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Sandia National Laboratories Early Career University Faculty Mentoring Program in International Safeguards

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Abstract

An international safeguards mentoring program was established by Sandia National Laboratories (SNL) for early career university faculty. The inaugural year of the program focused on professional development and connecting faculty to experts at national laboratories. Two faculty members were selected for participation from Penn State and Virginia Commonwealth Universities. One faculty member explored safeguards-by-design concepts, and the other studied topics related to potential applications of unmanned robotic systems in safeguards. To achieve the program objectives, faculty members were paired with SNL subject matter experts based on their areas of interest. The program included a two-week visit to SNL, where faculty members had an opportunity to tour facilities, interact with their mentors directly, and establish a wider professional network. The structure of this program provided junior faculty members with opportunities to make connections and build collaborations in the field of international safeguards. Additionally, junior faculty members utilized their newfound knowledge to develop new course materials to promote international safeguards education. Programs like this are important for professional development of faculty members and for strengthening connections between universities and the national laboratories.

I. Introduction

Educating the next generation of nuclear safeguards experts is essential to the prevention of nuclear weapons proliferation. University professors are an integral component of the training pipeline, but opportunities for advanced and continuing nuclear safeguards education for early career faculty are limited. The most prevalent programs are specific to students, postdoctoral researchers, and early career scientists within national laboratories. Faculty also face challenges related to obtaining funding for professional development; university resources for travel and training are typically focused on student opportunities, and research grants are not geared towards professional development for faculty. Thus, there can be a lack of resources available to new professors to assist

them with continuing education, professional networking, course development, and proposal writing.

Retention of early career faculty in nuclear safeguards related areas requires the development of a support structure. While most universities have an established mentoring plan, the mentors are typically senior faculty who can assist with the day-to-day navigation of academia, but not safeguards, or in some cases even nuclear science, subject matter experts (SMEs). This void in intensive continuing education opportunities for faculty resulted in the development of a Sandia National Laboratories (SNL) led, nuclear safeguards focused, mentorship program for early career professors. Two faculty members, one from Penn State University (PSU), and one from Virginia Commonwealth University (VCU), were selected as the participants for the first cohort. The first year of the program was focused on pairing faculty with SMEs at SNL to establish connections for future work in the field of nuclear safeguards and to produce safeguards related education materials. The faculty members are shown in *Figure 1* with two of the SNL mentors at the 60th Annual Institute of Nuclear Materials Management Meeting.

Figure 1. Faculty members and two SNL mentors at the 60th Annual Meeting of Institute of Nuclear Materials Management. Left to right: Natacha Peter-Stein (SNL), Braden Goddard (VCU), Azaree Lintereur (PSU), Alexander Solodov (SNL).

There are three common metrics used to assess faculty tenure applications: research, education, and service. Two of these metrics, research and education, were the focus of this mentoring program. Service requirements are typically assigned based on institutional needs and are generally not technical in nature, and thus this metric was not prioritized for this program.

Research, sometimes referred to as scholarly activity, encompasses the development of a sustainable program, including metrics such as funding obtained and publications. The PSU

faculty member is targeting potential research collaboration opportunities with SNL related to Safeguards-by-Design (SBD), specifically SBD for Molten Salt Reactors and Small Modular Reactors. The VCU faculty member has written two proposals related to radiation measurements using unmanned systems with collaborators at SNL since the start of this program. In addition, both faculty members submitted research proposals to the 2019 Department of State Bureau of Arms Control, Verification and Compliance Broad Agency Announcement as a result of being made aware of the opportunity through this mentoring program. The education metric includes the modification of existing courses and the development of new courses. The development of educational material also provides faculty the opportunity to introduce courses or topics that are not currently available and are of specific interest or are related to their research areas. Thus, the PSU faculty member used this opportunity to create a graduate level technical elective focused on SBD. The VCU faculty member used the opportunity to develop curriculum on the use of unmanned robotic systems for safeguards and related applications. Instead of using this curriculum to develop a new course, it will be integrated into multiple existing undergraduate and graduate level courses.

Presented here is a summary of the activities which occurred at SNL and the associated educational materials which were developed.

II. Program Structure

The goal of the Office of International Nuclear Safeguards (NA-241) Human Capital Development (HCD) Program is to develop sustainable academic and technical programs that support the recruitment, education, training, and retention of a new generation of international safeguards professionals. This program has addressed several areas within the mission of the HCD subprogram. It has strengthened university academic programs with focus on international safeguards by fostering more diverse, and knowledgeable, faculty members. It also provided mentoring opportunities for young professionals in the field and knowledge transfer and retention by transferring practical experience of national laboratory staff to new faculty members, who in turn will provide this knowledge to their students.

The program started by establishing each individual faculty member's goals. Each faculty member provided information detailing what they hoped to accomplish with their mentors, and that information was used to select the appropriate SMEs at SNL. Early communication and planning focused on logistics and establishing expectations for outcomes of the program. The majority of the mentoring interactions occurred during a two-week visit by the faculty members to SNL. This intensive mentorship visit allowed for focused interactions and knowledge transfer between the mentors and the mentees, as well as designated time to concentrate on the development of the education materials. In addition to mentor-mentee interactions the visit also enabled the faculty members to meet with other SMEs and tour SNL facilities relevant to their projects. SMEs in areas related to the educational materials of interest to faculty were consulted for resources and information. Examples included experts in nuclear security table top exercises and export control. Facility tours included the Tech Area V educational and training facilities as well as the National Solar Thermal Test Facility and an Unmanned Aerial Systems (UAS) acceptance testing demonstration.

The structure of the mentoring visit enabled the mentees to meet with multiple SNL SME and to gain experience and perspective from multiple sources. This program structure also allowed depth and breadth to be added to the educational material compared to what would otherwise have been produced. This program further provided an opportunity for connections to be made which will be beneficial for future career development, including research and funding opportunities.

III. Mentoring and Professional Development

The inaugural year of the program focused on mentoring, professional development and connecting faculty to experts at national laboratories. Through this program, the junior faculty members had opportunities to make connections and build collaborations in the field of international safeguards. Further, they utilized their newfound knowledge to develop new course materials to promote international safeguards education. The development of educational materials is beneficial for students, but can also serve as an effective means of enabling faculty to capture and compile knowledge on a specific topic. Thus, the faculty members used the creation of educational materials to capture the knowledge gained during their time at SNL. The two faculty focused their efforts on different topics, related to their areas of interest. Therefore, while there was some overlap in their efforts for this mentoring program, their educational material creation was done individually. The topics prepared by each professor areas described separately, below.

Safeguards-by-Design

International and domestic safeguards are essential for nuclear facilities. The inclusion of safeguards related considerations after facility design can lead to the need for retrofitting, and introduce measurement challenges; however, if safeguards requirements are considered during the design process it can result in facilities that are easier to safeguard. This approach is promoted through the concept of SBD, which is gaining international attention as new reactor designs are being explored [[1][2]]. However, there are currently limited opportunities for students to familiarize themselves with SBD. Thus, the PSU faculty member focused on developing material for a graduate level technical elective focused on SBD which will serve both as a stand-alone course, and as a complement to current course offerings. These educational materials will introduce students to the benefits of incorporating safeguards considerations into facility planning. The challenges associated with SBD will also be covered, including conflicting needs and costs. The ultimate goal is for students to gain a deeper understanding of the different aspects of SBD and the need for thorough analysis, critical thinking, and flexibility. SNL is home to experts in nuclear safeguards, covering areas from technology development to model and simulation development to training and education. An example of SNL's capabilities directly relevant to SBD includes the Separation and Safeguards Performance Model (SSPM), which is a powerful tool for safeguards design for processing facilities [3]. Access to the SNL nuclear safeguards experts resulted in educational material with increased breadth and depth compared to what would have been generated based solely on published information.

The PSU faculty member had prior experience with course development, but creating this course under the guidance of an SNL mentor with expertise in SBD provided invaluable insight into the essential topics. The SNL mentor was also able to provide resources, such as references and

content for lectures, and offered input on the best methods of material presentation. These contributions provided a broader, more comprehensive base for the course. In addition to guidance on the course topics, the SNL mentor facilitated meetings with additional SMEs. This included meetings with experts in table top exercises (TTEs) and cyber security. As a result of these meetings the course was expanded to include four case studies (including one specific to cyber security) which will be used as interactive in-class analysis exercises. A student project in the form of a TTE was also included. Student engagement and active learning opportunities were course priorities from the outset of planning, as they have been shown to increase retention and student interest, but translating these priorities into tangible course components was challenging [[4][5]]. The input from SMEs at SNL directly resulted in the inclusion of interactive process monitoring examples, the addition of a treaty negotiation exercise, and the development of the TTE. A student project was always planned to be included, but at the beginning of the professor's two weeks at SNL it was a concept without concrete structure; based on contributions from various SMEs the project was shaped into an exercise which will be the focal point of the course.

The unique access to international safeguards SMEs which was facilitated through the intensive mentoring period provided an opportunity for significant knowledge transfer. This enabled the faculty member to gain expertise relevant to the establishment of future research projects. Further, the knowledge transferred was captured in educational materials, which will be beneficial for students interested in safeguards by design and will strengthen safeguards education.

Unmanned Robotic Systems for Safeguards Applications

While at SNL, the VCU faculty member focused its mentoring on the use of unmanned robotic systems for safeguards and related applications. SNL has a concentration of experts regarding all types of unmanned robotic systems, including air, ground, and underwater. They have conducted research on topics such as how UAS pose a potential threat to nuclear facilities [6] as well as how they can be used to help safeguard uranium mines [7]. In addition to the depth and breadth of knowledge, SNL has advanced capabilities to fly and drive multiple types of unmanned systems of different size and applications.

Due to the fixed budget of the International Atomic Energy Agency (IAEA) and the expanded use of nuclear technology globally, there is a significant need to reduce the costs of safeguards on a per facility/country biases. The use of unattended monitoring systems and satellite imagery has already been implemented and has reduced operational costs of the IAEA [8]. Like many sectors, such as automotive manufacturing, the safeguards community is interested in the potential of unmanned robotic systems to reduce the human capital needs to safeguard a facility/country. These systems include air, ground, surface water, and underwater based locations. The curriculum developed with the newfound knowledge through this mentoring program also includes currently used vehicles and sensors, and the applications that they support. Examples of these applications include declared site evaluations and Design Information Verification using UAS. These systems could include high resolution and hyperspectral imagery as well as LiDAR to identify unexpected structures or components. Included in the curriculum is the capability of current sensors and analyses methods, such as image reconstruction to create a 3D model of the photographed location and the spatial resolution of the 3D model [9]. Challenges and potential solutions to these types of

measurements are also included. One such challenge is the dangers posed by UAS within a confined space, with currently available potential solutions being a collision cage around the UAS or advanced obstacle avoidance software and hardware on the UAS [10].

Another example area that the curriculum covers is environmental sampling and how unmanned robotic systems can be utilized. Air samples can be collected at different locations and altitudes using a UAS. This potential capability is compared and contrasted to air sampling done by the Comprehensive Test Ban Treaty Organization as well as post-detonation nuclear forensics air sampling approaches. Environmental sampling can also potentially be performed by unmanned watercraft and underwater systems. These systems would allow for water sampling of lakes, rivers, and other bodies of water. These samples could be collected at various locations and depths without the need to acquire a boat to carry the person doing the sampling to the various locations or water depths. Applications of this technology extend beyond safeguards and into the realm of safety and security, thus highlighting the unity of the "3S" approach to nuclear energy education [11].

This mentoring program allowed for the development of research capabilities of the faculty member by expanding the breadth and width of knowledge of unmanned systems for safeguards and other applications. This enables the faculty member to conduct research in this emerging field more efficiently. In addition to the improved research capabilities that this mentoring program facilitated, curriculum to educate both graduate and undergraduate students about the current technology of unmanned robotic systems and their potential applications to safeguards was created. Due to the diverse knowledge of the SNL mentors, the developed curriculum has broad appeal to many disciplines thus expanding the number of currently taught courses that this curriculum can be integrated into. This material will first be taught to undergraduate nuclear engineering concentration students within the Department of Mechanical and Nuclear Engineering at VCU as an online module in EGMN355 (Radiation Safety and Shielding).

IV. Facility Tours and Meetings with SMEs

In support of the program goals, three SNL facility tours were organized for the faculty members. These tours were designed to build potential collaborations and provide real-world examples of safeguards and related technologies in practice.

Technical Area V was the first facility to be toured. Several training facilities, including shipping/receiving, control room, and processing facility, were included in the tour. The Tech Area V training is focused on security systems, but discussions for how they could be synergistically used to support safeguards took place, as well as conversations about future training opportunities. The tour also included discussions about considerations and lessons learned for active training implementation. In addition to providing insight into training development, the tour sparked conversations about the possibility for future student tours and educational opportunities.

The next facility to be toured was the Technology Training and Demonstration center. This facility houses real-life systems developed by SNL to combat chemical, biological, radiological, and nuclear proliferation and terrorism. Several of the more nuclear focused systems are included in the developed curriculum and offered the faculty a hands-on experience to better describe the theoretical and practical use of these technologies. The technical expert guiding the tour provided

information and answered questions about system use, practicalities of fielding technology, and policies.

The last facility that was toured at SNL was The National Solar Thermal Test Facility, shown in *Figure 2*. At this location, the faculty learned about the needs of carbon free sources of energy, the size of industrial solar facilities, and the challenges associated with operations at industrial sized facilities. Of particular interest was the use of UAS at this facility to improve operation efficiency and reduce costs. Benefits and concerns with the use of UAS at this facility were studied and experienced first-hand to better understand their potential safeguards use at nuclear sites. Information from this tour was directly implemented into the material developed on the use of unmanned robotic systems.

Figure 2. Pictures of the faculty members and two SNL mentors at the SNL National Solar Thermal Test Facility. Left to right: Alexander Solodov (SNL), Natacha Peter-Stein (SNL), Azaree Lintereur (PSU), Braden Goddard (VCU).

V. Future Collaboration

This program had the benefit of expanding each faculty members' safeguards knowledge, broadening the safeguards knowledgeable contacts they have at SNL, and allowing them to capture the knowledge they gained in the form of educational materials. Further, the contacts they established will be important for future research projects. As a result of the connections made through this program, the faculty have written two joint proposals with SNL and are in the process of developing a third. These projects, if funded, will not only expand safeguards capabilities and related applications, but will also help support a pipeline of safeguards knowledgeable graduate and undergraduate students to fill personnel needs. Finally, in addition to strengthening the relationship between the universities and SNL, this program also produced a stronger connection between the PSU and VCU faculty members. There are plans for future joint educational

opportunities, including an INMM student chapter workshop and student nuclear facility tours. This SNL early career university faculty mentoring program in international safeguards has continued into its second year with two new faculty members, as well as additional mentoring opportunities for the original cohort.

VI. Summary

This program was a valuable professional development opportunity for early career faculty, and provided an effective platform for knowledge transfer and retention. Further, the faculty were able to expand their network of potential collaborators. The mentoring format enabled the knowledge transferred to extend beyond the individual mentees, which will benefit future safeguards experts. The ability to apply the knowledge gained to educational materials was appreciated by the faculty members, and helped them meet their own institutional needs. The material content that was produced as a result of this program is stronger than what would have been generated by the individual faculty. Future expansions of this program to include additional faculty and mentoring in other professional development areas, such as proposal writing and research program establishment, are being pursued.

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