Stanton Nuclear Security Fellows Seminar

PANEL 2: Nuclear Power and Nuclear Radiation

1. Austin Cooper, MIT SSP

Radiation Exposure in Nuclear Weapons Governance and Politics

On what nuclear security issue are you working and why is it important?

My research explores the place of radiation exposure in nuclear weapons governance and politics. This question cuts to the core of debates about nuclear exceptionalism, the claim that nuclear technologies—especially nuclear weapons—belong in a category of their own. Radiation exposure, and its effects on human health and the environment, make nuclear (and radiological) weapons unique. Radiation exposure informs battlefield considerations about nuclear use, and it shapes military, diplomatic, and humanitarian views of nuclear strikes on cities and other civilian installations. Radiation exposure also shapes the entire process of nuclear weapons development, from uranium mining to plutonium production to warhead manufacture. The suffering caused by radiation exposure from nuclear attacks and weapons testing remains a guard against nuclear use.

My research shows how concerns about radiation exposure during the Cold War widened and intensified global participation in nuclear weapons governance and politics. During the era of atmospheric nuclear testing—which peaked between 1945 and 1963, and which continued on a smaller scale into the 1980s—nuclear weapon states proved their capabilities by conducting nuclear explosions in the open air. The health and environmental risks, as well as their political meaning, propelled non-nuclear weapon states and non-state actors to intervene in debates about nuclear weapons. Nuclear weapon states and intergovernmental organizations charged with nuclear weapons governance faced claims that the Cold War arms race threatened health, environments, and sovereignty. Often these arguments came from states that were pursuing independence from colonial empires or that had just won it, and radiation detection backstopped charges that decolonization processes did not go far enough to make international relations more equitable.

These interlocking concerns about health, environments, sovereignty, and inequality remain salient to global debates about nuclear weapons. Survivors and victims of radiation exposure from nuclear weapons development—in nuclear weapon states, and in the non-nuclear weapon states (often former colonies) used during the Cold War as nuclear test sites—continue to advocate for official recognition, environmental remediation, and financial compensation. Disarmament advocates point to the health and environmental impacts of nuclear weapons development as reason to dismantle these arsenals. Understanding the history of radiation exposure matters for the future of nuclear deterrence and nonproliferation.

What is the big question that you are seeking to answer about that issue?

My research seeks to explain how radiation exposure informs nuclear security. Discussions of nuclear security tend to focus on deterrence and proliferation. These frames prioritize the perspectives of nuclear weapon states—which guarantee the global deterrence and nonproliferation arrangements—but these frames can marginalize the role of non-nuclear weapon states and non-state actors. Radiation monitoring, especially during the era of atmospheric testing, provided non-nuclear weapon states and intergovernmental organizations clear stakes in nuclear security debates.

How are you going to answer your question? What methods will you use and what evidence or cases will you explore?

My research draws on several years of international fieldwork in archival collections maintained by nuclear weapon states, advocacy groups, and intergovernmental organizations. Other key sources include newspapers and magazines, scientific literature, and official reports.

My first book project, *Saharan Fallout: French Explosions in Algeria and Nuclear Risk during African Decolonization (1960–66)*, is based on my PhD dissertation. It examines the beginnings of the French nuclear weapons testing program, which took place at two sites in the Algerian Sahara from 1960 to 1966. The first four French nuclear explosions occurred in the atmosphere, followed by 13 underground explosions beneath Saharan mountains. These detonations coincided with the Algerian War for Independence (1954–62), the making of the postcolonial Algerian state, and other African decolonization struggles surrounding this desert. Rather than French institutional history, the book shows how Algerian officials as well as the leaders of neighboring African states and transnational social movements made radiation exposure from Saharan fallout a political resource for challenging the Cold War arms race. These emergent forces made their case by drawing the attention of France's nuclear-armed allies and of intergovernmental organizations, including the International Atomic Energy Agency (IAEA) and Euratom, to Saharan fallout. Key sources include archival documents produced by several branches of the French state, French anti-nuclear groups, France's Atlantic allies, and intergovernmental organizations.

My second book project, in its early stages, surveys the global history of radiological disasters and close calls. It draws on this history to examine the common—yet often unpersuasive—distinction between military uses and civil applications of nuclear technology. Potential cases include the irradiation of the Lucky Dragon fishing boat during a botched U.S. atmospheric nuclear explosion in 1954; plutonium cleanup from the thermonuclear bomb that landed but did not detonate near Palomares, Spain in 1966; theft of radioactive materials from an abandoned hospital site in Goiânia, Brazil in 1987; debates about radiological terrorist attacks in the early 2000s; and recent Russian shelling of the Zaporizhzhia nuclear powerplant in Ukraine, which threatens to transform a civilian installation into something very similar to a nuclear weapon. Whether military or civilian, these events share key qualities but have uneven consequences, because of uneven resources and because of political and ethical judgments about different applications for similar technologies.

What is your answer to the question you are asking? That is, what is your argument or conclusion even if it is still tentative at this point?

My research suggests that claims about radiation exposure from nuclear weapons can provide a political resource for non-nuclear weapon states and non-state actors seeking to challenge the policies and actions of nuclear weapon states. In the case of the Algerian Sahara, it is likely that French forces would have conducted more atmospheric explosions than they did, and during a longer time-period, were it not for the broad pushback that they faced. The French encountered significant challenges at first moving their blasts underground, and they refused to abandon the possibility of resuming atmospheric explosions after 1961. But they did not resume atmospheric explosions in Algeria, and they acknowledged the political difficulties that such a plan would have created for them in the international arena.

How does your work fit into the existing work on your subject?

My work builds on international histories of the global Cold War and decolonization struggles, Science and Technology Studies work on risk and governance, and security studies.

What alternative arguments or explanations exist and why is your answer superior?

Prior scholarship has primarily framed debates about nuclear weapons development in terms of proliferation, deterrence, or expertise. First, U.S. and anglophone scholars tend to prioritize proliferation in studies of the early Cold War, but some question how neatly this frame fits the French case. My work shows that French nuclear ambitions raised other key questions about nuclear weapons, and it proposes discontinuities with the global nonproliferation regime that crystallized at the turn of the 1970s. Second, a generation of French scholarship during the 1990s justified the French nuclear testing program as necessary to create an independent French nuclear deterrent. This approach prioritized elite French perspectives, which it portrayed as universally supportive of French nuclear weapons, and it marginalized national and international criticism. One scholar from this era went so far as to describe African opposition to French nuclear ambitions as "irrational." My attention to radiation exposure helps clarify the stakes of the African resistance. But my work does not treat Saharan fallout as purely a scientific problem that experts could resolve. Lastly, it explains how radiation exposure signaled inequalities in international politics that decolonization had not addressed and that nuclear weapons appeared to guarantee.

How does your work add to or change our understanding of the issue you are studying?

My work on radiation exposure seeks to broaden our understanding of the Cold War arms race and its geography. My study of French nuclear testing uses this case as a window into international negotiations over nuclear weapons during the 1960s among the Atlantic allies in North America and Europe, European states pursuing new forms of integration on the continent, and African states struggling for autonomy and independence from colonial rule. At the same time, my work situates the Algerian Sahara in a global history of nuclear test sites, stretching from Pacific islands to the Central Asian steppes to the U.S. Southwest. Tracking contestations over fallout trajectories in Africa illuminates but decenters the role of the superpowers in Cold War geopolitics.

What do you see as your most important contribution?

I see my most important contribution as methodological. I mean this in two ways. First, my studies of French nuclear testing and the military-civil distinction both draw on a multinational source base, built from declassification requests and archival fieldwork across nuclear-armed democracies and intergovernmental organizations. This approach provides a broad perspective on nuclear negotiations and decision-making, including the views of the non-nuclear weapon states and non-state actors that garnered the attention of high-powered officials. Second, my projects use historical methods to trace the emergence of ongoing political issues raised by nuclear weapons, including disagreement among nuclear weapon states, non-nuclear weapon states, and non-state actors about the governance of these technologies. If something like a global nuclear order exists, broad-based, cross-cutting archival research is necessary to trace its development.

What policy implications flow from your work? What concrete recommendations can you offer to policymakers?

First, in nuclear-armed democracies like the United States and its Atlantic allies, public support for maintaining these arsenals depends in part on officials' recognizing and mitigating the inequitable harms that developing these weapons entailed. As the recent, bipartisan extension of the U.S. Radiation Exposure Compensation Act shows, this history can generate surprising political coalitions and public engagement with nuclear security issues. In France, too, top officials have bent to public pressure over the past year and changed longstanding policy on access to state records about French nuclear weapons development in Polynesia. Second, the importance of radiation exposure to the global history of nuclear weapons governance suggests that policymakers need to consider the perspectives of non-nuclear weapon states and non-state actors in developing nuclear security policy. Global resistance to nuclear weapons, including the health and environmental risks, could threaten international security arrangements predicated on nuclear deterrence.

What do you think is the weakest or most vulnerable aspect of your study and what sort of feedback would be most useful to you?

One limitation of my work, especially given the current international security environment, is little attention to Russia and China. Even when it considers the Pacific theatre, it relies heavily on Atlantic sources. I would most appreciate feedback on ensuring relevance to policy and security audiences as I revise and continue projects launched as part of a history of science program.

2. Hamza El-Asaad, Texas A&M

Assessing Radioactive Dispersion from a Terrorist Attack on a Nuclear Power Plant

- **On what nuclear security issue are you working on and why is it important?**

  This study will focus on the potential impact on society of radiological release from a terrorist attack against a nuclear power plant (NPP). We will use the two nuclear power plants in Texas as examples for our study. The International Atomic Energy Agency has classified the nuclear facility incidents and accidents on its International Nuclear Event Scale (INES) based on the amount of radiological materials released [1]. We will conduct a parametric study on a set of these INES-type radiological releases that could potentially result from a terrorist attack on these Texas NPPs. The impact of the radiological releases depends on the conditions at the site of release, hence in our study we use these two example NPPs because the conditions at these sites are different.

- **What is the big question that you are trying to answer about the issue?**

  The objective is to assess the radiation dose rate to the members of the public, as a function of time, from a hypothetical nuclear security event at a NPP. We will consider the radiological releases of the Fukushima magnitude [2]. Even though the Fukushima disaster was not caused by a deliberate attack, something of similar or reduced magnitude could be causes by a terrorist act. The study will provide information to the response team to such a nuclear security event.

- **How are you going to answer your question? What methods will you use and what evidence or cases will you explore?**

  Task 1

  This study plans to create a one-year database for each of the nuclear power plants in Texas using the Worldwide version of System for Prediction of Environmental Emergency Dose Information-Database (WSPEEDI-DB), created by Japan Atomic Energy Agency (JAEA) [3]. Initially, meteorological forecast data using the Weather Research Forecast from March 1st, 2020 to February 28th, 2021 will be collected, which will also include information such as terrain/topographies. This information will be used to calculate radiological material concentrations at regions around the NPP due to radiological material (varying source terms) releases at different release heights (20 m and 80 m). The release rate magnitudes considered will be similar to the Fukushima event based on the UNSCEAR report [2].

  Task 2

  Using the database, simulation outputs of plume dispersion and radiological depositions will be produced for both nuclear power plants in Texas. The start and end periods of the release rates will vary depending on the season. This study will demonstrate and distinguish the similarities, differences in plume patterns and depositions based on the various climates and weather. Using the WSPEEDI-

DB graphical user interface (GUI) graphs, tables and horizontal distribution figures and movies of plume analysis will be produced.

Task 3

The final step is compartmentalizing and narrowing down the data based on seasons to identify:

1) Similar plume patterns
2) Plume outliers
3) Locations of hot spots from depositions
4) Comparison of plume dispersions and depositions between STP and Comanche Peak
5) Compare theoretical monitoring post readings from various coordinates

- **What is the answer to the question that you are asking? That is, what is your argument or conclusion even if it is still tentative at this point?**

  This study will demonstrate that WSPEEDI-DB can be one of the tools technical advisors to the policy makers in the United States can use to help in risk and/or crisis management. The interface in WSPEEDI-DB for both input preparation and output analysis are very user friendly. Simulation outputs contain the various complexities and patterns of plume dispersions in a large domain of 100 x 100 km^2 in addition to swift outputs. The likely risk to the public may range from moderate to severe, depending on season, because Texas mostly has a flat terrain and plumes can travel long distances easier.

- **How does your work fit into the existing work on your subject?**
  - **What alternative arguments or explanations exist and why is your answer superior?**

    Similar studies of nuclear dispersion have been conducted using plume puff model simulations. These simulations are based on a small domain of approximately 10 x 10 km^2 [4]. However, this study's new investigation is focusing on large domains to investigate the effects of radiological movements, plume patterns, deposition and hotspots in areas further away from the nuclear power plants.

  - **How does your work add to or change our understanding of the issue you are trying to study?**

    This study will demonstrate the potential effects on local populations living near Texas NPPs in particular, but can be also used at any nuclear facility locations in the event of a terrorist attack on the facility. Seasonal and geographical dependence on the impact to public can be very well handled by WSPEEDI-DB.

  - **What do you see as the most important contribution?**

    The most important contribution of this study will be the estimation of public dose rate impact due to a large-scale security event at a nuclear facility involving radiological materials release. The scenarios will assume various releases from all weather patterns to cover all possible outcomes. In a crisis management, there is large unpredictability, therefore by learning useful lessons from the FDNPP, this study aims to mitigate or highlight case scenarios that have not previously been analyzed.

- **What policy implications flow from your work? What concrete recommendations can you offer to policymakers?**

  The results of this study can be used as for preparing precautionary measures and contingency plans to improve evacuation procedures in a radiological emergency. Recommendations such as where best to install monitoring posts in our domain study, where and when to dispatch moving monitoring posts and where highly potential hotspot locations maybe located, with respect to seasons. As a result, this will determine evacuation procedures and shelter-in-place orders.

- **What do you think is the weakest or most vulnerable aspect of your study and what sort of feedback would be most useful to you?**

  The uncertainties associated with the estimation of radiological release levels, especially in the initial phase of the nuclear security event, could introduce uncertainties in the dose rate predictions. Therefore, policymakers could refuse to use WSPEEDI-DB simulation outputs that may impact quick policy making, which was true during the Fukushima accident. However, the Fukushima experience later on showed that WSPEEDI-DB results were accurate enough, based on the ground truth verification. We would like to hear the level of uncertainties a policymaker will accept while using such tools for policymaking during crises.

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3. Philseo Kim, Texas A&M

Assessing the Nuclear Weapons Proliferation and Security Risks of Nuclear Trade for Nuclear Energy Newcomer Countries: The Case of Small Modular Reactors

On what nuclear security issue are you working and why is it important?

With heightened concerns about greenhouse gas emissions, more countries have become interested in nuclear energy to meet growing electricity demand (Jewell, 2011). In particular, these newcomer countries and major nuclear exporter countries have a growing interest in SMRs. This is because SMRs have more advantages than large commercial nuclear power plants in terms of governance, public perception, safety, and financial risk. SMRs are also known to enhance nuclear security by reducing the amount of plant area, implementing a passive safety system, and having a long refueling cycle in most core designs. However, the efficiency of SMRs will create several concerns in terms of nuclear security. SMRs can be vulnerable to adversary sabotage and insider threats when it is installed in remote areas. There will be also security threats when reactors loaded with nuclear fuel are transferred to the operating site. In particular, floating-type SMRs may have a hidden potential for nuclear threats, given that they can be easily targeted by terrorists.

Above all, potential concern about newcomer countries is their governance characteristics, political environment, and the resulting implications for nuclear safety, security, and project management. Many of these countries scored low on regulatory quality, government effectiveness, control of corruption, and political stability (Nguyen and Yim, 2019; Lin, Bae, and Bega, 2020). Lastly, we cannot ignore the risks due to the geographical characteristics of the newcomer countries in the Middle East and Southeast Asia, which are potential SMR clients.

The advent of Small Modular Reactor (SMR) technology lowers the threshold for deploying nuclear energy projects in newcomer countries, generating new uncertainties about future nuclear weapons proliferation and security risks. My research seeks to determine whether future SMR nuclear trade will contribute to nuclear weapons proliferation, and how this risk can be mitigated. The project will use a quantitative framework and expert elicitation to assess the proliferation and security risks arising from the deployment of foreign-built SMRs in newcomer countries. Moreover, my research will evaluate the spent nuclear fuel return system designed to reduce security/geopolitical issues raised by deploying SMRs in high-risk countries. The results of my work in estimating the risks for future trade can provide recommendations for policymakers in the United States and abroad seeking to promote peaceful nuclear cooperation while reducing nuclear proliferation/security risks.

What is the big question that you are seeking to answer about that issue?

The following questions will be addressed in this research:

- ✓ What are the nuclear weapons proliferation and security risks associated with the deployment of different types of SMRs in nuclear energy newcomer countries?
- ✓ What policies can lower the security risks stemming from the deployment of SMRs in these newcomer countries?

How are you going to answer your question?

As mentioned in the previous section, the SMR is very different from existing commercial nuclear power plants, in terms of the fuel type and replacement fuel cycle. Moreover, newcomer countries vary in nuclear fuel cycle options, governance characteristics, political environment, and project management. Therefore, nuclear security and proliferation risks will largely be affected by not only SMRs themselves but also country-specific characteristics. To assess the risks associated with various environments of a country and the characteristics of SMR, I will conduct the following activities:

A. Identifying newcomer countries

In this research, I will assess nine countries identified as nuclear newcomer countries interested in SMRs as part of the national energy development. These countries include Algeria, Egypt, Indonesia, Jordan, Malaysia, Morocco, Saudi Arabia, Thailand, and Vietnam.

B. Quantitative modeling methods: Bayesian network analysis

The Bayesian network has been widely used to provide a flexible tool for knowledge elicitation under uncertain risk assessments. For example, Bayesian Belief Network is used in estimating the proliferation/security risks when the newcomer countries deploy Generation III + nuclear power plants and Small Modular Reactors (Carless, Redus and Dryden, 2021). However, there are some ambiguity and uncertainty problems with expert probability judgment. To overcome these issues, another study has used Fuzzy-logic Bayesian network to assess the security risks of SMR (Prawira, 2019). In this project, I will choose one of these techniques and use it as my quantitative modeling of security risk.

C. Identifying the nodes of proliferation/security risk

The Bayesian network is composed of interconnected nodes (variables). A previous study (Carless, Redus and Dryden, 2021) has used various nodes in the Bayesian Network that can affect the proliferation/security risks. This includes: 1) responsible user of nuclear power, 2) energy needs, 3) technological capabilities, 4) type of ownership structure, and 5) nuclear fuel cycle.

In addition to these variables in the existing literature, I will use regulatory quality, control of quality, political stability, and absence of terrorism as country-specific characteristic nodes. Regarding SMR types, I will include 2 types of SMRs (Light Water Reactor and Molten Salt Reactor). The siting option node will consist of on-shore near the city, on-shore in the remote area, and off-shore (floating) options. Lastly, I will try to put physical cybersecurity protection scenarios in the nodes.

D. Expert elicitation

Since there is a lack of information on conceptual SMR facility design, expert opinions should be aggregated to determine the conditional probability of each Bayesian network node. As a nuclear engineer, I have been working on an autonomous SMR research project since 2016. As a result, I know how to connect with a variety of domestic and international SMR experts. I will gather experts across government, academia, private industry, think tanks, and research institutions, not only in Korea but also in the United States. By surveying them, I will compile their assessments of the proliferation/security risks specific to SMR deployment in newcomer countries. This expert survey will also include physical protection, cybersecurity systems, and remote monitoring, based on the scenarios of possible security threats.

What is your answer to the question you are asking?

My expected result of this research project is that proliferation/security risks will be the highest in Middle East countries (i.e., Saudi Arabia or Egypt) since it has geopolitical issues, nonproliferation norms ratification, and experiences in nuclear enrichment endeavors. In a nutshell, the central argument of my research is that country-specific factors are more important than SMR technology in shaping security risk.

What policy implications flow from your work? What concrete recommendations can you offer to policymakers?

To reduce the proliferation/security risks of the newcomer countries from my modeling results, I will examine potential solutions. Specifically, I will delve into the feasibility of implementing a spent nuclear fuel return system in the major supplier countries, such as the United States and South Korea. ROSATOM is the representative case using the repatriation provisions of the foreign spent fuel in its nuclear contracts (Nephew, 2022). These provisions can provide an attractive option for newcomer countries that lack spent nuclear fuel disposal systems. In addition, it brings nonproliferation benefits to suppliers by eliminating plutonium proliferation risks in the client countries. However, there will be safeguards/security issues in implementing the system. New regulation systems will be necessary to properly manage high enrichment and nonstandard maintenance procedures such as Pyroprocessing to realize this system. I will investigate the issues of the export SMR/return spent fuel options, and suggest policy recommendations to overcome these obstacles.

How does your work fit into the existing work on your subject?

My research project will overhaul the nuclear security assessments from the previous studies, incorporating all the SMR siting options, various types of SMRs, fuel cycle options, and country-specific characteristics. With the growth in global electricity demand and the concern over climate change, interest in nuclear power, including SMRs, is on the rise around the world. In light of this situation, it is important to analyze future proliferation/security risks. These future predictions will provide an understanding of the potential expansion of the SMR market. As

that market emerges, future proliferation and security implications may not follow what is dictated by the typical nuclear nonproliferation regime from the previous literature.
My engineering and social science research experiences allow me to understand and assess the proliferation and security risks of SMRs. I will disseminate the results through presentations, journal articles, and a policy report sent to interested scholars. I will arrange to give presentations in South Korea and in NSSPI as recommended by my fellowship advisors. Then I will use my results to develop policy recommendations for stakeholders in the United States and South Korea on how to responsibly develop and manage global SMR development. This interdisciplinary approach will benefit the Stanton and NSSPI by providing a new perspective on nuclear security and nonproliferation, which are key to its mission.

What do you think is the weakest or most vulnerable aspect of your study and what sort of feedback would be most useful to you?

Bayesian networks that rely on expert judgment can be vulnerable to human bias and the ambiguity of linguistics. Due to this vulnerability, any advice on the selection of survey personnel will help me to minimize the bias. I would also appreciate the feedback on any other methodologies to mitigate the bias and the comments on the spent nuclear return program.

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