neutron Detection, Baciak/McDonald/Mace
10:00	**Guest Lecture #2** – "Nuclear Forensics Analysis & Example," Jon Schwantes/PNNL
11:30	Student Presentations
12:00	LUNCH – Walk to 3850 Building
3850 Building - Room 121 (GPCL)	
1:00	**Activity #3B** – PSD & Fast Neutron Detection Lab Activity, Jim Baciak/Ben McDonald/Mace
4:30	Walk back to PSF 3430 Building
4:45	Adjourn
	Homework – Find Article for Monday Activity
Day 4 (Thursday, June 21, 2018)	
8:15	Meet in Front of Discovery Hall, Bus will depart @ 8:30
8:45	**Activity #4** – B Reactor Tour
1:15	Bus Arrives @ 3430 Building from B Reactor Tour
1:15	LUNCH FROM MEG'S CAFÉ ON THE BUS
2:00	**Lecture #7** – "Neutron Detection Systems," Bob Runkle/PNNL
3:30	**Guest Lecture #3** – "Stories from Captain Foss," Captain Shane Foss/CSTO

5:00	Adjourn
Day 5 (Friday, June 22, 2018)	
4:15 AM	Badger Hike
3430 Building - Marie Curie Room	
8:00	**Guest Lecture #4** – "Nuclear Cyber Security," David Manz/PNNL
9:30	**Activity #3C** – Review PSD & Fast Neutron Detection Lab Results
10:30	**Guest Lecture #5** – "Rapid Response & International Deployment Capabilities," Vincent Woods/PNNL
11:30	Student Presentations
12:00	LUNCH
1:00	Bus to RPL (Dosimeters Required)
1:30	**Activity #5** – RPL Lab Tours, David Meier/PNNL
3:15	Depart for RASA
3:30	**Activity #6** – RASA Tour, Vincent Woods/PNNL
4:30	Depart for PSF
4:45	Adjourn
Day 6 (Monday, June 25, 2018)	
3430 Building – Marie Curie Room	
8:00	**Activity #7** – Nuclear in the News, Ben McDonald/PNNL
9:30	Student Presentations
10:00	**Guest Lecture #6** – "Radiation Triage," Ches Simpson/PNNL
11:30	LUNCH
12:15	Bus to Framatome
12:30	Badging at Framatome
1:00	**Activity #8 -** Framatome Tour
3:45	Depart for 3430 Building PSF
4:15	Adjourn
Day 7 (Tuesday, June 26, 2018)	
7:40 Meet in front of Discovery Hall	
7:40	Bus to HAMMER – Field Exercise Building
8:00	**Activity #9 -** *Fuel Cycle Overview, Baker/Vermillion *Instrument Overview, Goodwin/Tucker/Thronas/Robertson
10:00	**Exercises** – Primary & Secondary Demonstrations, Rob Siefken/PNNL
11:30	**Exercises** – SCUD Missile, Rob Siefken/PNNL

12:30	LUNCH – Taco Tuesday at Hammer Cafeteria
1:15	Bus back to 3430 Building/PSF
1:30	**Lecture #8** – "Systems-level View of Nuclear Security," Bob Runkle/PNNL
3:00	**Guest Lecture #7** – "NA-22," Donny Hornback/NA-22
4:30	Adjourn
Day 8 (Wednesday, June 27, 2018) -TRUCK RESERVED-	
3430 Building – Marie Curie Room	
	Students will meet at 3430 – Marie Curie Room and then Walk Together to 3440 – Test Track
8:00	**Activity #10A** – Determining the Sensitivity of Radiation Portal Monitors: Tour & Setup, Paul Johns/3440/Test Track
	The Students will split up into two groups for Activity #10B
10:00	**Activity #10B** – **Group 1** Underground Laboratory Tour (3425 Building) **Group 2** – Challenge Measurements (Figure out settings) (3440/Test Track) Paul Johns
12:00	**Group 1 – LUNCH**
12:30	**Group 2 – LUNCH**
1:30	**Activity #10B** – **Group 1** Challenge Measurements (Figure out settings) (3440/Test Track) Paul Johns/PNNL
2:00	**Activity #10B – Group 2** Underground Laboratory Tour (3425 Building)
4:00	Return to 3430 – Marie Curie Room
4:10	Student Prep for who caught the bad guy!
5:15	Adjourn
Day 9 (Thursday, June 28, 2018)	
3430 Building – Marie Curie Room	
8:00	**Guest Lecture #8** – "A Death in London," Dr. Benjamin Garrett/FBI (retired)
9:30	**Activity #10C** – Who Caught the Bad Guy? (going over RPM results), Paul Johns/PNNL
11:00	**Lecture #9** – "Experiment Design and Detector Performance (ROC Curves)," John Schweppe/PNNL
12:30	LUNCH
1:30	**Guest Lecture #9** – "Defense Threat Reduction Agency," Jeff Musk/DTRA
3:00	Student Presentations
4:30	Adjourn
5:30	Group Dinner – Bob's Diner
Day 10 (Friday, June 29, 2018)	
3430 Building – Marie Curie Room	
8:00	**Lecture #10** – "Active Interrogation and Imaging" Jim Baciak/UF

9:30	**Lecture #11** – "Emerging Trends & Opportunities," Bob Runkle/PNNL
12:00	Questions & Discussion / FINAL EXAM / Feedback
12:00	Adjourn

Figure 2. Photograph of students during the Shallow Underground Laboratory (SUL) tour wearing cleanroom attire and holding samples of ultrapure copper.

Figure 3. Photograph of the “lost source” exercise on the first day of the course. Students chose from an assortment of handheld and backpack detectors to find and identify a missing source at the 3440 facility.

Table 3. Summary of activities and tours.

ACTIVITY/TOUR	PURPOSE	LOCATION
Modeling Source Terms and Detector Response	Introduce students to the modeling software GADRAS and use this software to explore the variety of factors that impact the signatures, primarily gamma-ray emissions, of bulk special nuclear material.	N/A
"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.	Large Detector Laboratory
Pulse Shape Discrimination	Introduce concepts, hardware, and software for pulse shaped discrimination between fast neutrons and gamma rays with a liquid scintillation detector.	PNNL detector development laboratory in 3850/GPCL.
Laboratory tours	Expose students to operational facilities and research and development laboratories.	Swedish Automatic Unit for Noble Gas Acquisition, Shallow Underground Laboratory, Radiochemical Processing Laboratory
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
Framatome Nuclear Fuel Fabrication Facility Tour	Provide students with a detailed tour that shows how fuel rods are produced (from UF6 to rods).	Richland, WA (close to PNNL)
Determining the Sensitivity of Radiation Portal Monitors	Introduce students to the operation of cargo and vehicle radiation portal monitors, including energy window discrimination, and observe the effects of shielding and naturally occurring radioactive material on the capability of portal monitors to detect special nuclear material.	Large Detector Laboratory Test Track
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

3.0 Outcome, Feedback and Findings

The key findings of the summer school in 2018 are provided in Table 4 below.

Table 4. Key Summer School Facts and Findings

ATTENDANCE	
Number	We hosted 16 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. One accepted applicant dropped out of the course due to a family emergency and was replaced with a PNNL intern.
Backgrounds	Consistent with previous years, the students possessed diverse academic backgrounds that included nuclear engineering, nuclear physics, materials science, chemistry and radiochemistry, and health physics. One student was active duty army. All the students expressed interest in career opportunities in nuclear security, although not necessary as federal employees.
Schools	Students from the following schools participated: University of Tennessee (3), University of Florida (1), University of Nevada, Las Vegas (2), North Carolina State University (2), Washington State University (1), Oregon State University (1), Clemson University (1), University of Colorado at Boulder (1), and PNNL Interns (4, Vanderbilt University, Oregon State University, Florida A&M University, and Prairie View A&M University).
CURRICULUM	
Lectures	The largest element of the summer school was a collection of 11 lectures. These lectures covered topics spanning nuclear security missions, signatures accessible via radiation detection, gamma-ray and neutron detection, active interrogation, nuclear security systems, and future opportunities.
Guest Lectures	Nine 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, modeling source-term signatures with GADRAS, pulse-shape discrimination analysis, border-guard training, and energy windowing algorithm implementation. 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. The highest scoring element was that 88 percent of the students found the summer school to be informative and engaging and that 88 percent of the students would recommend the summer school to other students. Their written comments provided a few common points: 1) more time for the experimental activities, 2) some material was repetitive between the lectures and tours, and 3) having 4 to 5 lectures in one day was too many (happened just once), consider having a mobile activity in-between.
key lessons learned	Activities and guest lectures formed the unique nature of the summer school. While these activities consumed most of the time and have been expanded over previous years, they should be further refined. Including time for post-activity analysis and interpretation should be included, as there was not often enough time to digest results and answer follow-up questions. Students also indicated the desire for more challenges and assessments such as with daily quizzes. We could also include a pre-course exam and compare results from that with the final exam to gauge student learning.

"The favorite part of summer school was:"

- B Reactor tour
- Framatome Tour, "that was super cool!"
- Emergency response lecture
- Lost source exercise
- All of the tours and practical applications
- Meeting amazing people and making incredible connections, also I almost cried at B-reactor so that was pretty cool
- Framatome tour
- All of the tours and activities
- HAMMER
- RPL tour, who caught the bad guy, test track/detection
- All tours, such incredible and unique experiences
- SUL, it was amazing to see the efforts towards reducing background
- Student presentations

"I would make improvements to the Radiation Detection for Nuclear Security Summer School by:"

- Bringing one of the guest speakers who have opposing views on nuclear security, just for curiosity and discussion
- Turning the student presentations into something like a poster session so that quick overviews are given and also more warning about the presentations
- Send the PowerPoint out before the first lecture
- More on policy and how the lectures navigated to their career
- Do activities in the afternoon instead of lectures
- Speeding up Jim's lectures
- Having daily quizzes
- Making the lectures a little shorter, but other than that it was all great

- Guest lectures and policy lectures were more interesting than the science lectures, during which I had a tendency to space out. Science instruction would be more useful and efficient with in-class exercises and/or take-home problem sets
- The programming activity could use another rewrite
- The tours and policy discussions were the best part
- An official certificate of completion would be nice
- Reserve housing and transportation and a small stipend would help
- Ensure that detection systems are working
- More outside guest lecturers and maybe some more "standard" lab spaces at PNNL like when we tried to do the PSD activity
- More activities/exercises related to emergency response
- Should probably have more diverse speakers (demographically speaking)

Other Comments:

- Thank you for teaching this course. While there was some info overload, it was also massively informative across all the realms of nuclear security. Very, very cool. Special shout out to Amy for organizing!
- Having done so much with the theory and simulation side of nuclear detection, it was amazing to see the practical applications.
- Thank you for this unparalleled opportunity. It made a major impact in my future in more than one way and I'm honored to be part of its legacy.
- This was an amazing experience!
- Thanks for having us and letting us be a part of this very informative and interesting course!
- Thanks for a good experience!
- Very encouraging.
- Thank you so much!
- Thank you very much for hosting this course; it was an invaluable experience. Great energy, Bob! Made the class more enjoyable. Please keep hosting this course, it helps students get more engaged in mission.

4.0 Conclusions and Future Plans

By all accounts, the 2018 summer school was a success. Some activities encountered technical hiccups, particularly the PSD lab, which is not surprising since it was the first time it was part of the school. Part of the course could be updated, shifting 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). External speakers such as Jeff Musk covered these topics well, but they could also be a part of the lectures and activities. Some other things that we will consider for future schools include a discussion panel with PNNL staff in different roles and points in their career who support nuclear security missions. Student feedback also indicated interest in more connection of technical and policy domains in the curriculum. 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. We plan to conduct a survey of alumni to gauge how the school has impacted their chosen fields and careers.

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