

Normalization by Other Means

Christopher Lawrence

Technological Infrastructure and Political Commitment in the North Korean Nuclear Crisis

“No package of incentives in the past quarter century has worked, and there is no reason to think that new diplomatic efforts could induce them, where so many have others failed.”¹ This passage sums up the conventional wisdom about North Korea’s nuclear weapons program: for twenty-five years, the United States has tried to coerce or bribe the North Korean regime into abandoning its quest for nuclear weapons, yet the regime’s determination has not wavered. A principal episode in that history was the 1994 Agreed Framework (AF),² a diplomatic arrangement that staved off U.S. military action against the North’s nuclear program but ultimately failed to prevent the regime from building the bomb. In the years since its collapse in 2002, analysts in the United States have often dismissed the AF as a policy of appeasement that was bound to fail, and this verdict has shaped later U.S. nonproliferation strategy toward both North Korea and Iran. Although many scholars point to the accord as a case study to validate their theories of nuclear proliferation,³ few have analyzed it in a rigorous way to challenge or confirm the conventional narrative. This article examines the negotiation and partial implementation of the AF and suggests that there is still much to be learned from that experience.

The AF is commonly interpreted as a U.S. offer of “carrots” in exchange for North Korea’s denuclearization.⁴ Central to this arrangement was a reac-

Christopher Lawrence is Assistant Professor of Science, Technology and International Affairs in the Edmund A. Walsh School of Foreign Service at Georgetown University.

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1. Remarks of Michael Auslin, “Stanford Experts Examine Options for U.S. in Dealing with North Korea,” *Stanford News*, September 22, 2017, <https://fsi.stanford.edu/news/stanford-experts-examine-options-us-dealing-north-korea>.

2. *Agreed Framework (AF-1994) of 21 October, 1994 between the United States of America and the Democratic People’s Republic of Korea*, Information Circulars 457 (INFCIRC/457), International Atomic Energy Agency (IAEA), November 2, 1994, <https://media.nti.org/pdfs/aptagframe.pdf>.

3. See, for example, Etel Solingen, *Nuclear Logics: Contrasting Paths in East Asia and the Middle East* (Princeton, N.J.: Princeton University Press, 2007), pp. 118–140.

4. For example, Curtis Martin describes the AF as reflecting a shift from a greater proportion of sticks to carrots. Martin, “Lessons of the Agreed Framework for Using Engagement as a Nonpro-

tor trade, whereby the regime agreed to dismantle its plutonium reactors and a U.S.-led consortium would build civilian light water reactors (LWRs) in North Korea to help resolve its ongoing energy shortage. The accord froze North Korea's plutonium capability, the story goes, and may have delayed its nuclear pursuits. But U.S. intelligence later discovered that the North was pursuing an alternate route to the bomb: a clandestine uranium enrichment program. Standard accounts then diverge into two opposing camps. The first argues that the secret enrichment program proved that the regime was simply buying time and planned to cheat all along.⁵ The second, more dovish camp, argues that although the North did in fact cheat, the United States also cheated by not delivering its carrots in a timely manner.⁶ Neither account explains why the AF called for LWRs to replace North Korea's plutonium reactors, when fossil fuel power plants (FFPPs) would have been a much better solution to its energy challenges.

The above narratives of failed engagement are born of a popular conceptual framework that I call the "inducement paradigm of carrots and sticks."⁷ This is a vision of American diplomacy with North Korea that sees all U.S. policy options as arrayed along a one-dimensional axis. At one end are more U.S. sanctions and North Korean isolation; these are the "sticks" that the United States could use to coerce the regime into giving up its nuclear weapons. At the other end are energy assistance, food aid, and security assurances—rewards designed to bribe North Korea into nuclear abstinence. Analysts often debate the appropriate "balance of carrots and sticks,"⁸ and how to maximize their effectiveness.⁹ But there is little consideration of the technical and political realities entailed in implementing those inducements or of what physical consequence may unfold on the ground in East Asia. If one does look back at the technical aspects of the AF, and how LWR construction was to be situ-

liferation Tool," *Nonproliferation Review*, Vol. 6, No. 4 (Fall 1999), p. 1, doi.org/10.1080/10736709908436777.

5. See, for example, Jonathan D. Pollack, *No Exit: North Korea, Nuclear Weapons, and International Security* (New York: Routledge, 2011).

6. See, for example, David C. Kang, "Response: Why Are We Afraid of Engagement?" in Kang and Victor D. Cha, *Nuclear North Korea: A Debate on Engagement Strategies* (New York: Columbia University Press, 2003), pp. 101–127.

7. The inducement paradigm of nonproliferation diplomacy is most explicitly outlined in Etel Solingen, ed., *Sanctions, Statecraft, and Nuclear Proliferation* (Cambridge: Cambridge University Press, 2012).

8. See, for example, Cha and Kang, *Nuclear North Korea*; and quotation from Paul Carrol, "Time to Break the North Korean Cycle," <https://ploughshares.org/issues-analysis/article/time-break-north-korean-cycle>.

9. See for example, Peter Harrell and Juan Zarate, "How to Successfully Sanction North Korea: A Long-Term Strategy for Washington and Its Allies," *Foreign Affairs*, January 30, 2018, <https://www.foreignaffairs.com/articles/north-korea/2018-01-30/how-successfully-sanction-north-korea>.

ated within a diplomatic process, a different picture emerges. Rather than a package of carrots to bribe the North, the LWR project looks more like an attempt to build the physical embodiment of a normalized political relationship between the United States and a denuclearized North Korea. If this was the true shared intention behind the AF—to “hardwire us all in” and lay down a physical path toward denuclearization and normalization—then the determinants of diplomatic success and failure may have been very different from what the common inducement narrative would suggest.¹⁰

This article presents an alternative interpretation of the AF, which I call the “techno-diplomacy” model.¹¹ My argument contains three parts. First, I identify a commitment problem at the heart of the North Korean nuclear crisis that made denuclearization of the Korean Peninsula unattainable either through written agreements or through positive and negative inducements.¹² Second, I argue that the reactor trade offered a way to circumvent this structural barrier to reconciliation, not by rewarding North Korea for nuclear roll-back, but by leveraging the LWR fuel cycle’s potential to physically alter the North’s political relationships with the outside world. Third, I suggest that this techno-diplomatic form of nonproliferation engagement succeeded at both physically rolling back North Korea’s nuclear weapons capabilities and influencing its long-term nuclear decisionmaking, but that it was compromised at key historical moments when domestic audiences in the United States reframed diplomacy in terms of carrots and sticks. By misinterpreting the costly signals of techno-diplomacy as rewards for North Korea, the one-dimensional inducement framing of nonproliferation engagement made the financial basis of the U.S. commitment to reconciliation politically untenable, and helped sow the seeds for the AF’s ultimate demise.

To develop these arguments, I begin with a theoretical discussion that draws from the scholarships of rationalist security studies and constructivist science and technology studies to help conceptualize the role of LWRs in U.S.–North

10. In this article, “normalization” refers to a wholesale change in relations between the United States and North Korea that would include a peace treaty, normal diplomatic relations, an end to economic sanctions, and revised role for U.S. troops on the peninsula. Ample evidence suggests that, in the late 1980s, normalization became a top priority for the Kim regime. See Leon V. Sigal, *Disarming Strangers: Nuclear Diplomacy with North Korea* (Princeton, N.J.: Princeton University Press, 1998), pp. 131–167; and Don Oberdorfer and Robert Carlin, *The Two Koreas: A Contemporary History* (New York: Basic Books, 2014). For additional sources, see online appendix A1.b. Ambassador Robert Gallucci, head of the U.S. delegation to North Korea, used the phrase “hardwire us all in” in a phone interview on January 19, 2018.

11. My term “techno-diplomacy” is adapted from Gabrielle Hecht’s “technopolitics,” which highlights the mutual shaping of technology and politics. See Hecht, *The Radiance of France: Nuclear Power and National Identity after World War II* (Cambridge, Mass.: MIT Press, 1998).

12. James D. Fearon, “Rationalist Explanations for War,” *International Organization*, Vol. 49, No. 3 (Summer 1995), pp. 379–414, doi.org/10.1017/S0020818300033324.

Korean engagement during the 1990s. I then combine the methods of diplomatic history and open-source technical analysis to retell the story of the AF.¹³ I illustrate how the LWR project offered diplomats an opportunity to incorporate North Korea into an international network of technical collaboration, shared vested interests, and mutual vulnerabilities that is unique to the LWR fuel cycle,¹⁴ and how it may have obviated the North's perceived need to build nuclear weapons. The negotiating history and content of the AF suggest that actors on all sides of the nuclear crisis recognized and pursued that opportunity. Following this, I summarize oral accounts of U.S. officials who participated in those negotiations,¹⁵ as well as official statements of the North Korean regime, showing that those accounts are more consistent with the techno-diplomatic history outlined here than with the common interpretation of the AF. I then compare the two interpretations side-by-side as competing paradigms of diplomacy, indicating several points where they are incommensurable, rather than in mere disagreement.¹⁶ I show that prominent aspects of the

13. Primary data on the AF include declassified documents from *The United States and the Two Koreas, Part I, 1969–2000*, National Security Archive [NSA], George Washington University, <https://proquest.libguides.com/dnsa/2koreas1> (hereafter NAS-US2K-I); *The United States and the Two Koreas, Part II, 1969–2010*, NSA, George Washington University, <https://proquest.libguides.com/dnsa/2koreasII>, (hereafter NAS-US2K-II); and semi-structured interviews. Secondary sources include Joel Wit, Daniel Poneman, and Robert Gallucci, *Going Critical: The First North Korean Nuclear Crisis* (Washington, D.C.: Brookings Institution Press, 2004); Sigal, *Disarming Strangers*; Oberdorfer and Carlin, *Two Koreas*; Robert Carlin, Joel Wit, and Charles Kartman, *A History of KEDO: 1994–2006* (Stanford, Calif.: Center for International Security and Cooperation [CISAC], Stanford University, 2012), https://cisac.fsi.stanford.edu/publications/a_history_of_kedo_19942006; and Robert Carlin and John W. Lewis, *Negotiating with North Korea: 1992–2007* (Stanford, Calif.: CISAC, 2008), https://cisac.fsi.stanford.edu/publications/negotiating_with_north_korea_19922007. For more empirical notes, see online appendix A. On open-source technical analysis of nuclear energy, see “Global Future of Nuclear Energy,” *Daedalus*, Vol. 138, No. 4, (Fall 2009), <https://www.amacad.org/daedalus/global-nuclear-future-vol-1>. AF implementation data are from annual reports of the Korean Peninsula Energy Development Organization (KEDO), 1995–2005. Data on North Korea's nuclear program reported in Siegfried S. Hecker et al., “North Korean Nuclear Facilities after the Agreed Framework” (Stanford, Calif.: CISAC, 2016), <https://fsi.stanford.edu/publication/north-korean-nuclear-facilities-after-agreed-framework>; and Siegfried S. Hecker, Chaim Braun, and Christopher Lawrence, “North Korea's Stockpiles of Fissile Material,” *Korea Observer*, Vol. 47, No. 4 (Winter 2016), pp. 721–749, http://www.iks.or.kr/rankup_module/rankup_board/attach/vol47no4/14833231665766.pdf. Developments at Yongbyon 1996–1998 from “Spent Fuel Team Reports” and “Daily Faxes” ($n = 195$), *NAS-US2K-II*.

14. World Nuclear Association, “The Nuclear Fuel Cycle” (London: World Nuclear Association, March 2017), <http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/introduction/nuclear-fuel-cycle-overview.aspx>.

15. The author received verbal and written consent from each of the interviewees cited to use their real names and to quote from their interviews. Institutional Review Board approval was not sought for this research project.

16. For “incommensurable paradigms,” see Thomas S. Kuhn, *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 1962). For incommensurable political frames, see Donald A. Schon and Martin Rein, *Frame Reflection: Toward the Resolution of Intractable Policy Controversies* (New York: Basic Books, 1994).

AF and of North Korea's nuclear behavior are difficult to understand under the carrot-and-stick paradigm—leading to convoluted or anti-scientific theories about the regime's political motives—but that they can seem natural and even expected under a techno-diplomatic understanding. I thus hope to leave the reader with little recourse but to abandon the inducement paradigm of nuclear crisis diplomacy.

The penultimate section moves beyond the AF to describe how this techno-diplomatic lens can help illuminate other nuclear proliferation crises. By outlining examples from throughout the histories of U.S. engagement with North Korea and Iran, I illustrate how political actors have sought to leverage technological infrastructures to resolve the commitment problems they faced, and how the common inducement paradigm fails to capture this recurrent underlying dynamic. I conclude by laying out some of the implications of this analysis for future nonproliferation policy.

Civilian Nuclear Power as a Physical Commitment

The role of LWRs in the Agreed Framework is incomprehensible under the carrot-and-stick interpretation of nonproliferation diplomacy. If the spirit of the AF was simply to reward North Korea with energy-generation technology and political normalization for ending its nuclear weapons program, then one would expect the regime to have wanted to obtain those carrots as quickly as possible, with minimal strings attached. One would also expect U.S. negotiators to have preferred whichever technology could deliver the energy with the lowest financial and political cost. Both sides were well aware that FFPPs would more readily fit those criteria than LWRs—they would be quicker and cheaper to build and easier to integrate into North Korea's energy grid¹⁷—yet the two delegations converged on LWRs during the early months of negotiations. The North Korean regime made LWRs one of its top demands,¹⁸ even though it knew that it would be unable to fuel or operate those reactors without continual assistance from the West.¹⁹ On the U.S. side, there is little evi-

17. Peter Hayes, "Should the United States Supply Light Water Reactors to Pyongyang?" paper to the symposium "United States and North Korea: What Next?" Carnegie Endowment for International Peace, Washington, D.C., November 16, 1993 (Berkeley, Calif.: Nautilus Institute, 1993), <https://nautilus.org/napsnet/napsnet-special-reports/should-the-united-states-supply-light-water-reactors-to-pyongyang/>.

18. LWRs were a top demand throughout North Korea's engagement with the United States from July 1993 through the six-party talks. See online appendices A1.b and A5.b.

19. State Department analysts observed debates between regime "conservatives" warning of the technical dependence that LWRs would entail and "realists" seeking an opening with the West who promoted LWR import. See U.S. Department of State, Bureau of Intelligence and Research [INR], "The Secretary's Morning Intelligence Summary (DPRK: Redefining Self-reliance)," July 17,

dence of any serious attempt to persuade the North Koreans to settle for FFPPs before the AF was signed,²⁰ despite the significant technical challenges that LWRs would entail. The apparent embrace of LWRs as the centerpiece of engagement has baffled observers of both North Korea's nuclear behavior and U.S. nonproliferation policy, and it quickly became a main target for domestic U.S. critics of the AF.²¹

So why did U.S. and North Korean negotiators choose LWRs to replace the North's plutonium-production complex? Why not build FFPPs instead and move more quickly toward denuclearization and political normalization? A key to answering these questions is to examine the structural context in which political choices were taken and to consider the physical implications of those choices for the political future of Korea. I thus refer to the "structure" of the North Korean nuclear crisis as an important resource for interpreting the observed choices of actors embedded in that structure,²² what alternatives may have been possible, and how the choices made would influence the structural context of later negotiations.²³ Moreover, I suggest that key historical actors on both sides of the crisis came to recognize the structural barriers that stood in the way of resolving it, and that they sought to incrementally adjust the structure of North Korea's international relationships in hopes to overcome those barriers. As one principal U.S. architect of the AF put it, in order to reach a political arrangement consistent with a denuclearized Korean Peninsula, negotiators would need to "bend the arc of reality."²⁴ Physical traces of their

1993, *NSA-US2K-II*, <http://search.proquest.com.ezp-prod1.hul.harvard.edu/docview/1679130204?accountid=11311>; discussed in Wit, Poneman, and Gallucci, *Going Critical*, pp. 75–76.

20. Documents from *NAS-US2K-I* and *NAS-US2K-II* from June 1993–October 1994 ($n = 178$) contain no indication of negotiation over the choice of LWRs over FFPPs. A brief attempt to persuade the North Koreans to consider nonnuclear options in August 1994 is reported in Wit, Poneman, and Gallucci, *Going Critical*, p. 273. The strategy memo for that round of negotiations, however, contains no mention of FFPPs ("conventional energy assistance" refers to heavy fuel oil). U.S. Department of State, "Strategy for Round Three," August 1994, *NAS-US2K-I*, <http://search.proquest.com.ezp-prod1.hul.harvard.edu/docview/1679080925?accountid=11311>.

21. See, for example, remarks by Gary Milhollin, "Joint U.S.–North Korea 'Agreed Framework' on Nuclear Issues" hearing before the Senate Committee on Energy and Natural Resources, 104th Cong., 1st sess., January 19, 1995, p. 48, <https://babel.hathitrust.org/cgi/pt?id=pst.000024361231&view=1up&seq=1>.

22. Geopolitical "structure" has been a mainstay in international theory since Kenneth N. Waltz, *Theory of International Politics* (New York: McGraw-Hill, 1979). This study adopts a "structurationist" approach as outlined by Alexander E. Wendt, "The Agent-Structure Problem in International Relations Theory," *International Organization*, Vol. 41, No. 3 (Summer 1987), pp. 335–370, <https://www.jstor.org/stable/2706749>; and Anthony Giddens, *Central Problems in Social Theory: Action, Structure, and Contradiction in Social Analysis* (Berkeley: University of California Press, 1979).

23. This is the essence of a "structurationist" account of political change. See Wendt, "The Agent-Structure Problem."

24. Author conversation with former Chief of Northeast Asia Division, U.S. Department of State, Robert Carlin, March 13, 2019, Washington, D.C.

attempt—the desiccated skeletons of half-built reactors on the ground in North Korea—attest that they may have begun to succeed.

COMMITMENT PROBLEMS, COSTLY SIGNALING, AND THE ARROW OF TIME

The Korean nuclear crisis was not driven by disagreements over the appropriate carrots to exchange in a bargain—these were articulated early in the crisis. The specifics of North Korea's denuclearization were spelled out in diplomatic statements as early as 1992,²⁵ and U.S. negotiators had been signaling that implementation of those terms would initiate steps toward diplomatic normalization since the waning years of the George H.W. Bush administration.²⁶ Rather, it was the credibility of that envisioned political solution that proved difficult to establish, and those credibility challenges tended to manifest along the dimension of time.²⁷

The challenges can be understood if one considers the entrenched structure of geopolitical relations on the Korean Peninsula at the end of the Cold War, and the plausible paths through which that structure appeared likely to change. The United States and North Korea had been in a technical state of war for more than three decades, involving extensive troop buildups along the demilitarized zone and Trading with the Enemy Act sanctions on North Korea. If the regime in North Korea wanted to alter that relationship, as it claimed it did, this would involve both physical changes on the ground and long-term commitments by the United States to maintain those changes in the future. At the same time, North Korea's plutonium-production capability was the primary impetus behind U.S. engagement and, hence, constituted the regime's

25. North Korea and South Korea agreed not to produce nuclear weapons, enrich uranium, or reprocess plutonium. See Joint Declaration on Denuclearization of the Korean Peninsula on January 20, 1992, Inventory of International Nonproliferation Organizations and Regimes, Center for Nonproliferation Studies (Washington, D.C.: Nuclear Threat Initiative, 2011), https://media.nti.org/documents/korea_denuclearization.pdf.

26. See, for example, U.S. Department of State, Bureau of East Asian and Pacific Affairs [EAP], Office of Korean Affairs, "Talking Points (U.S.–North Korea Relations)," 1992, *NAS-US2K-II*, points 1 and 2.5, <http://search.proquest.com.ezp-prod1.hul.harvard.edu/docview/1679131420?accountid=11311>; U.S. Department of State, EAP Office of Korean Affairs, "Meet with North Koreans," January 30, 1992, *NAS-US2K-II*, bullet 2, <http://search.proquest.com.ezp-prod1.hul.harvard.edu/docview/1679131469?accountid=11311>; and United States Department of Defense Assistant Secretary for International Security Affairs, "Contact with Ambassador Ho Jong, DPRK Deputy at the U.N.," 22 June 1992 (Includes Talking Points), June 23, 1992, *NAS-US2K-II*, <http://search.proquest.com.ezp-prod1.hul.harvard.edu/docview/1679143315?accountid=11311>. For empirics and analysis of U.S. intent toward North Korea, see online appendix A1.a.

27. It is commonly believed that impasses over the future presence of U.S. troops and IAEA special inspections prevented progress in negotiations. Problematic North Korean positions were often dropped, however, when the United States made other concessions, suggesting that the North Korean delegation had misrepresented its bottom line as a negotiating tactic. For North Korean acquiescence to an indefinite U.S. troop presence, see Sigal, *Disarming Strangers*, p. 36. On the safeguards issue, see Wit, Poneman, and Gallucci, *Going Critical*, p. 72.

sole bargaining chip. Therefore, if North Korea were to irreversibly give up that capability in exchange for written commitments by the United States to sustain a normalized relationship in the future, the regime could not expect the U.S. government to follow through on those commitments once it had given up its only source of bargaining leverage.

Rational-actor theorists refer to this type of dilemma as a “commitment problem.” In the words of James Fearon, a commitment problem is a “situation in which a mutually preferable bargain is unattainable because one or more sides would later have an incentive to renege on the terms.”²⁸ Notice that the crux of Fearon’s dilemma is manifest in the dimension of time: it is not the present incentive structure, but its foreseeable change in the future, that precludes a bargain.²⁹ Bargaining about future engagements is further complicated when actors cannot credibly observe or communicate long-term intentions and when each suspects the other of misrepresenting those intentions.³⁰ Consideration of these time dimensions of credibility have figured prominently in the concerns of U.S. and North Korean decisionmakers throughout the nuclear crisis, and both sides have attempted to leverage time-irreversible physical processes to manage those challenges.³¹

The concept of “costly signaling,” which also comes from the rational-actor literature, highlights the role of irreversible processes in interstate communication.³² As states attempt to communicate and ascertain the prospects of future engagements, the amount of reliable information contained in their signals or observed behaviors is related to the irreversible costs incurred by the state and to the distribution of those costs over time. Fearon parses out this cost-time landscape by distinguishing between a “sunk cost,” which is incurred in the physical act of making a commitment, and a “tied-hands” signal, which reaches into the future to irreversibly adjust a foreseen incentive structure in favor of a commitment’s durability.³³

28. Fearon, “Rationalist Explanations,” pp. 401–409.

29. Robert Powell identifies changing incentive structures over time as a defining feature of the commitment problem. See Powell, “War as a Commitment Problem,” *International Organization*, Vol. 60, No. 1 (Winter 2006), pp. 169–203, <https://www.jstor.org/stable/3877871>.

30. Fearon, “Rationalist Explanations,” pp. 390–401.

31. A time-irreversible physical process is simply one that cannot be reversed or undone without the cost of additional energy and resources. For a classic general-audience illustration of time-irreversible processes and the “arrow of time,” see Arthur S. Eddington, *The Nature of the Physical World* (Ann Arbor: University of Michigan Press, 1958), pp. 68–86. See also Richard Feynman, “Entropy (Part 01),” *Richard Feynman’s Lecture: Entropy*, YouTube video, 21:31, EduQuarks, July 11, 2018, <https://www.youtube.com/watch?v=ROrovyJXSnM>.

32. James D. Fearon, “Signaling Foreign Policy Interests: Tying Hands versus Sinking Costs,” *Journal of Conflict Resolution*, Vol. 41, No. 1 (February 1997), pp. 68–90, doi.org/10.1177%2F0141001004.

33. Fearon, “Signaling Foreign Policy Interests.”

These considerations of structure and temporality illustrate why the North Korean nuclear crisis could not be resolved by a simple exchange of carrots. Even if U.S. and North Korean decisionmakers could have earnestly articulated a mutually acceptable political future at the outset—comprising a denuclearized Korean Peninsula and normalized relations—they lacked both a credible path toward achieving it and reason to believe it could hold together once realized. Simple assurances or scraps of paper would not have resolved this problem, nor would transient inducements with negligible cost to the giving party. Instead, what was needed was a solid framework for costly signals distributed across time, one that could provide a regular stream of credible information between both sides and incrementally adjust future incentive structures toward ones more compatible with future cooperation.³⁴

DO LIGHT WATER REACTORS HAVE POLITICS?

Often, “what appear to be nothing more than useful instruments are, from another point of view, enduring frameworks for social and political action.”³⁵ The insight that different technological artifacts entail different modes of social interaction, and hence can function as “politics by other means” is foundational in science and technology studies. Bruno Latour and others even argue that the (re)structuring of social relations is one of the more consequential roles that technology can play in human affairs.³⁶ Social and political engagements, by themselves, are often fleeting and unstable. They require constant regeneration through face-to-face interaction and costless written word. Comparatively, tools are brute and obdurate. Their use can exact costs and rewards on disparate actors who are separated in space and time. And if an alluring tool draws its user into particular roles or relationships with other users or suppliers, then propagation and regular use of that tool can act to spread and solidify those relationships across social and geopolitical space.

Few technologies are more political than those associated with nuclear energy. In particular, the once-through LWR fuel cycle is widely recognized as one of the “most globalized technologies in existence,”³⁷ because it inevitably

34. For the role of stable communication in forging cooperation, see Robert O. Keohane, *After Hegemony: Cooperation and Discord in the World Political Economy* (Princeton, N.J.: Princeton University Press, 1984).

35. Langdon Winner, *The Whale and the Reactor* (Chicago: University of Chicago Press, 1986), p. x; see also *ibid.*, pp. 19–39.

36. Bruno Latour, *Reassembling the Social: An Introduction to Actor-Network-Theory* (Oxford: Oxford University Press, 2005), pp. 64–70; and Winner, *The Whale and the Reactor*, pp. 19–39.

37. The term “once-through” refers to reactor fuel cycles in which fuel is used only once, then stored as spent fuel indefinitely without reprocessing. Richard K. Lester and Robert Rosner, “The Growth of Nuclear Power: Drivers and Constraints,” *Daedalus*, Vol. 138, No. 4 (Fall 2009), pp. 19–30, at pp. 20–21, <https://www.jstor.org/stable/40543998>.

draws reactor-operating countries into the international networks of technical collaboration needed to operate large, modern power reactors. Given the high up-front capital costs and technological inertia associated with LWRs, the political relationships that attend these forms of technical collaboration tend to be less fungible and mutable over time than those associated with other forms of energy generation. And while these networks cannot be abstracted from the political choices of human actors, they acquire much of their shape and durability from the physical nature of the strong nuclear force, and the grotesque concentrations of energy and human agency it allows us to condense into small pieces of matter.

With this mixture of physical and social insight, it is possible to think about LWR technology not just as a set of tools that can energize an economy to pacify a suspect proliferator, but as a sophisticated network of signal paths and mutual leverage that can allow political actors to communicate and observe nuclear intentions, arrange future incentive structures, and thereby converge into more enduring modes of collective action as they sustain and operate the fuel cycle.³⁸ I argue that the LWR fuel cycle has indeed been deployed as a form of techno-diplomacy in this way, and that to understand its relevance in a given political context, one must consider its distinctive technical attributes.

FINANCIAL TIME-STRUCTURE. Initial reactor construction accounts for around 70 percent of the cost of nuclear energy,³⁹ and economies-of-scale factors favor large reactors. Once constructed, a reactor might provide return on the builder's investment for over half a century, but that relies on extremely low operating costs, which in turn require sound operation and cheap fuel supply. Hence, actors who design, finance, and construct reactors will have massive sunk costs, and their hands will be tied by having a stake in efficient reactor operation, safety, and maintenance for decades to come.

FUEL-SUPPLY REQUIREMENTS. LWRs need enriched uranium for fuel. Economically viable enrichment on an industrial scale has required decades of accumulated research on the part of countless actors, and this capability is concentrated within a small number of states, most of them working in consor-

38. Political scientists often look to international institutions for the mechanisms of communication needed to facilitate cooperation, as in Keohane, *After Hegemony*. My concept of techno-diplomacy simply suggests that international technological infrastructures, such as the nuclear fuel cycle, can also play this role. This insight highlights the costs and path dependencies of physical systems as important factors in shaping international relations.

39. For nuclear economics, see Harold A. Feiveson, "A Skeptic's View of Nuclear Energy," *Daedalus*, Vol. 138, No. 4 (Fall 2009), pp. 60–70, www.jstor.org/stable/40544001; Lester and Rosner, "Growth of Nuclear Power"; and William E. Mooz, *Cost Analysis of Light Water Reactor Plants* (Santa Monica, Calif.: RAND Corporation, 1978).

tia. Fueling requirements can therefore exert a tying-hands effect on LWR recipients and exporters who share a stake in continued reactor operation.

IN-CORE FUEL MANAGEMENT. LWRs run on high-burnup refueling schedules that reduce fuel costs, waste-storage requirements, and losses associated with a reactor's shutdown.⁴⁰ The complex evolution of materials in high-radiation environments over long periods introduces difficult technical challenges, however. Solutions to those challenges draw from vast stores of intellectual capital accumulated from operating hours at LWRs around the world. Reactor-core management is thus a complex international achievement and represents a shared vested interest among collaborating states.

DANGER OF RADIOLOGICAL ACCIDENT. Reactors pose an international safety risk.⁴¹ A leading contributor to reactor safety is the knowledge derived from LWR operating experience accumulated worldwide, an international asset to which an independent national reactor program would not have full access. Because the consequences of an accident are too great for market-based insurance to cover, adequate liability requires inclusion in global reactor insurance pools. The resulting tying-hands effects can work to bind exporter and recipient into a mutual interest in reactor safety and liability.

PROLIFERATION RESISTANT, BUT NOT PROLIFERATION PROOF. The cladding of LWR fuel allows for time-indefinite storage of spent fuel in countable unit assemblies that are easily safeguarded. Further, an LWR must be shut down to unload its fuel, making refueling schedules visible from satellite imagery.⁴² Thus, extracting plutonium from LWR spent fuel to produce a bomb would be immediately visible to the international community, which could then withhold fuel from the reactor. LWR-export recipients therefore acquire a modest form of nuclear latency,⁴³ but with a visible and costly technical line between latency and active proliferation.

Taking the above technical attributes into account can illuminate the role LWRs played in negotiators' efforts to overcome the commitment problem that defined the North Korean nuclear crisis. But interpreting those efforts requires one further level of nuance: in addition to analyzing how the physical tasks of

40. "Burnup" refers to the amount of energy extracted from fuel during in-core residence. See *Technical and Economic Limits on Fuel Burnup Extension*, IAEA technical documentation (TECDOC) 1299, Vienna, 2002.

41. See Lester and Rosner, "Growth of Nuclear Power"; Richard A. Meserve, "The Global Nuclear Safety Regime," *Daedalus*, Vol. 138, No. 4 (Fall 2009), pp. 100–111, <https://www.jstor.org/stable/40544005>; and Feiveson, "A Skeptic's View," p. 60.

42. Hui Zhang and Frank N. von Hippel, "Using Commercial Imaging Satellites to Detect the Operation of Plutonium-Production Reactors and Gaseous-Diffusion Plants," *Science and Global Security*, Vol. 8, No. 3 (Fall 2000), pp. 261–313, doi.org/10.1080/08929880008426479.

43. On nuclear latency, see Tristan A. Volpe, "Atomic Leverage: Compellence with Nuclear Latency," *Security Studies*, Vol. 26, No. 3 (2017), pp. 517–544, doi.org/10.1080/09636412.2017.1306398.

LWR construction could re-distribute political leverage and engagement patterns, I must monitor how diplomats intuitively perceived those physical consequences as they engaged in negotiations about the technology. In particular, when my analysis suggests that negotiators leveraged irreversible physical processes associated with various technical endeavors as costly signals of long-term national intent, the reader may worry that I give too much credit to their physical intuitions. To be sure, nowhere in the diplomatic lexicon does one find any reference to entropy or the second law of thermodynamics.⁴⁴ Yet while the language of diplomats differs from that of the physical scientist, it is often replete with vivid descriptions of how carefully negotiated technical steps or artifacts may “lock us in,”⁴⁵ “let the genie out of the bottle,”⁴⁶ or “degenerate to heaps of scrap metal.”⁴⁷ And although political actors frequently disagree over which steps are “essentially irreversible,”⁴⁸ there are many physical processes whose irreversibilities are so obvious—the breaking of eggs, shuffling of cards, and burning of combustible fuels are the common pedagogical examples—that even adversarial states can recognize and agree on them. As I show below, these are precisely the types of “corresponding measures” that find their way into the “frameworks” and “action plans” of techno-diplomacy.

The 1994 Agreed Framework—Crisis Diplomacy by Other Means

The Cold War’s end marked profound shifts in North Korea’s strategic and economic environment. Gone were the alternating patronages of China and the Soviet Union, and the North’s economy was in steep decline. Many Korea observers believe that these geopolitical changes prompted North Korean leader Kim Il-sung to make normalization with the United States a top foreign policy objective.⁴⁹ An improved relationship with the United States,

44. For entropy and the second law of thermodynamics, see Eddington, *Nature of the Physical World*, pp. 68–86.

45. Generally, U.S. negotiators interviewed by the author suggested that their North Korean counterparts sought U.S. concessions, and that the physical implementation of these concessions would “lock” or “hardwire” the United States into continued benign engagement with North Korea.

46. This wording is commonly used among nuclear practitioners to describe the revelation of sensitive nuclear data or designs.

47. Remarks of North Korean Safeguards Chief Ri Yong-ho to former Los Alamos Director Siegfried S. Hecker during Stanford Track II Delegation visit to Yongbyon in 2010, describing the fate of North Korea’s 50MWe and 200MWe GCRs at Yongbyon and Taechon. Reported by Hecker to author, 2015.

48. In all nonproliferation engagement episodes examined here, negotiators deliberated over the (ir)reversibility of implementation steps. The wording “essentially irreversible” comes from remarks of North Korean Ambassador Kang Sok-ju, to Siegfried S. Hecker, reported by Hecker to author, 2015.

49. See Sigal, *Disarming Strangers*, pp. 131–167. For further empirics, see online appendix A1.b.

the regime may have hoped, could help make way for a limited economic opening and balance against a rising China.⁵⁰ Regime officials communicated this objective in track II settings as early as 1990,⁵¹ and it has been a top North Korean demand throughout subsequent engagements with the United States.

North Korea's nuclear program also came to fruition around this time, and with it a capability to produce weapons-grade plutonium. Its first gas-cooled reactor (GCR)—the 5MWe pilot reactor at the Yongbyon nuclear complex—began operation in 1986, and U.S. satellites observed it running intermittently thereafter.⁵² Construction was also under way on the larger 50MWe and 200MWe reactors. Alongside this, North Korea mastered all aspects of the GCR fuel cycle. So by the end of the 1980s, North Korea was producing a small amount of plutonium at the 5MWe reactor—up to one bomb's worth per year—and was on the cusp of producing around thirty bombs' worth of material annually, pending completion of its two larger GCRs.⁵³

These developments prompted a national security review of U.S. policy toward North Korea in 1991.⁵⁴ Despite broad resistance to any engagement with North Korea from across the U.S. political spectrum,⁵⁵ the review recommended diplomacy as the best way to stop the regime from building nuclear weapons. Declassified internal documents indicate a mixed sentiment toward engagement within the George H.W. Bush and Bill Clinton administrations, but a consensus emerged on two key issues: the impetus and goal of diplomacy with North Korea was to stop its nuclear program, and diplomatic normalization would be acceptable after denuclearization.⁵⁶

Here are the makings of a commitment problem: both sides claimed to prefer denuclearization and normalization to their present realities of latent proliferation and armistice.⁵⁷ Denuclearization, however, would also amount to a

50. See Robert Carlin, "What North Korea Really Wants," PFO 07-009 (Berkeley, Calif.: Nautilus Institute, 2007), <https://nautilus.org/napsnet/napsnet-policy-forum/what-north-korea-really-wants/?view=pdf>.

51. See Sigal, *Disarming Strangers*, pp. 78–79. Also indicated by John Lewis, who had extensive track II engagements with North Korea. Author interview with Lewis.

52. Central Intelligence Agency Directorate of Intelligence, "North Korea's Nuclear Efforts (Excised) (Includes Map)," April 28, 1987, *NSA-US2K-II*, <http://search.proquest.com.ezp-prod1.hul.harvard.edu/docview/1679097102?accountid=11311>.

53. Hecker, Braun, and Lawrence, "North Korea's Stockpiles."

54. Conclusions of National Security Review 28 are described by Wit, Poneman, and Gallucci, *Going Critical*, p. 7.

55. See Sigal, *Disarming Strangers*, pp. 1–14.

56. See "U.S.-ROK Basic Positions, ca. August/September 1991, Secret (two versions: a and b)," September 1991, doc. 03a, briefing book 610, NSA, [https://nsarchive2.gwu.edu/dc.html?doc=4176668-Document-03a-Paper-US-ROK-Basic-Positions-ca](https://nsarchive2.gwu.edu/dc.html?doc=4176668-Document-03a-Paper-US-ROK-Basic-Positions-ca;); and "Briefing Book, Deputies Committee Meeting," December 1991, doc. 7, briefing book 610, NSA. For more empirics, see online appendix A1.a.

57. Positions of both sides are reflected in the opening statements of bilateral talks in June 1993.

power shift that may have been incompatible with a stable normalized relationship in the future, because there might be nothing to further incentivize the United States to maintain that relationship. For engagement to meaningfully ensue, the North's disarming steps would need to be reciprocated by similarly irreversible physical steps by the United States that would alter its own incentive structure in favor of continued engagement.⁵⁸ This is what the reactor trade of the AF was all about.

THE ART OF PHYSICAL COMMITMENT

The North Korean regime first proposed to trade its GCRs for Western LWRs during a high-level meeting with the United States in June 1993.⁵⁹ North Korean Ambassador Kang Sok-ju indicated that the idea had Kim Il-sung's backing and was designed to "open up North Korea."⁶⁰ A more formal proposal followed in July of that year, when the North Korean delegation offered to dismantle the country's entire GCR fuel-cycle complex, in a phased process, in exchange for Western LWRs and normalization with the United States.⁶¹ The U.S. delegation quickly seized on the offer, describing it as "exactly the right direction for the political and economic future of Korea."⁶² The main selling points from a U.S. perspective were the prospects of eliminating North Korea's plutonium capability and encouraging economic reform. Declassified documents from subsequent months indicate, however, that U.S. officials also analyzed the proposal from North Korea's perspective and came to understand the "central importance that the regime placed on the provision of LWRs as an indication of US good faith."⁶³

Opening up the technical attributes of LWRs and placing them into the strategic context of the crisis reveals that their importance was more than symbolic. Throughout the crisis, each side sought to front-load the other's con-

U.S. Department of State, "U.S. Opening Statement [First U.S.-North Korea Meeting about North Korean Nuclear Program]," June 2, 1993, *NAS-US2K-I*, <http://search.proquest.com.ezp-prod1.hul.harvard.edu/docview/1679096971?accountid=11311>. For more on the U.S. and North Korean positions, see online appendix A1.

58. North Korean insistence on "action for action" is noted in State Department Intelligence reports. See, for example, U.S. Department of State, INR, "The Secretary's Morning Intelligence Summary [DPRK: A Few Loose Threads]," February 22, 1994, *NAS-US2K-II*, <http://search.proquest.com.ezp-prod1.hul.harvard.edu/docview/1679142611?accountid=11311>.

59. Wit, Poneman, and Gallucci, *Going Critical*, pp. 54. Earlier proposal in low-level meetings reported in Sigal, *Disarming Strangers*, p. 39.

60. Sigal, *Disarming Strangers*, p. 68.

61. Wit, Poneman, and Gallucci, *Going Critical*, pp. 71–72.

62. *Ibid.*, p. 72.

63. U.S. Department of State, "Status Report: Korea, August 5, 1994," *NAS-US2K-I*, p. 3, <http://search.proquest.com.ezp-prod1.hul.harvard.edu/docview/1679097311?accountid=11311>. Reiterated by Ambassador Hubbard in author interview with Hubbard, March 1, 2018.

cessions so as to manage credibility problems.⁶⁴ This common bargaining imperative is mirrored in the financial time structure of LWRs, which is more front-loaded than that of FFPPs and represents a more profound shared investment in North Korea's energy future.⁶⁵ Additionally, the international endeavors of reactor fueling, operation, and safety could incorporate North Korea into the web of techno-political relationships that make reactors function and manage their international risks.⁶⁶ Because the reactors would then be running a substantial fraction of North Korea's industrial economy, they would give the international community strong leverage over the regime's subsequent nuclear choices. Altogether, Western LWRs on the ground in North Korea would have constituted a profound shift in shared vested interests, mutual vulnerabilities, and risks among nations in East Asia.

Building FFPPs in North Korea would have represented a much more limited commitment on the part of the international community, and for precisely the same reasons that they would have been a more convenient carrot than LWRs. The upfront cost and construction time would have been much smaller; the fuel supply would have been expensive and more anonymized by market economics; and the operational and safety requirements would have been much more straightforward. While U.S. officials acknowledged that "nuclear reactors are not the sort of things a country gives to an enemy,"⁶⁷ FFPPs in North Korea would have been more consistent with its continued isolation.

The reactor trade quickly became the focus of engagement between the United States and North Korea, but negotiations then bogged down over two seemingly peripheral issues: the sequencing of concessions, and the national source and identity of the LWRs. These disputes seriously jeopardized the prospect of a deal, and they too are mysterious under the inducement paradigm: if the LWRs were simply a carrot, then it is hard to imagine why the regime would jeopardize the prospect of receiving them, or risk stepping to the brink of war, over disagreements that seem so petty. A closer look at these skirmishes, however, reveals a high-stakes struggle over techno-political futures on the Korean Peninsula.

64. This was a persistent theme of the negotiations. See Wit, Poneman, and Gallucci, *Going Critical*, pp. 72–74; and Sigal, *Disarming Strangers*. In internal deliberations of the George H.W. Bush administration, officials also obsessed over how "forward leaning" U.S. diplomacy should be. See "Briefing Book, Deputies Committee Meeting," December 1991. For more empirics, see online appendix A1.a

65. Reflected in KEDO Supply Agreement (KEDO-SA), articles II-III and annex 3–4, <http://www.kedo.org/pdfs/SupplyAgreement.pdf>.

66. On fueling, see KEDO-SA, article VIII.1; on operation, see KEDO-SA, articles VII-IX; and on safety, see KEDO-SA, articles X-XI.

67. Hubbard interview, March 1, 2018.

The sequencing issue illuminates how the path dependencies of LWR construction might facilitate political changes that had previously seemed impossible, but only if steps were ordered in a way that both sides would perceive as “locking the other side into” those changes. At the outset of the crisis, the International Atomic Energy Agency (IAEA) had requested special inspections at two sites to resolve questions about North Korea’s nuclear past, and this had become a key U.S. demand. North Korean negotiators, however, were reluctant to forfeit the bargaining leverage associated with those questions,⁶⁸ and demanded substantial progress on construction of the LWRs before any special inspections could take place. Meanwhile, U.S. nonproliferation law prohibited the delivery of the “nuclear components” of a reactor to countries not in good standing with the IAEA.⁶⁹ This impasse forced the U.S. delegation to consult experts in Washington to determine what “percent” of the LWRs could be constructed prior to delivery of nuclear components. Under an inducement structure, this elaborate detour would be unnecessary—if only the carrot of energy generation was at stake, then the dilemma could have easily been avoided by choosing FFPPs instead. But as a techno-diplomatic struggle to shift political realities, it makes more sense. Sinking substantial Western investment into the nonnuclear foundation of a LWR could then incentivize two key political changes that had previously been major sticking points: North Korean acceptance of IAEA demands and a U.S. nuclear supply agreement with North Korea. The first would align North Korea with international norms, and the second would amount to a profound U.S. endorsement of the North Korean regime. Later dubbed the “percent solution,” this strategy was written into the AF and follow-on LWR supply agreement.⁷⁰

The second diplomatic roadblock—the national source and identity of the LWRs—presents yet another anomaly when LWRs are interpreted as a carrot. At multiple points, North Korea sought to ensure that LWR provision and financing would come directly from the United States.⁷¹ Yet, the Clinton

68. See Wit, Poneman, and Gallucci, *Going Critical*. North Korean negotiators would frequently suggest that U.S. demands would leave their country “naked” (p. 272). Additionally, they expressed the need to keep “leverage until the bitter end” (p. 253), and aimed to delay special inspections until “mutual trust” was built via LWR construction (pp. 275–276, 298–299).

69. “Nuclear components” defined in *Communication Received from Certain Member States Regarding Guidelines for the Export of Nuclear Material, Equipment or Technology*, INFCIRC/254, IAEA, Vienna, 1978.

70. The “percent solution” recounted in Gallucci interview, January 1, 2018; and author interview with Gary Samore, director of nonproliferation, National Security Council, February 29, 2016. See also Wit, Poneman, and Gallucci, *Going Critical*, pp. 307–310; and KEDO-SA, annex 4.

71. Indicated in interviews with Gallucci, January 19, 2018; Robert Carlin, Palo Alto, California, April 11, 2016; and Hubbard, March 1, 2018. For an outline of U.S.–North Korea negotiations over the reactor identity, the North Korean regime’s demands for U.S. reactors, the regime’s desire for U.S. financing, and its reluctance to accept South Korean reactors, see Wit, Poneman, and Gallucci, *Going Critical*, p. 286. For State Department analysis of “leadership sensitivities” over the reactor

administration knew that it would be impossible to persuade Congress to fund the entire LWR project. The U.S. delegation therefore proposed an international consortium with regional U.S. allies to build the LWRs and persuaded South Korea and Japan to volunteer large sums of money to pay for the project. These were dangerous prospects for North Korea, however: if the United States transferred too much of the sunk costs of the reactor project to its allies, it might lose interest in the relationship after North Korea disarmed. In particular, if the responsibility were shifted to South Korea—if the reactors became identified as South Korean reactors—then they might start to look like an investment in reunification under the South Korean government, which was the North Korean regime's worst fear.⁷² Nevertheless, the consortium became a hardened feature of U.S. demands. From there, North Korea fought to maximize U.S. responsibility for the LWR project by ensuring that the consortium had an "American face," leading to a prolonged struggle over the identity of the LWR.⁷³ If the regime just wanted to reap the benefits of energy generation, it is hard to imagine why it would risk scuttling the deal simply to determine who would provide the carrot or what it would be named. But if the struggle is interpreted as a contest to shape future geopolitical relations by distributing sunk costs among actors, then the mystery subsides. The North's first choice of direct provision of LWRs from the United States reflects its stated desire for a bilateral relationship made durable by a U.S. stake in North Korea's energy future. But as U.S. direct provision proved impossible, the regime insisted on U.S. leadership in the LWR project as a way to preserve U.S. political

identity, see Department of State, INR, "The Secretary's Morning Intelligence Summary [DPRK: Selling the Geneva Talks at Home]," July 24, 1993, *NAS-US2K-II*, <http://search.proquest.com.ezp-prod1.hul.harvard.edu/docview/1679117594?accountid=1131>. Similar perceptions from South Korean officials are reported in Carlin, Wit, and Kartman, *History of KEDO*, p. 19. For North Korean insistence on concluding a commercial contract for the LWR with a U.S. company, see DOS, "U.S.-DPRK Agreed Framework Implementation Report, November 1994," November 1994, *NAS-US2K-I*, <http://search.proquest.com.ezp-prod1.hul.harvard.edu/docview/1679096916?accountid=11311>.

72. Many observers interpret the regime's reluctance to accept South Korean reactors as driven by national pride. A North Korean foreign ministry statement on March 11, 1995, however, explicitly describes the KEDO Charter's reference to South Korean model reactors as a "declaration that the U.S. will break the AF." Other North Korean statements were noted by U.S. State Department analysts, including a statement that U.S. preference for ROK LWR provisions "raised doubts about U.S. intentions," noted by U.S. officials in DOS INR, "The Secretary's Morning Intelligence Summary [DPRK: Storm Warning]," February 16, 1995, *NAS-US2K-II*, <http://search.proquest.com.ezp-prod1.hul.harvard.edu/docview/1679131137?accountid=11311>. Statement noting that U.S. preference for ROK LWR provisions "violates spirit of AF," by U.S. officials in "The Secretary's Morning Intelligence Summary [DPRK: More Warnings on LWR Issue]" March 13, 1995, *NAS-US2K-II*, <http://search.proquest.com.ezp-prod1.hul.harvard.edu/docview/1679131391?accountid=11311>.

73. The LWR identity struggle produced many strange artifacts, including a "presidential letter of assurance" obligating the Clinton administration to use "executive powers" to ensure LWR construction (*Agreed Framework*, article I.1) and South Korean Standard Reactor design anonymized as "advanced version of US-origin design" (KEDO-SA, article I.1).

responsibility for overall AF implementation. In other words, putting an “American face” on the LWR project was an attempt to translate the sunk costs paid by U.S. allies into a political incentive for the United States to keep its commitments.

Tensions over the sequencing of implementation steps and the LWRs’ identity prolonged the nuclear crisis by more than a year, bringing the United States and North Korea to the brink of war. In October 1994, however, the AF was finally signed. The U.S.-led consortium—the Korean Energy Development Organization (KEDO)—would build two 1,000 MWe LWRs in exchange for the freezing and eventual dismantlement of North Korea’s GCR complex. The reactors would be of American design and would be built by the United States and its regional allies in the Kumho area near the North Korean port city of Sinpo.⁷⁴ Alongside the LWR project, KEDO would deliver regular shipments of U.S.-funded heavy fuel oil (HFO) to Sinpo, and this would continuously signal U.S. commitment to the AF.⁷⁵ The stated end goal of the accord was a fundamentally changed relationship between North Korea and the West, culminating in normalization with the United States and denuclearization of the peninsula⁷⁶—precisely the incredible political future articulated by both sides at the outset of the crisis.

ARROW-OF-TIME DIPLOMACY

One can now surmise both an initial state and an envisioned end state articulated in the Agreed Framework. In the initial state of affairs, the United States was engaging with North Korea primarily because the North Koreans could produce weapons-grade plutonium at Yongbyon. In the envisioned end state, North Korea would have dismantled this capability, but in its place would stand two large Western LWRs on North Korean soil, constituting the physical embodiment of a changed political relationship. But what about the path between these two realities? How was credibility to be managed along that path? This was one of the more carefully deliberated issues during negotiations, and the outcome was somewhat paradoxical—the AF itself was expressly not a binding written commitment.⁷⁷ Rather, it proposed a sequence of irreversible

74. At the time of the AF’s signature, there was a shared “expectation” that the United States would share the cost of the LWRs with allies. Remarks of Ambassador Hubbard, reported in Carlin, Wit, and Kartman, *History of KEDO*, pp. 17, 29.

75. HFO deliveries were described as “the most tangible evidence of [U.S.] commitment to uphold the Agreed Framework” in U.S. Department of State, “Update on KEDO and the Agreed Framework,” February 20, 1997, *NAS-US2K-I*, <http://search.proquest.com.ezp-prod1.hul.harvard.edu/docview/1679163891?accountid=11311>.

76. See AF-1994, articles II-III.

77. U.S. Department of State, Office of Legislative and Intergovernmental Affairs [OLIA], “Response to Dole Letter on the Framework Agreement (Not Being a Treaty) [Includes Attachments],”

physical processes to build the credibility of a pending political future—a physical path, in other words, toward denuclearization and normalization. If commitments to that envisioned future were not credible on paper, then the essential innovation of the AF was to take those commitments out of the juridical space of written agreements,⁷⁸ and attempt to express them incrementally on the ground at Yongbyon and Kumho.

The proposed sequence of physical commitments was more precisely spelled out in Annex 3 of the KEDO LWR supply agreement (see figure 1).⁷⁹ North Korea's most irreversible steps toward denuclearization were to be spread out across time and synchronized with the costliest and most irreversible steps in the LWR construction process. While the carrots associated with many of these interlocking steps would be reversible—at any point during the process, KEDO could simply halt construction and the North could restart the 5MWe reactor—the costs entailed in each step would be irreversible without additional costs associated with backtracking. Dollars invested in LWR construction could not be recovered if the LWRs were never operated, and each dismantlement step or freeze-year of the North's GCR complex would push it closer toward an unsalvageable physical state. With this careful combination of irreversible costs and reversible pending benefits, each pair of synchronized steps could function as an exchange of costly signals, indicating both sides' willingness to continue down the path and incrementally shifting the incentive structure in favor of taking the next step. By the time the LWRs would be operational, U.S. allies would have invested upward of \$5 billion (1994 dollars) in North Korea's energy future, and the physical destruction of North Korea's GCR complex would be complete.

Had they been fully constructed, however, the KEDO LWRs alone would not have been enough to ensure expanded relations between North Korea and the outside world. Rather, they were described as a possible "lynch pin" to set the stage for further techno-diplomatic engagements.⁸⁰ Toward this end, physical changes on the ground were intended to precede and hopefully cata-

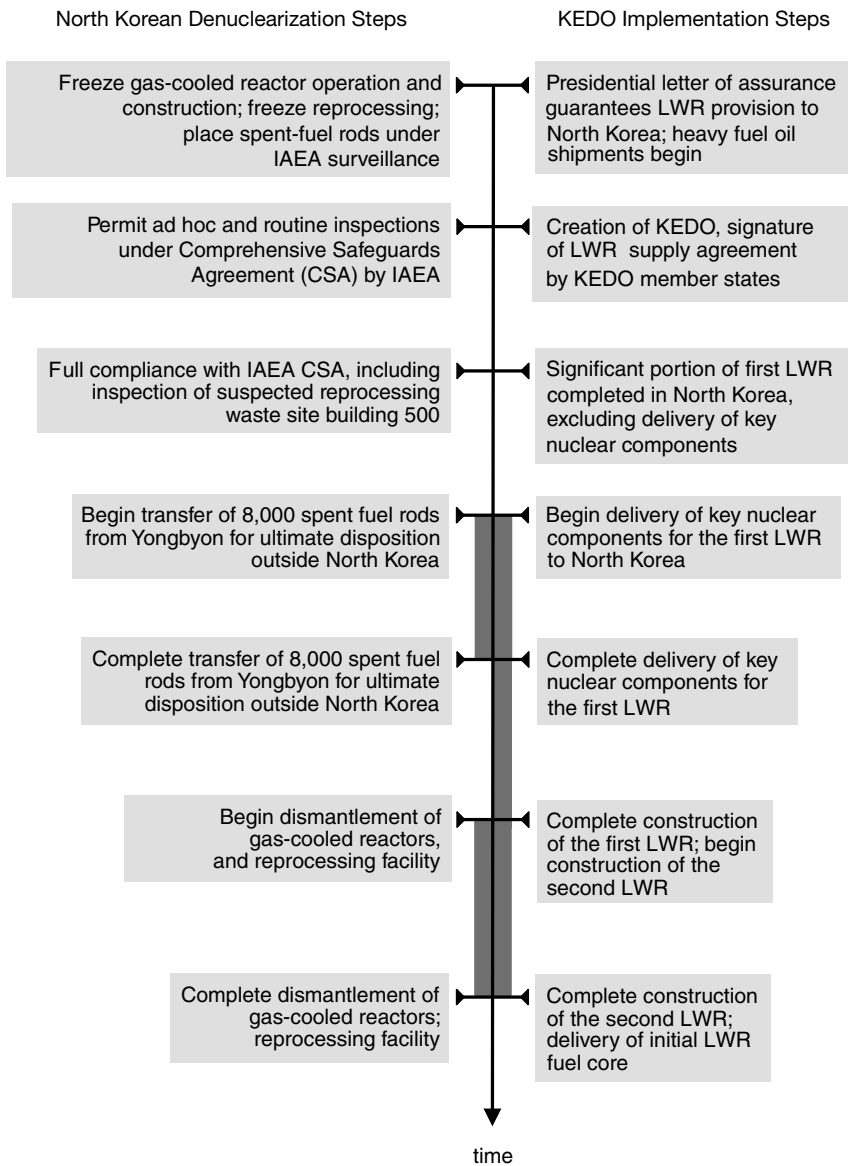
April 5, 1995, *NAS-US2K-I*, <http://search.proquest.com.ezp-prod1.hul.harvard.edu/docview/1679080809?accountid=11311>.

78. The legal counsel to the U.S. delegation insisted that the AF was "not an agreement, but a framework for action. We do stuff, they do stuff. The stuff we do depends on what they do, but at present [time of AF signature] there is no 'agreement.'" Passage recounted in Gallucci phone interview, January 19, 2018; and Carlin interview, April 2016.

79. KEDO-SA, annex 3.

80. Joel Wit, senior adviser to the U.S. delegation during the AF negotiations, outlined extraneous effects of the KEDO project envisioned by Department of State officials. See Wit, "The Korean Peninsula Energy Development Organization: Achievements and Challenges," *Nonproliferation Review*, Vol. 6, No. 2 (1999), pp. 59–69, 62–63, <https://doi.org/10.1080/10736709908436750>. Reiterated in Carlin interview, April 11, 2016. The term "lynch pin" was used by Thomas Fingar in interview with author, Palo Alto, California, April 1, 2016.

Figure 1. Timeline of Synchronized Irreversible Implementation Steps Outlined in Annex 3 of the Korean Energy Development Organization (KEDO) Light Water Reactor (LWR) Supply Agreement



NOTE: This figure was created by the author.

lyze important political changes within KEDO member states. Bilateral nuclear cooperation agreements, labor protections, and lifts on communication and travel bans were previously unthinkable in respective capitals. But with the first large-scale, Western-style construction project in North Korea hanging in the balance, they might suddenly become imperative for both sides. Connecting the LWRs to North Korea's energy grid would be another avenue for precipitated cooperation. The needed grid upgrades would require North Korea to obtain financing from international institutions, which would in turn require changes in U.S. laws that opposed international loans to North Korea. They would also entail further exposure of the regime to international finance norms and Western civil-engineering practices.⁸¹ Because the fate of KEDO's own loans would be tied to extracting electricity from the LWRs, KEDO members would face new incentive to facilitate these changes.⁸² Again, FFPPs sized to fit the existing grid did not offer the prospect of catalyzing any of these further investments or political evolutions.

A NEW REALITY, BUT NO GUARANTEED OUTCOME

If the Agreed Framework articulates a physical path between two disparate political realities—a path otherwise blocked by structural barriers to commitment—then significant, actualized progress along that path is evident in the partially constructed nuclear reactors at Yongbyon and Kumho. The North Korean regime is said to have “taken a bet on the AF, and essentially shut the lights out at Yongbyon.”⁸³ Many of the steps outlined in the KEDO supply agreement were never carried out, however. Construction steps and HFO delivery were both chronically delayed (because of a lack of U.S. funding), leading North Korea to protest that the United States was not committed to the process. And shortly after entering office in 2002, the George W. Bush administration re-evaluated the available intelligence on North Korea's procurement activities and accused North Korea of “cheating” on the AF by pursuing a clandestine uranium enrichment program.⁸⁴ The United States then ordered KEDO to halt HFO shipments and LWR construction, and North Korea responded by restarting the 5MWe reactor and reprocessing the spent fuel from its initial core. These events constituted the political collapse of the

81. Ibid.

82. Ibid.

83. Common wording of anonymous KEDO and U.S.-DOE officials, some of whom were present at Yongbyon during implementation of the AF, in conversation with the author throughout 2017–18.

84. See Mike Chinoy, *Meltdown: The Inside Story of the North Korean Nuclear Crisis* (New York: St. Martin's Griffin, 2008), pp. 81–102.

AF. All told, U.S. allies had invested nearly \$2 billion in the first LWR, and North Korea had essentially gutted its GCR complex, leaving its 50MWe and 200MWe reactors in ruins and only a meager plutonium-production capability intact.

Two important observations can be made about the partial success and ultimate collapse of the AF. First, the techno-diplomacy of the KEDO process achieved two goals central to U.S. nonproliferation diplomacy: influencing the regime's long-term nuclear decisionmaking, and physically rolling back its nuclear weapons capability. Throughout the eight years that the AF was in force, the most salient aspects of North Korea's nuclear behavior correlated in time with the political and financial status of the KEDO project.⁸⁵ These facts strongly suggest that the regime was modulating its nuclear activities in response to signals of a U.S. commitment, or lack thereof, to eventual normalization, and that those signals were embodied in KEDO's activities. By the time the AF collapsed, North Korea had effectively divested more than 98 percent of its emerging plutonium-production complex.⁸⁶ No other U.S. strategy has been so successful at altering the physical capabilities or political choices behind North Korea's nuclear program.

The second observation is that the AF was set on a path toward collapse when the Clinton administration, unable to establish a substantive financial and political U.S. stake in its implementation, was forced to displace most of the costs of diplomacy to its allies. This limited financial stake attenuated the signal of U.S. commitment from the perspectives of both North Korea and U.S. allies,⁸⁷ leading the regime to harbor skepticism about the AF and hedge against its collapse. It also opened the way for the Bush administration to abandon the AF with little political cost to itself. (I later trace KEDO's financial problems to the dominance of inducement tropes in U.S. domestic political deliberation about nonproliferation diplomacy.)

Subjective Accounts of Techno-diplomacy

My account of the Agreed Framework has thus far relied on structural descriptions of the North Korean nuclear crisis and how LWRs were situated within a diplomatic process. In this section, I argue that the accounts of actors who ne-

85. The correlations are illustrated in online appendix A2, which combines archival evidence, oral accounts, and open-source data to illuminate the timing of key events and the regime's fixation on KEDO's progress and sustainability.

86. See Hecker et al., "North Korean Nuclear Facilities."

87. U.S. documents note Japanese and South Korean concerns over a lack of U.S. financial support for KEDO. See, for example, DOS, "Background Paper: Korean Peninsula," March 1996, *NAS-US2K-I*, <http://search.proquest.com.ezp-prod1.hul.harvard.edu/docview/1679080701?accountid=11311>.

gotiated and implemented the AF are broadly consistent with my interpretation. For the U.S. side, I conducted a series of semi-structured interviews with U.S. officials who participated in the negotiation or implementation of the AF. For the North Korean side, I describe other empirical sources that shed light on the regime's intent.

Three points of clarification are needed to carefully interpret the accounts of U.S. officials. First, my interview subjects gave varying appraisals for the AF collapse, some of which differ from mine. Second, U.S. officials made clear that they did not pursue normalization with North Korea as an end in itself. Rather, they saw it as a crucial part of any realistic path to a nuclear-free Korean Peninsula. Finally, no single account describes all elements of the techno-diplomatic nonproliferation strategy that I have described; there was no mastermind behind the AF. Instead, I consider how each actor was situated within a structural context that defined their possibilities for political action, and how the actions taken could in turn influence the structural context for future decisionmaking. Sociologist Anthony Giddens highlighted this "recursive relationship between structure and agency" in his "theory of structuration,"⁸⁸ which has since become a mainstay of constructivist international relations.⁸⁹ Following his analytical program, I pay particular attention to how negotiators imagined that their concerted actions could incrementally shift their structural environment to create political opportunities that had not previously existed. Their frequent musings about how the KEDO LWR project could create "a new reality" on the Korean Peninsula suggest a vivid awareness of the structural barriers that they faced, and how those geopolitical structures may have been mutable over time.

U.S. ACCOUNTS OF THE REACTOR TRADE

"We didn't think of the KEDO LWRs as a carrot, but as an instrument to manage the relationship," observed Thomas Fingar.⁹⁰ With this remark, Fingar captures the overall theme that U.S. officials presented when I interviewed them. Interview subjects variously described the KEDO LWR project as a "vehicle for engagement,"⁹¹ a "platform for sustained contacts,"⁹² and a "means for each side to judge the others' intentions."⁹³ Many explicitly indicated that the LWR project was an attempt to change North Korea's political relationships with the

88. On "structuration," see Giddens, *Central Problems*.

89. Wendt, "The Agent-Structure Problem."

90. Fingar interview, April 1, 2016.

91. Carlin interview, April 11, 2016.

92. Author interview with Charles Kartman, director of Korean affairs, U.S. Department of State, 1992-96, March 9, 2017.

93. Author interview with Joel Wit, senior adviser to U.S. delegation, February 10, 2017.

outside world.⁹⁴ Meanwhile, inducement metaphors such as “carrots,” “bribery,” and “cheating” were largely absent.

Ambassador Robert Gallucci, head of the U.S. delegation that negotiated the AF, illuminated the substantive distinction between inducement and technodiplomacy when we discussed how the national identity of the LWRs became such a challenge for negotiators: “The LWR project was a manifestation of a changing relationship, because it would take quite a long time to build, and substantial financial investment. The North Koreans wanted the United States to be the ones who were on the hook. That was what the LWR project was a manifestation of. It wasn’t just that they’d get 2,000 MW of electricity, but that the LWR project would have meant the United States was hardwired in. And we would have gone further if there were a way for us to finance it, but there wasn’t.”⁹⁵ This passage explicitly foregrounds the financial time structure and irreversibility of the LWR project, while relegating its intrinsic utility to North Korea—2,000 MWe of energy generation—to the periphery. His focus is precisely the opposite of that of an inducement account, which would instead point to the “carrot’s” intrinsic value to the regime and treat the cost and duration of its delivery as a regrettable trade-off.⁹⁶

Two interview subjects presented an interesting exception to the above summary. Mitchell Reiss and Gary Samore interpreted the choice of LWRs over FFPPs as simply an idiosyncratic North Korean demand. In addition, they pointed to North Korean “cheating” as the sole cause of the AF’s collapse (other interview subjects avoided the “cheating” metaphor and gave a more mixed appraisal). At first glance, these dismissals appear to conflict with my account of the AF. But on closer examination, they articulate the technodiplomatic prospects of LWR export with high fidelity, but from the point of view of U.S. officials entering a negotiating environment already dominated by the prospect of LWR exports to North Korea.

Reiss began his account by sidelining the LWR choice and black-boxing North Korea’s motives behind its demand: “The North Koreans wanted LWRs, they didn’t want anything else. So the technology itself wasn’t an option for us. It was the shiny new toy [for the regime].” These are the beginnings of an inducement account. But when later distinguishing between LWRs and FFPPs from a U.S. strategic perspective, Reiss described how the technical challenges of bringing LWRs online could be a mechanism for transparency and U.S. influence in North Korea: “The LWRs would require much more extensive training [of North Korean operators]; they’d be harder for them to manage; they’d

94. For example, Hubbard interview, March 1, 2018.

95. Gallucci interview, January 19, 2018.

96. For similar accounts, see online appendix A3.

take longer to bring online. LWRs are much harder than FFPPs to operate and repair. And then there are the safety and liability issues that require long-term interaction. I wouldn't call it a Trojan horse because it was their [the regime's] idea, but we were gonna be in there for a really long time." Reiss then highlighted how the process of upgrading the grid (to bring LWRs online) could catalyze additional modes of financial and technical collaboration: "We talked about IMF loans [to finance the grid upgrade]. And the Japanese were quietly talking about tens of billions of dollars of infrastructure. So yeah, we'd be all over that country [if the LWRs had materialized]. People were thinking that there was an upside to us being so intimately involved with their fundamental national decisions."⁹⁷

Samore's account follows a similar trajectory. When asked about the possible North Korean intent behind the LWR preference, Samore responded, "God knows [why they insisted on LWRs]. When pressed, their explanation was something along the lines of 'Kim Il-sung said so'." But when discussing Annex 3 of the LWR supply agreement from a U.S. strategic perspective, he recounted the "percent solution," whereby a maximal nonnuclear investment was to be made on the ground at Kumho to incentivize North Korea to allow IAEA special inspections at Yongbyon: "The theory behind the LWR project [from a U.S. perspective] was that it would create an incentive for the North Koreans to come into compliance with their safeguards agreement, because the project would halt if they didn't. And it was deliberately set up that way."⁹⁸

These accounts align with my structurationist analysis of techno-diplomacy. Both Reiss and Samore led negotiations with North Korea after the choice of LWRs had already solidified. Hence, unlike earlier U.S. delegations, they were not called upon to critically analyze that choice, and it is unsurprising that they attribute it to North Korean idiosyncrasy. But when situated within a U.S. strategic perspective at the negotiating table with North Korea, Reiss and Samore expertly navigate the unique constraints and opportunities within that strategic setting, which by that time had been shaped by the LWR plan. This recursive relationship between structure and agency emerged poignantly in Reiss's concluding homage to the achievements of his predecessors: "I used to say that the AF didn't guarantee anything. What it did was provide an opportunity that didn't previously exist for North Korea and the outside world to have a fundamentally different relationship. That's not to minimize what Bob [Gallucci] did—he created a new reality. But he didn't guarantee the outcome. It was up to the [subsequent] players to fill that role."⁹⁹

97. Author phone interview with Mitchell Reiss, February 22, 2018.

98. Samore interview, February 14, 2018, Cambridge, Massachusetts.

99. Reiss phone interview, February 22, 2018.

NORTH KOREAN ACCOUNTS OF THE REACTOR TRADE

When the LWR proposal originally surfaced in 1993, North Korean Ambassador Kang Sok-ju indicated that it was “designed to open up North Korea.”¹⁰⁰ During more than a decade of subsequent negotiations with the United States, North Korea insisted that LWRs were crucial for resolving the “nuclear issue.”¹⁰¹ As late as 2005, track II diplomats relayed to Washington an unequivocal message from Ambassador Kim Gye-guan: “No reactor, no deal.”¹⁰² Despite the lack of direct access to North Korean official documents or interview subjects, there is ample information to help interpret why LWRs may have been so important to the regime.

The accounts of U.S. diplomats provide some of the best insights into the regime’s thinking. Subjects interviewed for this project had either direct negotiations or informal discussions with North Korean officials. All of them report a North Korean fixation on the credibility of a path toward normalization and on the central role of the LWRs in managing that credibility. I also examined notes and summaries from the Stanford track II delegation’s visits to Yongbyon and Pyongyang, which contain quotes from North Korean officials. In these settings, North Korean officials call for a recursive process of “action for action”—composed of steps that are “essentially irreversible”—that would be needed for each side to build the credibility of its commitments.¹⁰³

Declassified U.S. documents, which fall into two categories, offer a second data set. First, there are intelligence analyses of the North Korean regime’s strategy and internal politics. These provide insights into how different factions within the regime debated engagement with the United States and the role of LWRs in that process.¹⁰⁴ Second are diplomatic cables that report on what U.S. diplomats were hearing from North Korean negotiators and the sticking points and breakthroughs that emerged in the negotiations. These sources also show a North Korean fixation on the credibility of U.S. commitments and on the importance of LWRs as an “indication of U.S. good faith.”¹⁰⁵

Finally, there are official statements from the North Korean regime. Although often filled with vitriolic statements about the “U.S. hostile policy,” these are regularly interspersed with statements that make North Korean policy contingent on U.S. actions and credibility. Perhaps the most vivid artic-

100. Sigal, *Disarming Strangers*, p. 68.

101. For example, in conversation with Hecker during track II meetings, recounted to author in 2015.

102. Recounted in Hecker interview, 2015; and Lewis interview, 2015.

103. Charles Day, “Visiting Korea: Q&A with Siegfried Hecker,” *Physics Today*, February 23, 2011, <https://physicstoday.scitation.org/doi/10.1063/PT/.4.032/full/>.

104. See online appendix A1.b.

105. See “Status Report: Korea,” *NAS-US2K-I*.

ulation of the techno-diplomatic role of LWRs came in a statement from North Korea's foreign ministry in 2006, shortly after the United States called for the dissolution of KEDO: "The U.S. should not even dream of the DPRK's dismantlement of its nuclear deterrent before providing LWRs—a physical guarantee of confidence building. One should wait and see how the United States will move in actuality at the phase of action-for-action in the future."¹⁰⁶ By explicitly referring to the LWRs as "a physical guarantee for confidence building," and saying nothing about the energy or prestige that North Korea might receive from them, this statement unmistakably announces a strategy of techno-diplomacy.

Two Paradigms of Diplomacy in a Nuclear Proliferation Crisis

This section argues that the inducement and techno-diplomacy paradigms of nonproliferation engagement are incommensurable in the sense that they cannot be combined into a coherent understanding of nuclear proliferation crisis. In fact, the two framings often suggest precisely the opposite prescriptions for U.S. policy. This insight can help illuminate the political developments in the United States that contributed to the collapse of the Agreed Framework, and it offers lessons for future nonproliferation strategy. I begin by listing several points of incommensurability where the two paradigms appear in direct opposition. I then examine U.S. congressional hearings that took place shortly after the AF was signed and illustrate how the main features of the AF appeared incomprehensible to policymakers fixated on the inducement tropes of popular nonproliferation discourse. The resulting cognitive dissonance made it impossible to secure substantive U.S. funding for KEDO implementation or to sustain a coherent policy toward North Korea. Finally, I outline the popular historical interpretation of the AF's collapse that runs counter to my account and show its reliance on inducement tropes. Several observable facts appear as anomalies in that interpretation, but fit parsimoniously into the techno-diplomatic interpretation presented in previous sections.

INDUCEMENT VERSUS TECHNO-DIPLOMACY: POINTS OF INCOMMENSURABILITY

I have borrowed the terms "paradigm" and "incommensurability" from historian Thomas Kuhn's famous theory about the discontinuous evolution of scientific theories. Kuhn sought to describe historical "shifts" between "scientific paradigms" and to show how the concepts of a new paradigm are often

106. Statement of North Korean Ministry of Foreign Affairs, September 20, 2006. Cited in Chinoy, *Meltdown*, p. 151.

inarticulable in the language of an older paradigm. He pointed to the visual phenomenon of the gestalt switch as an analogy, in which a single visual stimulus can give rise to multiple incommensurable image recognitions. The hallmark of these gestalt-switch pictures is that the two competing images cannot be integrated into a single whole, and the visual apparatus instead flips erratically back and forth between them. For instance, the familiar “duck-and-rabbit” picture can be seen as either a duck or a rabbit, but it cannot be seen as both at the same time. Cognitive scientists and moral philosophers have shown that similar incommensurability can arise in the cognitive realm between different ways of framing and interpreting the world.¹⁰⁷ In the realm of policymaking, these “frame conflicts” can lead to intractable political controversies and incoherent national policies.¹⁰⁸ Below are seven points of incommensurability between the inducement and techno-diplomacy paradigms of nonproliferation engagement. Each point is described as a “shift” in perception that occurs abruptly when the mind switches from the former interpretation to the latter.

THE PRIMARY CURRENCY OF CONCESSIONS BECOMES TRANSFORMED. Under inducement, concessions should be designed to offer an intrinsic utility to the target state in a timely manner to reward good behavior. Conversely, if concessions under techno-diplomacy are designed to bind states into a mutual interest in continued positive engagement (as in a tying-hands costly signal), then they must offer an enduring shared utility that is contingent on that continued engagement.

APPROPRIATE ORDER OF COERCION AND CONCESSIONS IS REVERSED. Under inducement, carrots should be given only after the denuclearization steps they are designed to reward have been completed, which in turn should be preceded only by coercive measures to pressure the target state. Under techno-diplomacy, the appropriate order is reversed: U.S. concessions serve as costly signals to establish the credibility of U.S. commitments to normalization, and it does not become rational for the target state to forfeit leverage through nuclear rollback steps until it has received those signals. Coercive measures prior to denuclearization steps can signal and reinforce continued adversarial engagement, and thereby enhance the irrationality of denuclearization steps for the target state. At the same time, implementing techno-diplomatic conces-

107. For gestalt shifts in moral reasoning, see Peggy DesAutels, “Gestalt Shifts in Moral Perception,” in Larry May, Marilyn Friedman, and Andy Clark, eds., *Mind and Morals: Essays on Cognitive Science and Ethics* (Cambridge, Mass.: MIT Press, 1996), pp. 129–143.

108. Schon and Rein, “Policy Controversies as Frame Conflicts,” *Frame Reflection*, pp. 23–36.

sions can create new forms of pending coercive leverage, the growing threat of which can promote future abstinence from nuclear-weapons activities (such as, in the LWR case, the power to shut down an economy by withholding the technical cooperation needed for continued LWR operation).

FOCUS SHIFTS FROM CONTENT TO SOURCE OF CONCESSIONS. Under the inducement paradigm, the intrinsic value of inducements is central, and their source and cost are of peripheral importance. Under techno-diplomacy, concessions figure as costly signals, and the bearer of the cost is the actor about whose intention the signal speaks. For example, as shown previously, the source and identity of the LWRs became a central issue of AF negotiations, and the 2,000 MWe of energy generation became peripheral.

RELATIONSHIP BETWEEN COST AND CREDIBILITY IS INVERTED. Under inducement, the cost of concessions is relevant primarily to the domestic audiences of the states that pay for them. Costly concessions are more difficult to justify to domestic audiences, so lowering costs adds to the credibility that they will be given. Under techno-diplomacy, the cost itself is the signal about future intent, and the credibility of the signal increases monotonically with cost.

TIME HORIZONS BECOME OPEN-ENDED. If the content of inducements and quick cessation of nuclear activities are the primary stakes, then a final resolution to “the nuclear problem” is preferable to open-ended solutions that can be framed as stop-gap measures. But if the future relationship and nuclear status are the primary stakes (as in techno-diplomacy), then open-ended arrangements are crucial because they indicate endurance of political changes indefinitely.

LOCUS OF COMMITMENT MOVES FROM JURIDICAL TO PHYSICAL SPACE. If the realization of inducements themselves is the primary stake, then legally binding, written commitments should be sought to enhance the credibility that they will be realized. But if an envisioned political future is the primary stake (as in techno-diplomacy), then irreversible physical changes on the ground constitute much more binding commitments than do politically reversible written agreements.

CHEATING ON AGREEMENT BECOMES HEDGING AGAINST COLLAPSE. Under inducement, a clandestine, latent nuclear capability is morally incompatible with concurrent positive inducements and, hence, is considered cheating. Under nuclear techno-diplomacy, possession of a clandestine, latent nuclear capability figures as hedging and can contribute to the mutual leverage needed to stabilize continued engagement. All rational actors will hedge against the possible collapse of a bargain, and these hedges are often needed to make a bargain possible in the first place.

INDUCEMENT DISCOURSE IN CONGRESS

The signing of the Agreed Framework was followed by a series of U.S. congressional hearings to deliberate how it would be funded and implemented.¹⁰⁹ Two important outcomes emerged from these hearings: a mandate that no U.S. funding could be contributed to the LWR project, and a de facto limit on U.S. funding for KEDO to \$30 million per year. As noted earlier, this shortfall in U.S. funding brought KEDO into deficit financing, contributed to delays in the LWR project, and chronically damaged the credibility of U.S. commitments to the AF in the eyes of virtually all KEDO member states.¹¹⁰ This section traces those outcomes to an inducement framing of the AF that rendered the agreement's primary function inarticulable, and left both proponents and critics baffled by its basic elements.

In a Senate hearing on January 19, 1995, Chairman Frank Murkowski described the AF as a list of "what we get" versus "what they get"—the natural focus of inducement diplomacy.¹¹¹ He then pointed to the AF's three major oddities as viewed through an inducement lens: the choice of LWRs rather than FFPPs, the timing of concessions, and the AF's nonbinding legal status. These anomalies formed the basis of questions from both proponents and critics of the AF; there was little discussion of what the AF's steps would mean for North Korea's relationship with the outside world or how those political changes might shift the future incentive structure in favor of nonproliferation.

Bewilderment at the choice of LWRs is exemplified in the testimony of nonproliferation expert Gary Milholin: "Why does North Korea want LWRs? Nobody outside the country seems to know. It is agreed . . . even by the [Clinton] Administration . . . that the United States could provide coal-fired plants much faster and cheaper."¹¹² This question underscored a common theme throughout the hearing, leaving AF proponents to concede that FFPPs "would have been better," but that North Korea simply would not have accepted them. With little discussion of the political interdependencies associ-

109. "Implications of the U.S.–North Korea Nuclear Agreement," hearing before the Subcommittee on East Asian and Pacific Affairs of the Senate Foreign Relations Committee, 103rd Cong., 2nd sess., December 1, 1994, <https://babel.hathitrust.org/cgi/pt?id=uc1.31210013757180&view=1up&seq=1>; "Joint U.S.–North Korean 'Agreed Framework' on Nuclear Issues," hearing before the Senate Committee on Energy and Natural Resources, 104th Cong., 1st sess., January 19, 1995, <https://babel.hathitrust.org/cgi/pt?id=pst.000024361231&view=1up&seq=1>; and "North Korea Nuclear Agreement," hearing before the Senate Committee on Foreign Relations, 104th Cong., 1st sess., January 24–25, 1995, <https://babel.hathitrust.org/cgi/pt?id=uc1.31210014068405&view=1up&seq=3>.

110. For U.S. recognition of Japanese and South Korean concerns, see "Background Paper: Korean Peninsula," March 1996. For North Korean concerns, see online appendices A1.b and A2.

111. "Joint U.S.–North Korean 'Agreed Framework' on Nuclear Issues" hearing, January 19, 1995.

112. *Ibid.*

ated with the construction and operation of the LWRs or how they might exert leverage over the regime's future nuclear choices, senators were left to conclude that the United States had been coerced into funding a bizarre prestige project for North Korea.

Senator John McCain voiced similar concerns: "There is nothing in that agreement that forces North Korea to account for [previous] diversion. . . . It places no obligation on North Korea to come into compliance with the Nonproliferation treaty. . . . Dismantlement of the nuclear facilities will not begin until [North Korea has] received one fully operational \$2 billion LWR . . . and they do not have to complete dismantlement until the second LWR is completed."¹¹³ For McCain, the timing of the concessions in the AF was backward, because North Korea would receive benefits before correcting past transgressions and thus be rewarded for bad behavior. And without a contractual agreement for both sides to follow through on their respective inducements, the AF would be merely a best-effort arrangement that relied on North Korean trustworthiness.

Proponents of the AF generally responded by highlighting the intrinsic value to U.S. security of "freezing the program in its tracks" and buying several years before North Korea reached a nuclear weapons capability. By focusing on the carrots traded in the bargain, the proponents neglected to point out the potential shifts in the incentive structure associated with LWR construction steps, as the following exchange between Senator Murkowski and Gary Samore illustrates:

Senator Murkowski: Why did you negotiate [immediate special inspections] away?

Samore: We focused our attention on the biggest immediate problem . . . the 25 to 30 kg [kilograms] of plutonium we know the North Koreans have [from the first reactor core] . . . [and on stopping] their ability to complete their larger reactors. [Those priorities] are addressed in the agreement. The AF calls for North Korea [to allow special inspections] before any nuclear components arrive. . . . We would not have been able to achieve immediate compliance . . . as an immediate issue.

Senator Murkowski: Well, immediate or five years [implying a stop-gap or kick-the-can solution].

Samore: What we get in return [freezing the program] . . . is very attractive to us.¹¹⁴

113. *Ibid.*

114. *Ibid.*

This conversation did not address why IAEA compliance might be more likely once the foundation of the first LWR was in place in North Korea. And by focusing on the intrinsic value of the freeze itself, Samore and other AF proponents say little about why North Korea might have been less likely to resume plutonium production after the LWRs were in place. Under this framing, the AF is nothing more than a stop-gap solution.

The general theme of the hearings—that the KEDO project amounts to nuclear bribery—made support for AF implementation politically awkward for Democrats and political suicide for Republicans. Devoting U.S. tax dollars to “rewarding North Korea” became particularly offensive, even when compared to the much higher cost of alternative policies.¹¹⁵ Secretary of State Warren Christopher (an AF proponent) attempted to correct this perceived flaw by guaranteeing to Congress that the U.S. financial contribution to KEDO would not exceed \$30 million per year.¹¹⁶ The danger that limiting U.S. funding might damage the credibility of the AF was undetectable through an inducement lens—if KEDO’s activities were simply a package of carrots, then offsetting their cost would not interfere with their function as such. But if KEDO’s activities were a sequence of signals bearing information about U.S. commitment, then diminishing their cost cut to the heart of the AF by attenuating the signal.

ANOMALIES UNDER THE COMMON INTERPRETATION OF THE NUCLEAR CRISIS

Many Western analysts interpret North Korea’s clandestine uranium enrichment program as proof that the regime had always planned to cheat on the Agreed Framework. This appraisal suggests that North Korea prioritized nuclear weapons above other goals, and that it used engagement to extract the carrot of energy technology from the West. Although it is impossible to rule out any interpretation of regime intent, several anomalies arise under this common narrative, making it a needlessly convoluted theory of North Korean strategy.

These anomalies become clear if one considers the hypothetical perspective of a North Korean regime that was allegedly determined to build nuclear weapons. In the early 1990s, the emerging GCR complex offered North Korea its surest and quickest route to massive stockpiles of bomb fuel. When the regime proposed to dismantle that plutonium complex in exchange for LWRs from the West, it knew that the United States would gain control over North Korea’s ability to operate the LWRs and run its industrial economy.¹¹⁷ Also, the

115. Sigal compares costs of the KEDO LWR project and cooperative threat reduction to those of U.S.-Korean troop exercises in Korea in *Disarming Strangers*, p. 9.

116. “North Korea Nuclear Agreement” hearing, January 24, 1995.

117. Regime discourse on LWRs and technical dependence noted in “The Secretary’s Morning Intelligence Summary: DPRK: Redefining Self-reliance,” July 17, 1993.

U.S. delegation had made clear that “no sitting president would ever accept nuclear weapons in North Korea.”¹¹⁸ Meanwhile, the regime had abandoned its enrichment program after having completed only modest centrifuge studies. The uranium route to the bomb was thus a distant and unsure prospect, and developing any confidence in it would require extensive research and development. Yet, available intelligence suggests that the program remained dormant until 1997, a full four years after the reactor trade proposal was made.¹¹⁹

With the incorporation of the above observations, the commonly held theory of North Korean proliferation strategy can be restated as follows: the regime apparently chose to forfeit a well-developed plutonium program to buy time for a then-nonexistent uranium bomb program, and to obtain LWRs that would be impossible for North Korea to operate if it ever succeeded in becoming a nuclear weapons state. These pieces simply do not fit into a coherent theory of regime strategy; yet, this is what one is left with if one thinks in terms of carrots, sticks, and cheating. But if North Korea’s centrifuge procurement in 1997 is instead interpreted as a hedge to preserve nuclear leverage while the nominally preferred path toward normalization was coming into question, then it fits parsimoniously into a techno-diplomatic strategy.¹²⁰ This is precisely how the enrichment program was later deployed by North Korean negotiators as the AF fell apart.¹²¹

Beyond the Agreed Framework: Understanding Proliferation Crises

Two recurrent proliferation crises—one in North Korea and the other in Iran—have many important similarities. Both involve politically isolated states in asymmetric standoffs with the United States; both feature nuclear technologies as prime bargaining chips; and both threaten to change the power dynamics in important geopolitical regions. Further, many area specialists point to prominent reformist factions within both countries that seek reconciliation with the West; these experts argue that engaging those factions may be the key to rolling back their nuclear programs.¹²² This section moves beyond the Agreed Framework to examine the strategic dynamics common to these proliferation

118. Wit, Poneman, and Gallucci, *Going Critical*, pp. 51–77.

119. See Hecker, Braun, and Lawrence, “North Korea’s Stockpiles”; and online appendix A2.

120. For another articulation of the “hedging” argument, see Siegfried S. Hecker, “Lessons Learned from the North Korean Nuclear Crises,” *Daedalus*, Vol. 139, No. 1 (Winter 2010), <https://www.amacad.org/publication/lessons-learned-north-korean-nuclear-crises>.

121. The North Korean regime repeatedly sought to use HEU as bargaining leverage to draw the George W. Bush administration into negotiations after the collapse of the AF. See Chinoy, *Meltdown*.

122. For the North Korea case, see Sigal, *Disarming Strangers*. For the Iran case, see Trita Parsi, *Losing an Enemy: Obama, Iran, and the Triumph of Diplomacy* (New Haven, Conn.: Yale University Press, 2017).

crises, to characterize the structural barriers that obstruct their resolution, and to identify factors that may have helped circumvent those barriers when progress has been made.

One of the hallmarks of these crises is that bargaining usually hinges not on the stated end goal of negotiations, which is often agreed early in the process, but on the sequencing of irreversible steps to reach that end goal and how to manage credibility along the way. These fixations on sequencing and irreversibility can be traced to the time structure of the commitment problem that animates most proliferation crises.¹²³ Because those commitment problems result from the compact physical dimensions of the nuclear bargaining chips,¹²⁴ workable resolutions typically require shifting the focus of engagement to some alternative physical medium that allows the redistribution of political leverage among actors and across time. The reactor trade of the AF was an example of one of these techno-diplomatic circumventions of the commitment problem.

The remainder of this section examines recent episodes of U.S. nonproliferation engagement with North Korea and Iran.¹²⁵ In each case, bargaining began when both sides identified a mutually acceptable political future, but intuitively recognized the challenge of credibly committing to that envisioned political arrangement. From there, sequencing issues emerged, as both sides guarded against unreciprocated forfeitures of leverage that could have allowed the other to abandon continued engagement. A diplomatic breakthrough was achieved when both sides identified some form of technological infrastructure whose reconfiguration could have changed the structure of the engagement and offset the forfeiture of leverage that denuclearization would entail. Progress halted when one or both of the negotiating teams reverted to inducement thinking and recast diplomacy in terms of carrots and sticks.

2019 HANOI SUMMIT: "GATE OF DENUCLEARIZATION" OR "VIRTUOUS CIRCLE"
The 2018 Singapore Joint Statement between the United States and North Korea called for the denuclearization of the Korean Peninsula and the normalization of relations between the two countries.¹²⁶ In subsequent months, the

123. For the time-structure of the commitment problem, see Powell, "War as a Commitment Problem."

124. Rational-actor models indicate that large, foreseeable shifts in power, such as those tied to discrete bargaining chips, can lead to commitment problems. See James D. Fearon, "Bargaining over Objects That Influence Future Bargaining Power," paper presented at the annual meeting of American Political Science Association, Washington, D.C., August 28–31, 1997, <https://web.stanford.edu/group/fearon-research/cgi-bin/wordpress/wp-content/uploads/2013/10/Bargining-Over-Objects-That-Influence-Future-Bargaining-Power.pdf>.

125. Additional cases are discussed in online appendix A5.

126. "Joint Statement of President Donald J. Trump of the United States of America and Chairman Kim Jong Un of the Democratic People's Republic of Korea at the Singapore Summit,"

United States proposed infrastructure investment in North Korea as an “additional pillar of the Singapore Statement.”¹²⁷ These initial overtures mirror those that took place at the outset of the first nuclear crisis. In parallel, officials from North Korea and South Korea met in a series of historic summits during which Chairman Kim Jong-un committed to full denuclearization and South Korean President Moon Jae-in proposed a series of infrastructure development projects in North Korea that, if completed, would link the two Koreas and incorporate the North into a “New Economic Map” (NEM) in East Asia.¹²⁸

As in the first nuclear crisis, however, lofty visions of future reconciliation were complicated by a crucial division over the path to that future. Official statements from the U.S. Department of State specified that the “path to a secure and prosperous future for North Korea runs through the gate of denuclearization.”¹²⁹ Until the regime chose to walk through that gate, North Korea would face maximum pressure. Favoring this inducement timeline, hardliners in the Donald Trump administration insisted that no sanctions relief could be negotiated until denuclearization had been fully verified. President Trump’s diplomacy with Chairman Kim, however, faced the same commitment problem that had defined the nuclear crisis for the past twenty-five years. Western analysts highlighted this dilemma by asking, “Could any [written] security guarantees ever be sufficiently credible to convince Kim to give up nuclear weapons?”¹³⁰

Meanwhile, other states with a geopolitical stake on the peninsula envisioned a phased process, reciprocated with corresponding measures, as the only imaginable path toward denuclearization. Moon’s administration, for instance, suggested establishing a “virtuous circle” between infrastructure development and denuclearization in North Korea.¹³¹ A close look at the infrastructure investments proposed in President Moon’s NEM reveals all the makings of a techno-diplomatic approach. Like the KEDO LWR of the AF,

June 12, 2018 (Washington, D.C.: White House, 2018), <https://www.whitehouse.gov/briefings-statements/joint-statement-president-donald-j-trump-united-states-america-chairman-kim-jong-un-democratic-peoples-republic-korea-singapore-summit/>.

127. Remarks of anonymous U.S. State Department officials, 2019.

128. Seong Yeon-cheol and Jung In-hwan, “President Moon Offers Methodology for the Denuclearize North Korea,” *Hankyoreh*, February 28, 2018, http://english.hani.co.kr/arti/english_edition/e_northkorea/834098.html.

129. For example, remarks of Deputy Assistant Secretary of State for Japan and Korea Marc Knapper, Wilson Center Korea Global Forum, November 15, 2018, event attended by author.

130. Ankit Panda and Vipin Narang, “The Trump-Kim Summit and North Korean Denuclearization: The Good, The Bad, and the Ugly,” *War on the Rocks* blog, March 14, 2018, <https://warontherocks.com/2018/03/the-trump-kim-summit-and-north-korean-denuclearization-the-good-the-bad-and-the-ugly/>.

131. “Creating a Virtuous Circle with North Korea,” *Christian Science Monitor*, July 17, 2018, <https://www.csmonitor.com/Commentary/the-monitors-view/2017/0717/Creating-a-virtuous-circle-with-North-Korea>.

the construction projects are designed not to simply “reward” North Korea, but to integrate it into inert technological infrastructures that subtend national borders.¹³²

The techno-diplomacy of the NEM is most visible in its proposed investments in rail-transit infrastructure. Rather than just modernize North Korea’s aging rail lines, the NEM proposes to connect South Korea to the Eurasian mainland through North Korea.¹³³ This could potentially turn North Korea into an obligatory passage point for the international trade that would be routed along those lines. It would also require considerably more investment, because North Korea’s existing infrastructure would need to be harmonized with the rail lines that span the continent. Physical differences in rail gauge, weight limits, turn radii, and platform heights would all need to be reconciled,¹³⁴ at an estimated cost of \$35 billion.¹³⁵ In early 2018, North Korea signaled its interest in these physical integrations by supporting South Korea’s membership in the Organization for Cooperation between Railways, the international consortium that coordinates these specifications for Eurasian international rail networks.¹³⁶ It then expressed willingness to verifiably dismantle its Yongbyon nuclear complex in exchange for “corresponding measures” to foster economic development.¹³⁷ Other projects proposed in the NEM, including a regional electrical supergrid and shared pipeline for liquid natural gas, were similarly designed to integrate North Korea with neighboring states through costly shared infrastructure.

Construction steps for any of these projects are forbidden by international law so long as North Korea remains under the current sanctions regime. But

132. See Christopher Lawrence, “A Theory of Engagement with North Korea,” Discussion Paper 2019-02 (Cambridge, Mass.: Project on Managing the Atom, Belfer Center for Science and International Affairs, Harvard Kennedy School, February 2019), <https://www.belfercenter.org/sites/default/files/files/publication/A%20Theory%20of%20Engagement%20with%20North%20Korea.pdf>.

133. The Presidential Committee on Northern Economic Cooperation, “Future Plan: New Economic Map for the Korean Peninsula” (Seoul: Presidential Committee on Northern Economic Cooperation, 2017), http://bukbang.go.kr/bukbang_en/vision_policy/plan/.

134. Victor Cha, Joseph Bermudez, and Marie DuMond, “Making Solid Tracks: North and South Korean Railway Cooperation,” *Beyond Parallel* (Washington, D.C.: Center for Strategic and International Studies, December 10, 2018), <https://beyondparallel.csis.org/making-solid-tracks-north-and-south-korean-railway-cooperation/>.

135. S. Nathan Park, “An Ingenious Plan to Modernize North Korea’s Trains,” *CityLab*, May 4, 2018, <https://www.citylab.com/transportation/2018/05/inter-korean-summit-rail-project/559652/>.

136. Kim Tae Won and Yoon Sojung, “Seoul Joins International Railway Cooperation Body Thanks to Pyeongyang’s Support,” *Korea.net*, June 8, 2018 (Sejon, South Korea: Korean Culture and Information Service, 2018), <http://www.korea.net/NewsFocus/policies/view?articleId=159972>.

137. Christopher Lawrence, “A Window into Kim’s Nuclear Intentions? A Closer Look at North Korea’s Yongbyon Offer,” *War on the Rocks* blog, January 15, 2019, <https://warontherocks.com/2019/01/a-window-into-kims-nuclear-intentions-a-closer-look-at-north-koreas-yongbyon-offer/>.

shortly before the second Trump-Kim summit was scheduled to be held in Hanoi in 2019, Special Envoy to North Korea Stephen Biegun suggested that his team was considering a “phased approach” similar to that promoted by the Moon administration.¹³⁸ Anonymous reports indicate that sanctions waivers for North-South construction projects were on the table in exchange for Yongbyon dismantlement as part of an interim deal to make way for more ambitious negotiations. But when the dramatic summit came to a close, the deal was left unsigned. Although accounts differ on the details of the diplomatic collapse, nearly all suggest that the Trump administration had reverted to its preferred inducement sequencing of denuclearization up front and “rewards” for North Korea after.¹³⁹

THE IRAN NUCLEAR NEGOTIATIONS IN MINIATURE—A NUCLEAR FUEL SWAP

Reformist political factions in Iran have sporadically sought political and economic reconciliation with the West since the mid-1990s,¹⁴⁰ and the United States has often rebuffed their overtures. But in 2002, Israeli intelligence leaks indicated that Iran had quietly developed the capability to enrich uranium.¹⁴¹ As subsequent IAEA inspections revealed the extent of Iran’s nuclear capabilities, the government of Mohammad Khatami sought to “turn threats into opportunities” and to use those capabilities as a medium for engaging the West.¹⁴² The rudiments of an envisioned political future of reconciliation can be detected in various Iranian proposals as early as 2003,¹⁴³ and are spelled out

138. U.S. Special Representative to North Korea Stephen Biegun, “Remarks on the DPRK,” speech at Stanford University, Stanford, California, January 31, 2019, https://fsi-live.s3.us-west-1.amazonaws.com/s3fs-public/transcript_stephen_bieugn_discussion_on_the_dprk_20190131.pdf.

139. See Chad O’Carroll and Chloe Joo, “North Korea in March 2019: A Month in Review and What’s Ahead,” *NK Pro*, April 3, 2019, <https://www.nknews.org/pro/north-korea-a-month-in-review-and-whats-ahead-4/>; and Lesley Wroughton and David Brunnstrom, “Exclusive: With a Piece of Paper, Trump Called on Kim to Hand Over Nuclear Weapons,” Reuters, March 29, 2019, <https://www.reuters.com/article/us-northkorea-usa-document-exclusive/exclusive-with-a-piece-of-paper-trump-called-on-kim-to-hand-over-nuclear-weapons-idUSKCN1RA2NR>.

140. Iran’s economic isolation from the West became written into U.S. law in 1996, when Congress signed the Iran-Libya Sanctions Act to bar U.S. companies from investing in Iran’s energy sector and sanctioned international companies engaging therein. Examples of Iranian overtures are outlined in Jay Solomon, *The Iran Wars: Spy Games, Bank Battles, and the Secret Deals that Reshaped the Middle East* (New York: Random House, 2016), pp. 29–53; and Parsi, *Losing an Enemy*, pp. 37–53.

141. Christopher Lawrence, “Heralds of Global Transparency: Remote Sensing, Nuclear Fuel-Cycle Facilities, and the Modularity of Imagination,” *Social Studies of Science*, online first, October 11, 2019, doi.org/10.1177%2F0306312719879769.

142. See Seyed Hossein Mousavian, *The Iranian Nuclear Crisis: A Memoir* (Washington, D.C.: Carnegie Endowment for International Peace, 2012), p. 99.

143. See, for example, memorandum of Iranian proposal relayed by Swiss Ambassador Tim Guldiman to Washington, D.C., May 2003, http://www.nytimes.com/packages/pdf/opinion/20070429_iran-memo-expurgated.pdf.

in a 2005 official letter from Iran to the IAEA.¹⁴⁴ The letter outlined how reconciliation could be embodied in a normalized civilian nuclear program, including a legitimized enrichment capacity limited to meet the “contingency fuel requirements of Iran’s power reactors,” “immediate conversion of all enriched uranium to (oxide) fuel rods,” and “continuous on-site presence of IAEA inspectors” at all bulk-handling,¹⁴⁵ nuclear fuel-cycle facilities.¹⁴⁶ These are the stated end goals that would later become enshrined in the 2015 Joint Comprehensive Plan of Action (JCPOA), also known as the Iran deal.

Iranian and U.S. geopolitical visions may have started to converge in 2009, when the incoming Barack Obama administration turned U.S. policy toward reconciliation with Iran and planned to accept limited uranium enrichment on Iranian soil.¹⁴⁷ Unprecedented verbal and written overtures were exchanged,¹⁴⁸ but the preceding decades of political animosity had congealed into physical infrastructures that would require more than mere words to dismantle. Steps by either side to roll those infrastructures back could be downright dangerous if they were not reciprocated by the other. On the U.S. side, the multilateral sanctions coalition had taken years to construct. If sanctions were relaxed in a negotiated settlement, they could not necessarily be “snapped back” if Iran reneged on the deal, especially if international economic actors laid down physical roots on the ground in Iran through direct foreign investment. For Iran’s part, its scientific elite had invested years into its centrifuge capability and growing stockpile of low-enriched uranium (LEU). These bargaining chips could not simply be “cast to the wind” without assurances that the other side would remain invested in continued engagement.¹⁴⁹ Both sides recognized that some sort of reciprocal confidence-building measure would be needed to “break the ice” and make way for more enduring engagement.¹⁵⁰

144. “Communication dated 8/1/2005 received from the Permanent Mission of the Islamic Republic of Iran to the Agency,” INFCIRC/648, IAEA, 2005, <https://www.iaea.org/sites/default/files/publications/documents/infircs/2005/infirc648.pdf>.

145. “Bulk-handling” refers to facilities that handle nuclear fuel not contained in countable fuel rods or assemblies. Bulk-handling facilities require a more continuous presence to safeguard against diversion than do “item-handling” facilities. See V. Schuricht and J. Larrimore, “Safeguarding Nuclear Fuel-cycle Facilities,” IAEA Bulletin 1/1988, IAEA, 1988, <https://www.iaea.org/sites/default/files/publications/magazines/bulletin/bull30-1/30103450812.pdf>. Continuous, on-the-ground presence at bulk-handling facilities surpasses the requirements stipulated in a standard Comprehensive Safeguards Agreement and is colloquially known as the “Japan Standard.”

146. See INFCIRC/648, p. 4.

147. The Obama policy review is outlined in Parsi, *Single Roll of the Dice*, pp. 134–168; U.S. plan to accept enrichment in Parsi, *Losing and Enemy*, pp. 174–196.

148. Trita Parsi, *A Single Roll of the Dice: Obama’s Diplomacy with Iran* (New Haven, Conn.: Yale University Press, 2013), pp. 62–65.

149. Common Iranian description of wasted bargaining leverage. See, for example, Hossein Moussavi, statement, October 30, 2009, quoted in Parsi, *Losing and Enemy*, p. 97.

150. Wording of U.S. Department of State officials, reported in Parsi, *Single Roll of the Dice*, p. 115.

An opportunity for a techno-diplomatic breakthrough presented itself in the summer of 2009. Iran had requested IAEA assistance in purchasing fuel pads for its Tehran Research Reactor (TRR). When Director General of the IAEA Mohammad ElBaradei relayed the request to U.S. officials, they worked together to construct a “fuel swap” proposal.¹⁵¹ Under the plan, the United States would ship 1,200 kilograms of LEU out of Iran and use it to fabricate the fuel pads, which would then be sent to Iran to refuel the TRR. ElBaradei presented the proposal to the head of Iran’s Atomic Energy Organization, Ali Akbar Salehi, who immediately recognized it as a “very smart proposal.” Both agreed that the fuel swap simultaneously embodied a “technical proposal” and a “political gesture” that might open the door to further engagement with the West.¹⁵²

As with the LWRs of the AF, understanding the techno-diplomatic significance of the fuel swap proposal requires opening up its technical attributes and relating them to the political visions articulated in previous written statements. Although Iran’s nuclear scientists were capable of producing the fuel pads for the TRR, such action would be problematic for two reasons. First, it would require enriching uranium up to 19.75 percent,¹⁵³ which would in turn exacerbate international pressure, because doing so would bring it much closer to the enrichment level needed for nuclear weapons. Second, Iran would need to ultimately burn a substantial portion of its LEU stockpile in a civilian reactor, and thereby lose its most significant bargaining chip without achieving any progress in engaging the West. Alternatively, the fuel swap would keep enrichment within the low levels associated with Iran’s civilian power reactor at Bushehr. Meanwhile, roughly a bomb’s worth of uranium enriched on Iranian soil would be circulated through the civilian nuclear infrastructures of multiple IAEA member states, and ultimately transform from weapons-usable fuel into reactor fuel pads to meet a demonstrable, “contingent” civilian need in Iran’s TRR. Moreover, U.S. financial and political support for the process would amount to de facto legitimization of limited Iranian enrichment, as the cross-national nuclear collaboration entailed in the transformation would be barred under international law so long as Iran’s enrichment program was deemed a threat by the West.¹⁵⁴ If Iran’s 2005 letter to the IAEA

151. For descriptions, see Parsi, *Single Roll of the Dice*, pp. 114–150; Parsi, *Losing an Enemy*, pp. 88–115; and Mohamed ElBaradei, *The Age of Deception: Nuclear Diplomacy in Treacherous Times* (New York: Metropolitan, 2011), pp. 286–313.

152. Exchange reported in ElBaradei, *Age of Deception*, pp. 295–296.

153. Ahmad Lashkari et al., “Neutronic Analysis for Tehran Research Reactor Mixed-Core,” *Progress in Nuclear Energy*, Vol. 60 (September 2012), pp. 31–37, <https://doi.org/10.1016/j.pnucene.2012.04.006>.

154. United Nations Security Council Resolution 1696 (2006) declares Iran’s enrichment program a threat to international peace and security. “Security Council Demands Iran Suspend Uranium

had articulated a political future of peaceful nuclear normalization for Iran, then the proposed fuel swap could etch the essential features of that politics, in miniature but with high fidelity, into the physical substrate of nuclear fuel.

The fuel swap was a microcosm of the more sweeping political changes articulated in Iranian and U.S. overtures,¹⁵⁵ and so came up against its own miniature commitment-problem time structure. Although the U.S. and Iranian delegations were able to agree on the physical end state of the swap during a short round of negotiations in early October 2009, dispute quickly arose over the sequencing. The United States wanted the LEU transported in a single shipment, whereas Iranian negotiators explained that if all 1,200 kilograms of LEU were shipped from Iranian soil at once, Iran could not trust the United States to follow through on the deal or continue engaging with it. To retain bargaining leverage to incentivize continued implementation, Iran demanded that the transfer be divided into three sequential shipments with simultaneous delivery of completed fuel pads. But from the standpoint of the United States, if the swap was to be spread out over time while Iran's enrichment program continued, Iran's LEU stockpile would not dip substantially below a bomb's worth of fuel. A phased shipment would thus attenuate the costly signal from Iran that would be carried as the fuel left its territory, and that signal was needed to build credibility for the next phase of negotiations. The proposal broke down over this sequencing impasse.

Months later, Iran agreed to a modified swap proposal that incorporated Brazil and Turkey, whereby Iran's LEU would be stored in escrow on Turkish soil under IAEA surveillance to retain mutual leverage as the swap was implemented. This agreement, however, followed several months of paralysis in Tehran resulting from domestic-political struggles;¹⁵⁶ in the interim, Iran's nuclear scientists began enriching uranium to 19.75 percent and expanded its 3.5 percent LEU stockpile such that Iran would retain nearly a bomb's worth even after the shipment. Hence, the techno-diplomatic relevance of the swap had diminished. Meanwhile, the United States had reverted to its inducement policy, and U.S. officials saw the modified swap proposal as a distraction from the coalition building required to effectively sanction Iran. The Obama administration rejected the new proposal, and Iran went on to produce the TRR fuel indigenously. The collapse of the fuel swap led to another three years of esca-

Enrichment by 31 August, or Face Possible Economic, Diplomatic Sanctions," 5500th meeting (am), July 31, 2006, United Nations press release, <https://www.un.org/press/en/2006/sc8792.doc.htm>.

155. This was described as the "essence" of the fuel swap. See Parsi, *Single Roll of the Dice*, pp. 117–119; and ElBaradei, *Age of Deception*, p. 294.

156. See Parsi, *Losing an Enemy*, pp. 96–98; and ElBaradei, *Age of Deception*, pp. 309–313.

lating sanctions and enrichment before negotiations would resume and ultimately culminate in the JCPoA.

Conclusion

Nonproliferation discourse in the United States defines “engagement” as simply the “willingness to consider positive inducements” to bribe states into dismantling their nuclear capabilities.¹⁵⁷ Under this definition, the United States explored the full space of engagement policies when it signed the 1994 Agreed Framework with North Korea. At high cost to its allies and steep moral hazard to the global nonproliferation order, the United States offered North Korea an extravagant package of carrots in the form of energy infrastructure and the promise of political normalization, yet these were insufficient to outweigh the regime’s determination to build nuclear weapons. The prevailing conclusion among nonproliferation analysts is that engagement with North Korea has been futile. Yet, an analysis of the technical challenges of LWR construction and operation reveals the difficulty of trying to explain why the regime would offer to trade its plutonium reactors for LWRs if its primary goal was nuclear weapons. And if the regime wanted to extract the carrot of energy generation and then renege on the AF, it is incomprehensible why it would insist on LWRs over FFPPs when it knew it could not operate them without continued technical assistance from the West. These anomalies strongly suggest that the popular inducement understanding of the AF should be revised.

I have attempted to provide a new model of engagement to explain the North Korean nuclear crisis. I began by acknowledging the commitment problem that arose between North Korea and the United States at the end of the Cold War and the reciprocal credibility challenges that stood in the way of denuclearization and political normalization. I then examined nuclear technology to outline the role that LWR export played in charting a resolution to those credibility dilemmas. After decades of hostility and isolation between the two countries, denuclearization and normalization were not credibly expressible in the usual languages of diplomacy and international law. Instead, U.S. and North Korean negotiators sought to express those commitments in an alternate medium, by building the physical embodiment of normalization in the form of a shared technological infrastructure that was understood to be proliferation resistant, technologically inert, and deeply international. The AF and associated KEDO project were an attempt at diplomacy by other means—diplomacy

157. Stephan Haggard and Marcus Noland, “Engaging North Korea: The Efficacy of Sanctions and Inducements,” in Solingen, *Sanctions, Statecraft, and Nuclear Proliferation*.

by more credible and durable means. And if in the end that endeavor had a fatal shortcoming, it was that the United States managed to offset the physical cost of diplomacy to its allies, leaving a U.S. stake in normalization that was constituted more on paper than in steel or concrete. By progressively diminishing its costs, the United States consistently signaled its noncommitment to the normalization path, which the North Korean regime insisted was the central purpose of the AF.

The history of the AF and other proliferation crises offers a straightforward lesson for future U.S. nonproliferation diplomacy: isolated latent proliferators have been most responsive to U.S. moves that spoke credibly about their place in a political future; they have been relatively immune to sanctions and transient rewards. This history suggests that nonproliferation diplomacy is not really about inducement at all, but about building credible commitments to the political reconciliation that is needed to make denuclearization a rational path. Instead of attempting to coerce or bribe target states into verifiably ending all weapons-relevant nuclear activity, a techno-diplomatic approach to nuclear nonproliferation would seek to build robust techno-political realities that render nuclear weapons less relevant altogether.

The conceptual shift from inducement to techno-diplomacy has several implications for future nonproliferation policy. If the primary stake in a proliferation crisis is a political future, then the most likely path to denuclearization is not coercion or bribery, but a phased sequence of synchronous concessions that constitute mutual commitments to political change. The primary currency of these concessions will not be the intrinsic utility to the target state (as in inducement), but the sunk costs to the conceding state and the pending costs and utilities that are contingent upon continued future engagement. Self-imposed costs and incentive-structure adjustments are the modes through which political commitment is earnestly expressed, and often these are more credible when embodied in irreversible physical processes—such as shared infrastructure investments and physical deconstruction of previous nuclear investments—than when codified in written commitments and bound to politically malleable juridical norms. And finally, any agreeable path to resolving proliferation crises will, in accordance with the basic time structures of technological inertia and rational-actor bargaining, always leave a hedge for the weaker, but nuclear-capable state.