Stanton Nuclear Security Fellows Seminar

1. Edward Blandford, CISAC

Strengthening the Global Nuclear Safety Regime in a Post-Fukushima World

Introduction

In the Fall 2009 *Daedalus* special issue on "Global Nuclear Futures", Richard Meserve, the former chairman of the U.S. Nuclear Regulatory Commission, described the collective international enterprise, known as the global nuclear safety regime, responsible for establishing the level of performance expected of all nuclear power plant operators and regulators, and monitoring that performance and building competence and capability among these operators and national regulators. The key stakeholders that are responsible for industry learning include the regulatory and other relevant government authorities, licensees and their shareholders, industry organizations, media, and non-governmental advocacy organizations. In light of the recent nuclear accident at the Fukushima-Daiichi plant in Japan, strengthening this regime has never been more crucial; in particular with many industrializing countries heavily pursuing nuclear power as well as many new countries starting up nuclear programs. Mechanisms to facilitate and, where needed, enforce mutual learning among countries is not as effective today as it is within countries and may not be adequate to prevent avoidable disasters.

Through my research with the support of a Stanton Nuclear Security Fellowship, I plan to develop ways to strengthen the global nuclear safety regime in order to help the world realize the full potential of nuclear energy. More specifically, I plan to explore whether there are ways to strengthen this global nuclear safety regime through better information sharing, import-export agreements based on safety standards, agreements to facilitate cooperation among regulatory authorities, and the participation of financial interests such as investors and insurers. Much of the information sharing on best practices on nuclear safety occurs in the United States through a private organization known as the Institute for Nuclear Power Operations (INPO) and internationally through another private organization known as the World Association of Nuclear Operators (WANO)[1]. History has shown us that the former has led to significantly improved domestic plant operations, while the latter lacks the 'teeth' to effectively enforce mutual learning across international boundaries. The knowledge to do this comes from experience. Most of it, fortunately, has been obtained from research and day-to-day learning, without for the most part major accidents. Nevertheless, the recent accident at the Fukushima-Daiichi plant has challenged this paradigm.

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[1] It should be noted that other organizations such as the Electric Power Research Institute (EPRI), the IAEA, the NEA, and national research laboratories also contribute to the collective learning process.

Research Methodology

My proposed research project builds off a recent publication I co-authored with Dr. Michael May titled "*Lessons Learned of 'Lessons Learned': Evolution in Nuclear Power Safety and Operations*" for an upcoming Nuclear Enterprise Conference at the Hoover Institution[2]. In this paper, we focused on the way the organizations responsible for operating and regulating the global nuclear industry have learned from operational experience, their own and that of others. Throughout this history there have been a range of reactor events ranging in severity. Many of these events have been deconstructed and better understood through root-cause investigations yielding a set of '*lessons learned*'. Our focus in this paper was to examine these sets further and develop insights about how the industry and other stakeholders collectively learn from accident experience.

During my Stanton fellowship, I propose to first determine how appropriate safety standards are determined, set and implemented for dealing with accidents ranging from anomalies to severe accidents. Since nuclear safety and security share a common objective of protecting the local population and environment from a large radioactive release[3], security standards will also be examined with an emphasis on emerging nuclear countries. Since a global safety regime based on a sole global regulator is highly unlikely and perhaps even a negative, I will focus on identifying mechanisms that could potentially spur regional regulatory networks to be established. One could conceive that regional regulatory networks could help strengthen international organizations such as WANO or the IAEA through establishing a minimum set of safety standards where failure to meet would have realizable financial consequences.

This leads directly to the next topic of my proposed research approach which is the observation that improved cooperation will also rest most securely on lasting shared economic interest among vendors, owners-operators, government regulators and the public. At the same time, the international nuclear power and nuclear fuel cycle markets will become if anything more competitive than they have been. No solution to this problem is in sight at present. Elements of a solution that I will examine, using historical precedent in nuclear and other relevant capital-intensive industries, include the following:

- Potential forms of import-export agreement such as the Nuclear Suppliers Group (NSG) which now monitors for weapons-sensitive materials and components. Those efforts rest on an agreement at the state level and the same would be true of a safety-oriented agreement. If there were such agreement among states, one could envisage that any vendor wishing to export reactors or other potentially dangerous nuclear facility would need a license certifying that the design is meets modern safety standards. There are only a few international reactor vendors, so that implementation might be feasible.
- Reactor design is not the only ingredient of safety. Siting, construction practices, operations also enter in essential ways, as do accident management, regulatory review and lessons learned feedback. Agreement at the state level strengthening cooperation among regulatory authorities,

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[2] The Hoover conference on October 3rd and 4th is organized by Sec. George Schultz and Dr. Sidney Drell and is titled "*The Nuclear Enterprise*".

[3] Diversion or theft of material is also a major security challenge but is more a focus of safeguards. Additionally, it should be noted that there are many areas where safety and security objectives are in strong conflict.

even perhaps setting standards for independence of those authorities, would be a step to meet problems there. There is no clear consensus on what structure best assures such independence, or rather effectiveness at managing an inherently interdependent process that involves many stakeholders. A conversation on the subject that would take into account national precedents and institutions is needed before any attempt is made at discussing standards.

- Finally, investors and insurance companies have strong incentives to avoid serious accidents. Insurance company liability is generally limited, leaving investors and taxpayers to take losses. In most countries, investment comes in part from government, in part from bond sales. Investment represents a potential source of leverage to avoid accidents but to date it has not been harnessed toward effective action, in part because of lack of knowledge, in part because nuclear-related investments may be only a small part of the portfolios.

In order to achieve these objectives I will engage a number of nuclear safety experts from both established nuclear states and, more importantly, new emerging nuclear energy states, which have expressed interest in expanding their nuclear technology portfolio, but have little experience in managing the safety and security of these technologies. I recently coordinated and organized a workshop sponsored by the Korean Atomic Energy Research Institution (KAERI) and Stanford's CISAC, where I invited nuclear energy specialists from South Korea and the United States to discuss nuclear energy development and security best-practices. These workshops and Track II meetings have allowed me to have informal discussions on the topic of my research and share with them how our governments and the nuclear energy industry can work together to strengthen the global nuclear safety regime. I plan to organize similar workshops with other emerging nuclear countries.

Nuclear safety is not only a domestic challenge in the United States, but also a global challenge. As part of my research, I plan to interview nuclear safety experts from emerging nuclear energy countries to better understand how they have developed their nuclear safety infrastructure and how well their technical experts have been trained in managing nuclear safety risks within the fuel cycle. Through my experiences as a nuclear engineer from U.C. Berkeley's Nuclear Engineering Department, an employee in the nuclear energy industry, and as a postdoctoral fellow at CISAC, I have fostered a number of contacts within the nuclear arena. While at Stanford University as a postdoctoral fellow at CISAC, I have worked closely with Dr. Siegfried Hecker, Dr. Michael May, Dr. Alan Hanson, Dr. Sidney Drell, Dr. Scott Sagan, and Dr. Burt Richter on issues pertaining to nuclear safety and security. Working with these experts, I have had the chance to see how nuclear scientists, industry personnel, and policy experts view the issue of nuclear safety and security. The global challenges of nuclear safety are truly interdisciplinary. As a result of my close working relationship with those experts previously mentioned, I have access to senior nuclear security experts and officials from around the world. These interviews and Track II discussions will not only help my research, but allow me to engage with the future nuclear safety experts within emerging nuclear countries to better understand their nuclear safety regimes.

Summary and Policy Implications

There is a special need for nuclear installations to demonstrate and maintain higher standards of safety than the utility fossil industry norm, given the potential for severe accidents at some of the installations and the public apprehension over all things nuclear. The domestic United States fleet of nuclear power plants is to a certain extent hostage to the performance of nuclear power plants across the world. As recent decisions made by the German, Italian, and Switzerland governments to put a moratorium on new builds or phase out existing plants have shown, a nuclear accident anywhere in the world can have tremendous consequences everywhere. Strengthening the global nuclear safety regime while ensuring the peaceful use of nuclear energy is an integral component of United States energy and national security policies. However, this safety regime must be realizable within all nuclear nations' legal, political, economic, and societal constraints. Recognizing these drivers early on will make efforts to strengthen the global nuclear safety regime more likely to achieve success. I plan to disseminate the results of my research to relevant policymakers in Washington, regulatory authorities, and private organizations concerned with reactor safety. This will be achieved through publications, workshops, and conducting Track II discussions with nuclear experts around the globe.

2. John Downer, CISAC

Unknown Unknowns: Reexamining Tacit Knowledge and Nuclear Proliferation

Synopsis

The goal of this project is to reanalyze the relationship between tacit knowledge and nuclear proliferation, by revisiting a classic case study in light of recent work in the Science and Technology Studies (STS) literature.

The STS literature on tacit knowledge -- which takes inspiration from Polyani (1967), but is elucidated most clearly, in an STS sense, in the work of Collins (2001; 2010) -- speaks to the idea that "we know more than we can tell." When explored in the context of engineering, it highlights the often unrecognized extent to which complex technologies depend on informal knowledge, cultures and practices that are not codified in formal accounts, and are difficult to reproduce without a degree of apprenticeship. As such, it has far reaching implications for a range of discourses around technology, not least those pertaining to nuclear proliferation. Unsurprisingly, therefore, a number of scholars have invoked the concept to make strong claims about the development and dissemination of nuclear weapons.

In an influential and compelling (1996) article, for instance, MacKenzie and Spinardi draw on detailed interviews with US weapons designers to illustrate the role of tacit knowledge in nuclear weapons design, and then leverage it to argue that nuclear weapons might be 'uninvented' by disrupting the institutions and associations through which the tacit practices of their production are maintained and reproduced. Their argument, although complex in execution, is simple in principle. Having shown that the design and manufacture of nuclear warheads depends on esoteric skills and understandings that cannot be codified in blueprints and manuals, they then speculate that if the people with those skills were kept from passing on their knowledge to others, then nuclear weapons would become difficult to reproduce from accounts alone.

MacKenzie and Spinardi were the first to explicitly invoke the notion of tacit knowledge in a security context, and their detailed account has served to substantiate the concept for others in the security literature, who subsequently have invoked it relatively uncritically as part of wider arguments about proliferation. Montgomery (2005), for instance, uses tacit knowledge to explain why the dissemination of information seems to have had limited effect on the timeframes of most nuclear programs. Then, more substantially, he draws on it to explain why proliferation networks appear to operate in a 'hub-and-spoke' configuration, where one nation (the 'hub') shares expert knowledge with other nations (the 'spokes') who do not share with each other. His argument is that only the 'hub' is possessed of certain tacit technical competencies, so the 'spokes' depend on it (even after they own the physical technologies and blueprints), and are unable to substantially aid their peers. This is a strong claim. It suggests that *all* proliferation networks will *necessarily* operate in this configuration, and, hence, speaks to the literature on 'second-tier' proliferation among aspiring nuclear states (eg: Braun & Chyba 2004) by suggesting that second-tier networks, which appear to be rising in significance, might be substantially disrupted by impeding the activities of the 'hub'.

Beyond these examples, it is easy to see how tacit knowledge might have further implications for debates around nuclear proliferation. Vogel (2006), for instance, suggests one avenue when she invokes the idea to moderate assessments of how difficult it is to reproduce biological weapons from academic accounts of their manufacture. She argues that biological weapons depend on skilled practices that are both difficult to learn and impossible to codify in reports, so there will always be something essential that is missing from leaked accounts -- an invisible barrier to proliferation. The same argument, easily transposed onto the nuclear realm, speaks to the concerns of proliferation 'determinists' who argue that 'loose' blueprints and documentation emanating from the A.Q. Kahn network -- copies of copies of copies passed furtively among defiant states -- are effectively lowering technological barriers and accelerating nuclear development (Montgomery 2005: 155).

In the same vein, proliferation discourse might also look to Collins' (1985) book, in which he follows the attempts of various laboratories to recreate a new kind of laser, many of which were unsuccessful for long periods even though the principle behind the laser was well understood and had been proven in practice. Collins shows how a timeline of the successful attempts mapped more closely onto the movements and interactions of people than it did onto resources or onto the diffusion of codified knowledge such as blueprints. It is straightforward to imagine how this might be relevant to proliferation questions: suggesting, as it does, how technological achievements move more easily with people than with documents.

A Critical Perspective

Insights into tacit knowledge are no doubt useful to proliferation debates, therefore, in that they draw attention to a consequential but often under-recognized dimension of technological practice. At the same time, however, it is important to consider them skeptically. As noted above, most invocations of tacit knowledge treat it unproblematically; often building on the fieldwork of Mackenzie and Spinardi, by applying their finding -- that nuclear engineers *know more than they can tell* -- to new contexts. In recent years, however, STS scholars have started to refine their understanding of tacit knowledge and explore it more deeply. Rather than treating it as a homogenous term encompassing all uncodified knowledge (as the security literature invariably does), most studies now argue that it can usefully be parsed into several categories, each with distinct practical and epistemic implications (Collins 2001, 2010; Doing 2009; Olesko 1993). To pick four prominent examples, 'tacit knowledge' might be divided into:

1. Knowledge that has not been codified because it is excluded by the stylized nature of formal accounts such as blueprints and scientific papers. (For instance: information about how long it took the authors of a scientific paper to achieve a result.)
2. Knowledge that has not been codified because its significance is unrecognized (In Collins account of the lasers, for instance, it eventually became apparent that, unbeknownst to the laser pioneers, the gauge of the wires they were using was critical to their success).
3. Dexterous 'skills,' which we understand but cannot formally explain. (Such as knowledge of how to ride a bicycle.)

4. 'Socially-situated knowledge.' (The knowledge we possess solely by virtue of our 'being-in the-world,' such as the art of knowing when we are behaving 'appropriately' in a nuanced and dynamic social setting).

Significantly for questions regarding proliferation, sociologists now believe that these different dimensions of 'tacit knowledge'; have very different properties, and varying relationships to engineering practice.

Take, for example, the question of codifiability (ie: the extent to which something can be formally recorded or 'codified'). Many studies that invoke tacit knowledge do so in a way that makes strong claims about codifiability. '*Engineers have knowledge they cannot tell:'* this is the principle that underpins MacKenzie and Spinardi's claims about the 'uninvention' of nuclear weapons, as well as claims about the primacy of people over texts. A closer examination of the categories above, however, suggests that most forms of tacit knowledge have a more nuanced relationship to codifiability.

Categories 1 and 2 consist of knowledge that engineers *could*, in principle, tell, but don't; either because they are blind to its significance, or because of the constraints of formal documents. Yet, it is reasonable to assume that such knowledge might come to be codified over time, either in formal accounts, (as the unrecognized significance of specific details become apparent), or in peripheral and informal literatures such as biographies and FAQs, which are less stylized than blueprints are scientific papers and allow a greater range of expression.

Category 3 -- dexterous 'skills' -- certainly represents a knowledge that engineers are unable to 'tell', in a literal sense. Yet to say that skills are unlikely to be captured in prose is not, necessarily, to say they are not codifiable in other media. After all, modern industrial robots are able to record (codify), and then reproduce, the precise actions of skilled wielders. And, even if some skills cannot be captured entirely, they routinely become obsolete as tools and instruments expand. (Producing text in this exact font would once have required me to undergo years of calligraphic practice).

Category 4 -- 'socially-situated' knowledge -- sociologists argue, has a much stronger claim to being inherently uncodifiable (and, hence, untransferrable). But despite being of intense interest to academic epistemologists, and an abiding concern for artificial intelligence experts, it is difficult to see the direct relevance of this kind of knowledge to most meaningful engineering endeavors, especially as they pertain to proliferation.

Reexamining tacit knowledge's relationship to codifiability in this fashion casts new light on much of the work that invokes it in relation to nuclear proliferation. This perspective still suggests that there may be (and probably is) a lot of important engineering knowledge that is possessed by experts alone and is missing from documents and accounts, (and, hence, for instance, that formal documents alone are unlikely to carry proliferators 'all the way'). At the same time, however, it suggests that the amount of uncodified knowledge pertaining to nuclear design is likely to diminish over time, as it slowly becomes codified, mechanized, or made obsolete, and, thus, that the notion of tacit knowledge will have neither a consistent nor a straightforward relationship with proliferation.

It is the goal of this study to further explore this argument, along with various other implications of new tacit knowledge research, in light of nuclear security issues. Instead of treating tacit knowledge as an unproblematic concept, it will directly revisit many of the same issues and cases that MacKenzie and Spinardi use to justify their account, and reexamine them in light of the new conceptual frameworks. In doing so, it hopes to speak to the academic STS literature (by examining new debates in the context of an important case study); and, more significantly, to both the academic and policy nuclear-security communities, by refining, reframing and rethinking the relationships between tacit-knowledge, expert practice and technology proliferation.

Methods:

Although I am current with much of the STS literature on tacit knowledge, from previous work, the nuclear proliferation literature is less familiar to me, and a goal of the forthcoming year will be to explore it further. The larger part of the research, however, will be to revisit accounts of tacit knowledge in weapons manufacture. As is typical of STS research, this work will be primarily qualitative. It will draw on a range written and oral accounts, as well as a series of semi-structured interviews with scientists and engineers who have experience of weapons design and manufacture at the national laboratories (which should be relatively straightforward to arrange through CISAC). Although work in this tradition is never explicitly framed in turns of 'null-hypotheses', it is rare indeed that one comes away from such interviews with every preconception intact and presumption confirmed.

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3. Togzhan Kassenova, Carnegie

Implementing UN Security Council Resolution (UNSCR) 1540 in Developing Countries

Project description

The research project I would like to pursue relates to the implementation of UNSCR 1540, which calls upon all UN member states to develop domestic controls to prevent WMD proliferation to non-state actors. The way in which different countries view UNSCR 1540 and its objectives reveals interesting and telling patterns. While no country openly pushes back against UNSCR 1540 objectives, many countries with developing economies and no history of WMD programs see its mandate as an indiscriminate imposition of mainly Western objectives to curb WMD proliferation on all. The debate on UNSCR 1540 objectives often points to a broader North-South divide on issues of disarmament and nonproliferation. Many countries in the global South perceive UNSCR 1540 as a "North-driven priority" and its implementation as detrimental to the South. Non-nuclear states often quote a lack of progress towards nuclear disarmament by nuclear states as a source of further frustration with nonproliferation-focused initiatives like UNSCR 1540.

A significant number of states face challenges with implementing UNSCR 1540-mandated requirements, more often than not due to a lack of resources and expertise. More importantly, many see the implementation of comprehensive proliferation controls as an unnecessary burden and not the best way to spend limited resources. In some regions, there has been only limited recognition that proliferation threats stem not only from the supply side (when a given country can be a source of sensitive goods or technology), but also from unregulated transit and transshipment flows of goods.

In this context, I am specifically interested in exploring how concerns about UNSCR 1540 in developing countries fit into a larger debate on disarmament and nonproliferation, and how they relate to tensions along the North-South divide. My objective is to explore perceptions, motivations, and obstacles to implementing UNSCR 1540 in developing countries. I also aim to develop recommendations on how countries can be persuaded to strengthen UNSCR 1540-mandated proliferation controls based on national development and security interests. Potential motivating factors include but are not limited to strengthened abilities of governments to tackle arms and drug trafficking, and terrorism; economic benefits of being a secure trading partner and transit/transshipment hub; and facilitation of high-tech transfers possible due to confidence that proliferation risks are minimized.

Research methodology

This project will be a case study of a select number of developing countries. The selection of countries for this study will take into account the overall importance of any given country to the global nonproliferation regime. Among the factors to be considered: the geographic location (is a country a major transit/transshipment hub?); the industrial profile (does the country have an emerging dual-use industry? Is the country considering introducing nuclear power?); security environment (does a country have active terrorist networks?).

The study will rely on primary and secondary documents, interviews with officials and experts, and methodological assessment of the countries' relevant legislative and institutional capacity to implement domestic proliferation controls.

Target audience

The primary target audience of the study consists of several distinct groups of stakeholders: the UNSCR 1540 committee members and UNSCR 1540 group of experts; key Western governments, specifically the United States; governments in the developing countries, specifically in countries selected for the study; international development community; scholars and policy experts working in the field of nonproliferation and disarmament.

Policy implications

The key objective of the study is to provide actionable policy recommendations on how to promote implementation of UNSCR 1540 to ensure greater sustainability and buy-in among developing countries. Using UNSCR 1540 experience as a case study, this project will contribute to the policy debate on how to bridge the gap between nonproliferation and disarmament objectives. It will provide recommendations on how to minimize tension of objectives and capitalize on shared interests between the countries of the Global North and the Global South.