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Nuclear Energy Safety and International Cooperation

Closing the world's most dangerous reactors

Spencer Barrett Meredith, III

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Nuclear Energy Safety and International Cooperation

Twenty-five years after the Chernobyl explosion, disaster struck once again after a tsunami overwhelmed the considerable safety measures at the Fukushima nuclear power plant in Japan. However, Fukushima had in place a solid containment structure to reduce the spread of radiation in the event of a worst-case scenario; Chernobyl did not. These two incidents highlight the importance of such safety measures, which were critically lacking in an entire class of Soviet-designed reactors.

This book examines why five countries operating these dangerous reactors first signed international agreements to close them within a few years, then instead delayed for almost two decades. It looks at how political decision makers weighed the enormous short-term costs of closing those reactors against the long-term benefits of compliance, and how the political instability that dominated post-Communist transitions impacted their choices. The book questions the efficacy of Western governments' efforts to convince their Eastern counterparts of the dangers they faced, and establishes a causal relationship between political stability and compliance behavior. This model will also enable more effective assistance policies in similar situations of political change where decision makers face considerable short-term costs to gain greater future rewards.

This book provides a valuable resource for postgraduate students, academics and policy makers in the fields of nuclear safety, international agreements, and democratization.

Spencer Barrett Meredith, III has worked in the field of international relations as a professor and practitioner for more than a decade, teaching at the undergraduate and graduate levels, as well as serving as a Fulbright Scholar in the Caucasus and a guest lecturer for the US Department of State in South and East Asia. He is currently an Associate Professor at the College of International Security Affairs in the US National Defense University.

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Soli Deo gloria

Preface

This project began in 1999 as part of my time at the US Department of State during a break from doctoral studies. It included first hand interviews with many of the principle players in nuclear safety in the United States and the European Community. Later research at the International Atomic Energy Agency (IAEA) in 2002 in the midst of Western compliance efforts added the views of Eastern European nuclear officials. The final project came together after Lithuania officially closed the last reactor at the Ignalina power plant in 2009, thereby closing a dangerous period in global environmental safety. Unfortunately two years later, and twenty-five years after Chernobyl exploded, the Fukushima disaster occurred, once again drawing safety concerns to the nuclear industry. This book examines the first efforts to close dangerous reactors, with the hope that the world will need no further reminders of the risks of delaying disaster.

Acknowledgements

I wish to thank my wife for her ongoing support and encouragement through many late nights working. I also thank my sister for her editing of this manuscript from its first, very rough draft, and my father for his sacrifice for me to complete my doctoral degree that began this research. In addition, my children have been a great motivation to do this job well and on time so I can play when the work is done. Finally, I offer my profound gratitude to Carol Kessler, without whom none of this would have been possible.

Contents

1 Political rules and nuclear safety

Nuclear power is here to stay. It produces fewer greenhouse gases than fossil fuels, and despite enormous start up costs, is relatively cheap over decades of operation. Unfortunately, nuclear power also generates by-products whose harmful effects are not measured in generations, but in millennia. Even in the United States, the ongoing failure to establish a long-term waste storage facility highlights concerns of future contamination, as well as the potential acquisition of radioactive materials by terrorist organizations. Making matters worse, simply operating nuclear power plants can expose local populations to lethal radiation, as seen after the Fukushima nuclear meltdown in March 2011. The level of damage there surpassed the considerable safety measures at the facility, showing the worst-case potential of continuing global contamination for otherwise "good" reactors.

That disaster occurred twenty-five years after the world witnessed the worst-case scenario for a "bad" reactor when the nuclear power plant at Chernobyl exploded in April 1986,[1] spewing radioactive material over the surrounding countryside and as far away as North America and Japan. Once lush areas of Ukraine and Belarus became uninhabitable, and decades later, Moscow fruit vendors still sold contaminated wild berries collected hundreds of miles away. As bad as that accident was though, Chernobyl also pointed to a series of problems with an entire class of Soviet-designed reactors, problems that could easily have led to similar disasters throughout the region.

The Soviets built nearly seventy reactors during the Cold War, approximately half of them in Russia and the rest going to proxy states in the Eastern bloc and three Soviet republics.[2] The two main types consisted of carbon based, graphite-moderated (RBMK) and pressurized, light-water cooled (VVER) reactors.[3] Graphite-moderated reactors also use water to cool the nuclear reaction, but problems can occur when water turns to steam thereby reducing the water's safety effects on the fissile material, known as the void coefficient. Positive void coefficients are particularly dangerous in RBMKs because they can lead to an increase in the fuel cycle that culminates in core meltdown. Control rods prevent the reaction from getting out of control, but the accident at Chernobyl showed what happens when that control is lost – engineers had been conducting a low-level test that failed to supply enough power to the control rods in time to prevent the disaster. Soviet nuclear officials raised the void coefficient safety standards for all RBMKs after the accident, and after the Soviet Union's collapse a great deal of international assistance went into upgrading the computer systems that control the nuclear reaction. However, fundamental flaws in the RBMK design remained unchanged for decades.

In contrast, VVER's models follow a similar design to Western reactors by using compressed nuclear fuel pellets kept under pressure. Water cools and regulates the reaction, which slows down in the event of a loss of water pressure. The Soviets designed three models based on the size of pipe ruptures that each type could safely sustain before catastrophic failure: 440/213,[4] 440/230, and 1000 (the only new VVER models currently produced by Russia.) The VVER designs offer greater inherent safety measures than the RBMKs, but the older 440/230s and 440/213s lacked uniform safety standards resulting in *ad hoc* procedures across the industry.

Much of this information remained secret during the Cold War until its end revealed the poor condition of all Soviet-designed reactors. At that time, the International Atomic Energy Agency (IAEA) identified numerous problems with all the RBMK and VVER models, claiming that many were too unsafe to continue operating in their present conditions. The list of deficiencies covered everything from poor safety systems and training for plant personnel, to faulty engineering designs and low quality construction materials.[5] Given enough money and opportunity to bring in Western technical skill, upgrades could overcome many of the problems, but nothing would solve the fundamental design flaws in the RBMK and VVER 440 models as neither have external containment structures to prevent the release of radiation in the event of an accident.

The Chernobyl effect

Despite the myriad problems with the Soviet-designed nuclear reactors, the industry as a whole has had strong support since the first commercial units came online in the 1950s, and prior to the 1986 disaster, nuclear power had proven itself a valuable addition to fossil fuels. French nuclear output rose significantly with the construction of nearly fifty reactors from 1963 until Chernobyl's explosion, while the United States followed a similar path despite the accident at Three Mile Island in 1979. Unlike that facility though, Chernobyl lacked the concrete and steel housing that had saved the surrounding Pennsylvania countryside eight years earlier.

Making matters worse, the details of the accident remained a closely guarded Soviet secret, even from those who experienced its immediate effects. Kiev residents received no warning that radiation had reached their city, and while party officials rushed to secure the city's supply of radiation-absorbing medicine for themselves and then remained indoors for several days, the masses were told to participate in the annual May Day parade despite the contamination risks. Moscow kept the event out of the media for several days until international sources detected radiation spikes outside the Soviet borders, and only after the world learned that something terrible had happened did the Soviet leadership finally release information about the incident.[6]

On the fateful day, operators lost control of the nuclear reaction in unit 4, and fires quickly spread throughout the facility. They managed to shut down the remaining three reactors quickly, but could do nothing to prevent the roof from exploding over the damaged reactor. Radioactive material poured out of the gaping hole for ten days, and while most of the material had very short half-lives and dissipated quickly, dangerous levels of iodine, cesium, and strontium penetrated the soil and water table around the plant, while prevailing winds carried lethal materials to other areas of Ukraine, Belarus, and Russia as well. Eventually, the area around the plant became a modern-day ghost town after the governments of Ukraine and Belarus created exclusion zones surrounding the most dangerous hotspots. In the end, casualties included dozens of firefighters and plant personnel who died from acute radiation poisoning; several hundred more were hospitalized, their life expectancies greatly shortened as a result of exposure. The most widespread effects led to a significant rise in leukemia, thyroid cancer among children, and radiation damage to unborn babies resulting in severe mental retardation and cancer.[7]

Chernobyl showed just how bad it could get when reactors lack a failsafe containment structure, yet regrettably, it was not alone in suffering from a litany of serious safety deficiencies, a sobering fact that participants at the 1992 G7 Munich Conference pledged to correct. Western donor states and organizations offered to help those countries in Eastern Europe and the former Soviet Union that operated similarly unsafe reactors by providing technical assistance as part of larger democratization aid packages. Most importantly, the assistance remained strictly conditioned on commitments to close all such first-generation Soviet reactors before the end of their design lives – the estimated length of operation determined prior to construction.[8] The goal was to prevent another Chernobyl from ever happening again, and the governments of Ukraine, Armenia, Lithuania, Slovakia, and Bulgaria agreed. Over the next four years each committed to improve day-to-day operational safety, develop bureaucratic agencies capable of ensuring the success of those efforts, and decommission all reactors lacking containment structures within set timetables. Amazingly though, with the threat of disaster looming ever closer with each day of unsafe operation, those same governments balked at the requirements they themselves had signed, and disasters like Chernobyl remained a realistic possibility for almost two decades.

Since the beginning of Western safety efforts twenty years ago, no study has been done to explain either that resistance or the final decisions to shut down dangerous nuclear reactors. This book fills that gap. The project focuses on countries that have operated first-generation Soviet nuclear reactors and made binding agreements regarding them in order to receive benefits from future cooperation with the West, ranging from trade and diplomatic agreements to full EU membership. Accordingly, each country promised to 1) improve operational safety based on Western technical assessments, 2) create an autonomous regulatory agency with financial and legal authority to implement required upgrades and establish decommissioning protocols, and 3) set aside necessary funds then shut down RBMK and VVER 440 reactors before the end of their design lives. These three conditions serve as the three levels of compliance within each country examined in this study. Soviet centralization produced a common background in training, reactor design, and fuel processing, as well as dependence on Moscow for guidance in resolving operational problems, all of which enables comparisons across the cases as well.

Russia meets part of the criteria but remains outside the study because no Russian government has agreed to the early-closure requirement for international assistance as offered to its former satellites. Nor has any Russian leader had the option of full compliance as a condition for gaining future cooperation with the West, the central benefit to aid recipients in this study. Excluding Russia from a project on nuclear energy seems counterintuitive at first, but the goal of this study is to explain comparable ranges of compliance outcomes, not present an exhaustive list of nuclear power producers and their safety records.[9]

Compliance – Choosing "the devil you don't know"

The end of the Cold War produced a significant increase in compliance studies as the overarching global competition between the superpowers no longer constrained the types and effectiveness of international agreements. Monetary and environmental regimes developed out of the strengthening of European unity and rising international concerns about climate volatility, while academic studies tended to focus on three primary categories of variables in the creation and maintenance of those agreements. The first evaluated the characteristics of those international regimes, such as the durability and uniformity of rules, the types of monitoring procedures for participating governments, and the narrowness of the regime's focus seeking to prevent global catastrophes or more local problems.[10] A second group focused on the nature of incentives offered by foreign governments through "carrots and sticks" and their relevance to domestic actors,[11] while a third approach examined enforcement mechanisms to deter non-compliance either through increased reputational costs (shaming and the loss of future cooperation) or overt penalties (monetary, legal, trade, etc.).[12] Across these studies, constructivist models of socialized learning utilized inter-governmental dialogue and information exchanges, as well as the normative arguments used in the development of international human rights agreements.[13]

These studies generally explained compliance through international factors rather than domestic ones. As such, none could explain variations in compliance with nuclear safety agreements in Eastern Europe and the former Soviet Union because neither regime types, nor incentives, nor enforcement mechanisms varied at the international level. Western assistance was a) comparably generous to each country,[14] b) future benefits consistently depended on compliance, and c) enforcement remained weak compared to other international agreements.

Peering into the domestic level, strategic bargaining models propose that officials may simply want the benefits that go with being a member of the in-group, and therefore promise compliance with little or no intention of carrying out their obligations over time.[15] Signature becomes a way to defray criticisms by international advocates in more powerful countries, or it functions as a means of delaying real change during the interim years between signature and ratification – buying time and buying off opponents remain two possible reasons for signing an international agreement.[16] However, all the countries under examination here complied to some meaningful and costly degree with their agreements. Therefore, whatever the intentions regarding initial signature, something else drove the actual behavior of each country. This book argues that compliance was universally conditioned by elite assessments of the domestic costs and benefits of keeping those promises.[17]

Domestic cost/benefit analysis appears as a background condition in previous compliance studies,[18] and while some have suggested that domestic governmental stability in particular may be a factor affecting compliance behavior,[19] previous models miss the important role that variations play by treating stability as an assumption. In contrast, this study argues that stability of the rules of the domestic political game determined elite decision making regarding nuclear safety compliance. Since these "rules effects" have not been examined in the context of compliance, nor has the compliance literature addressed nuclear safety agreements after the breakup of the Soviet Union,[20] this project presents a necessary addition to studies on international law, Eastern European and post-Soviet regions, energy and environmental policies, and governance research more broadly. It also has a high degree of generalizability to other subjects with comparable costs and benefits.

The Western perspective

In contrast to the model presented here, the leading approach by Western government agencies has focused on the normative safety culture held by nuclear industry and government decision makers, categorizing risk propensity as either averse or tolerant. Western safety standards have been held up as safe (risk averse) with pressure applied to teach Eastern European officials to forsake their unsafe views (risk tolerance) in favor of the stronger Western norms.[21] Each of the international agreements regarding nuclear safety in the region espoused this kind of risk aversion combined with a teaching approach to increase compliance, arguing that acceptance of those norms would enable elites to come to their senses about the risks of operating unsafe nuclear reactors.[22]

This approach explained compliance as normative "Westernization" and noncompliance as a persistence of backwards, unreasonable risk tolerance. Partial compliance did not represent a distinct choice based on evaluations of costs and benefits since elites did not differentiate the costs and benefits of compliance, instead simply viewing one approach as better than the other. Consequently, this model explained the Chernobyl disaster as a result of risk tolerance that allowed fundamental design deficiencies to creep into the region's nuclear power plants. Those flaws demanded drastic measures to correct, and Western agencies interpreted the reluctance of Eastern nuclear and political officials to do so as a foolish belief that their designs were safe enough in their present conditions.

Exemplifying the point, a US Department of Energy official commented to me on the slow progress of nuclear safety work in the region during the years of Western assistance. He wondered with a great deal of frustration, "Don't they realize what they are dealing with? What the hell are they thinking?"[23] His reaction was understandable given the assumption that Eastern European and former Soviet elites would comply if they properly understood the risks. The perceived lack of such an understanding formed the basis of extensive Western education programs in the region.

To that end, the IAEA worked for years to change Eastern European safety culture as a way to increase compliance. Miroslav Lipar, a former Slovak nuclear regulator working as head of the IAEA Operational Safety Section, showed me scores of documents on training conferences, internal workshops, and collaborative efforts with Western nuclear industry groups that all stressed safety culture as the most important aspect of compliance.[24] This approach was not limited to the IAEA though. I also met with several US Environmental Protection Agency and Department of Energy officials who stressed the need to "get inside their heads and make them think the right way" – restating that safety culture must be the priority for compliance.[25] However, the underlying assumptions were incorrect because they misunderstood compliance, which was always more complex than this approach allowed as it varied over time, while the domestic safety culture in the target countries remained almost universally risk tolerant. Even more so, the safety culture model could not adequately explain partial safety improvements short of full decommissioning since fixing some of the operational dangers included an awareness of what could go catastrophically wrong; improvements in one area required later levels of compliance to ensure the worst did not happen. In addition, decreasing compliance posed an even more serious problem for the model by showing that extensive international efforts to change risk propensity were largely ineffective, thereby calling into question the process of norm education. In both instances, something else influenced compliance behavior, namely the political context in which elites made evaluations about the risks of operating their nuclear power plants.[26]

In particular, stability in the rules of the political game conditioned the evaluations of short-term costs and long-term benefits, the heart of nuclear safety compliance in these cases.[27] The lack of such stability can explain why some governments were reluctant to close down reactors that met energy needs, despite their poor safety records. A critical element of that perspective appeared when I asked the Armenian Ambassador to the International Atomic Energy Agency why his government kept failing to keep its commitments. He explained that the government's decisions depended on degrees of risk: the risk of a nuclear accident versus the risk of the population freezing to death.[28] Beyond such practical considerations, he added that his understanding of risk depended heavily on the stability of the political system, whether the system would survive into the foreseeable future and how long he could realistically expect to participate if it did.

How politicians understand risks depends on many factors, and this study focuses on personal experiences in political transitions (notably turmoil in the government, economy, and societal connections), and learning based on the experiences of others under similar conditions.[29] That kind of learning can occur at the individual level, within a community, or both, and the skills come from some combination of normative values, utility calculations, and cognitive mapping.[30] Too often though, insufficient information prevents a completely accurate risk assessment, and decision makers face constraints due to bounded rationality and preconceptions derived from biased information.[31] Long periods of political transition can also increase the likelihood of uncertainty because the degree of stability 1) effects preference ordering; 2) draws greater attention to core cultural values, which may be opposed to norms espoused by international agreements; and 3) can make short-term thinking more important in utility calculations.[32] Once the decision is made though, elites still face the problem of applying the correct information since self-fulfilling prophecies, *ex post facto* rationalizations, and cognitive dissonance can limit the process of effective learning about risks as well.[33]

Government decision makers in Eastern Europe and the former Soviet Union were especially hard-pressed to make accurate risk assessments as they had to overcome severe economic hardships during their transitions from communism, while also trying to balance social pressures for political change. Widespread popular support for peaceful transitions toward democracy and democratic consolidation afterward aided them in this process, and some were quite successful. Even so, most endured major challenges as the outcomes remained uncertain for a long time.

Rules of the political game become even more important in the context of such transitions. They influence notions of community survival and personal involvement in the process, which serve as key elements in risk assessment.[34] They also define the totality of acceptable behavior and power relationships between political decision makers,[35] and the stability of those structures and processes shape how willing political actors will be to pay present costs to gain future rewards.[36] Considerations for nuclear safety compliance were particularly challenging because costs required payment almost exclusively in the short term, while benefits did not accrue for several years to come.[37] This book examines the context for those evaluations, specifically how the stability of the rules defining the political system determined elite decision making regarding their countries' unsafe nuclear reactors.

Causality of the rules of the game

Domestic rules of the game belong to a larger body of literature dealing with stability in different types of political systems. The democratization literature has implicitly touched on aspects of rules stability,[38] but only as part of a broader