
ARTICLES

Attacking the Atom: Does Bombing Nuclear Facilities Affect Proliferation?

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ABSTRACT What are the consequences of military strikes against nuclear facilities? In particular, do they ‘work’ by delaying the target states ability to build the bomb? This article addresses these questions by conducting an analysis of 16 attacks against nuclear facilities from 1942 to 2007. We analyze strikes that occurred during peacetime and raids that took place in the context of an ongoing interstate war. The findings indicate that strikes are neither as uniformly fruitless as the skeptics would suggest, nor as productive as advocates have claimed. There is evidence that the peacetime attacks delayed the target’s nuclear program, although the size of this effect is rather modest. The wartime cases were less successful, as attacks often missed their targets either due to operational failure or limited intelligence on the location of critical targets. In our concluding section we show that many of the conditions that were conducive to past success are not present in the contemporary Iran case. Overall, our findings reveal an interesting paradox. The historical cases that have successfully delayed proliferation are those when the attacking state struck well before a nuclear threat was imminent. Yet, this also happens to be when strikes are the least legitimate under international law, meaning that attacking under these conditions is most likely to elicit international censure.

KEY WORDS: Preventive war, Counterproliferation, Nuclear proliferation, Iran

Introduction

What are the consequences of military strikes against nuclear facilities? In particular, do they ‘work’ by delaying the target states ability to build the bomb? Policymakers in the United States, Israel, and even

Arab countries such as Saudi Arabia¹ have implied an affirmative response, indicating that military force might frustrate Iran's current nuclear program. Yet, this perspective is at odds with concerns in the scholarly literature that the use of force is ineffective and should be avoided at all costs.² If attacks against nuclear programs significantly delay proliferation, then policymakers may be correct to keep military force in the nonproliferation toolkit. On the other hand, if strikes are ineffective tools of nonproliferation, then countries are wise to heed the cautionary advice of scholars who urge them to pursue other strategies.

This article speaks to the debate on the efficacy of military force by analyzing the historical record of attacks against nuclear programs. We identify four theoretical mechanisms for how strikes may affect nuclear weapons' production capacity. First, and most directly, attacks can delay the target's ability to build nuclear weapons by destroying chokepoint facilities that are critical for bomb development. Strikes may also delay the target's program through three indirect mechanisms. Raids could produce a change in the target's fissile material production strategy, make foreign suppliers less willing to provide nuclear assistance, and lead to enhanced international inspections. These outcomes can be thought of as externalities of strikes because they are unrelated to the original aims of the attacker but can nevertheless frustrate the target's ability to proliferate.

To assess these mechanisms, we conduct a comprehensive analysis of all 16 attacks against nuclear programs that have occurred from 1942 to 2007.³ We analyze strikes that occurred during peacetime as well as those that took place in the context of an ongoing interstate war. 'Bolt from the blue' attacks are qualitatively different from strikes against nuclear facilities during wartime, but both types of cases are useful in

¹Ian Black and Simon Tisdall, 'Saudi Arabia Urges US Attack on Iran to Stop Nuclear Programme,' *The Guardian*, 28 Nov. 2010.

²See, for example, Dan Reiter, 'Preventive Attacks against Nuclear Programs and the "Success" at Osirak,' *Nonproliferation Review*, 12 (July 2005), 355–371; Dan Reiter, 'Preventive Attacks against Nuclear, Biological, and Chemical Weapons Programs: The Track Record,' in William Walton Keller and Gordon R. Mitchell (eds), *Hitting First, Preventive Force in US Security Strategy* (Pittsburgh, PA: Pittsburgh UP 2006); Richard K. Betts, 'The Osirak Fallacy,' *The National Interest* 83 (2006), 22–5; Bennett Ramberg, 'Preemption Paradox,' *Bulletin of Atomic Scientists*, Jul./Aug. 2006, 48–56.

³We define attacks against nuclear programs as the state-sanctioned use of force against facilities related to a nuclear weapons program that has the intention of delaying a country's acquisition of nuclear bombs. For further details, see Matthew Fuhrmann and Sarah E. Kreps, 'Targeting Nuclear Programs in War and Peace: A Quantitative Empirical Analysis, 1941–2000,' *Journal of Conflict Resolution* 54/6 (2010), 831–59.

understanding this issue.⁴ Peacetime cases, such as Israel's 1981 attack against Iraq and its 2007 strike against Syria, are ideal for evaluating both the direct and indirect mechanisms because we can isolate the effects of limited raids from the broader effects of interstate conflict. This is more difficult for wartime cases, including World War II, the Iran–Iraq War, and the 1990–91 Persian Gulf War. For example, the post-Persian Gulf War inspections regime influenced Iraq's ability to reconstitute its weapons program in the 1990s, but it is hard to know whether strikes against nuclear infrastructure during the campaign contributed to this outcome independent of Iraq's military defeat. We therefore study wartime cases to evaluate the direct mechanism, that is, whether the strike removed past progress by destroying relevant nuclear facilities.

As we show, the use of force did not significantly delay the target's nuclear weapons program in many of the wartime cases. Strikes failed in large part because there was limited intelligence on the location of targets. Further, targets were not always effectively destroyed even when their location was known. On the other hand, the peacetime attacks tended to delay the target's nuclear program, providing some support for both direct and indirect mechanisms. The size of this effect was rather modest, however, since neither Iraq nor Syria was on the verge of building nuclear weapons at the time of the raid.

Our findings challenge both sides of the debate on whether force works and suggest that neither perspective is as clear cut as its proponents would have us believe. The view that strikes 'are generally ineffective, costly, unnecessary, and potentially even counterproductive'⁵ downplays evidence of prior strikes that delayed the target state's nuclear program. The competing view that strikes might be a panacea for international proliferation does not take into account the number of instances in which attackers failed to destroy key nuclear facilities in the target country. We offer a more nuanced picture; we show that there have been instances of both success and failure and explain why there is variation.

While we conclude that some cases bought time for the attacker, this finding should be seen in a qualified light when it comes to predicting the consequences of future events. In his study of why countries build nuclear weapons, Scott Sagan aptly pointed out that 'predicting the

⁴As Reiter notes, 'intra-war cases are important, both because they offer lessons ... and because intra-war preventive strikes against [nuclear, biological, or chemical] programs are possible in the future'. See Reiter 'Preventive Attacks against Nuclear, Biological, and Chemical Weapons Programs,' 29.

⁵Dan Reiter, *Preventive War and its Alternatives: The Lessons of History* (Carlisle, PA: Strategic Studies Institute 2006), 2.

future based on such an understanding of the past ... [is] problematic, since the conditions that produced the past proliferation outcomes may themselves be subject to change.⁶ As we show in the discussion of this paper, the same is likely true for attacks on nuclear facilities. This has important implications for contemporary debates on how to respond to Iran and other proliferators.

This article proceeds in four parts. First, we outline four mechanisms by which the use of military force could affect the target state's nuclear program. Second, we evaluate all four theoretical mechanisms by analyzing the two Israeli peacetime raids. Third, we analyze the direct mechanism by considering strikes undertaken in the context of interstate war. The final section discusses the findings, assesses the conditions under which strikes might be useful in delaying a proliferator's nuclear program, and evaluates the likely effects of strikes against Iranian nuclear facilities.

How Could Attacks Affect Proliferators' Weapons Programs?

We begin with the straightforward observation that the acquisition of nuclear weapons requires both political willingness and technical capacity. Security threats or being insulated from the global economy often motivate states to pursue the bomb.⁷ Yet states cannot cross the nuclear threshold without the requisite nuclear technology, materials, and knowledge. A growing number of quantitative studies show that supply-side considerations, particularly whether a country has the requisite nuclear infrastructure, are salient in explaining who acquires nuclear weapons.⁸ This indicates that political will is not a sufficient condition for going nuclear – even if a country is determined to get the bomb. The historical record supports this assertion. Although 22 countries have had nuclear weapons programs since 1942, only 10 have

⁶Scott Sagan, 'Why Do States Build Nuclear Weapons? Three Models in Search of the Bomb,' *International Security* 21/3 (1996/97), 85.

⁷See, for example, Sagan 'Why Do States Build Nuclear Weapons?'; Sonali Singh and Christopher Way, 'The Correlates of Nuclear Proliferation: A Quantitative Test,' *Journal of Conflict Resolution* 48/6 (2004), 859–95; Dong-Joon Jo and Erik Gartzke, 'The Determinants of Nuclear Weapons Proliferation,' *Journal of Conflict Resolution* 51 (2007), 167–94; Etel Solingen, *Nuclear Logics: Contrasting Paths in East Asia and the Middle East* (Princeton, NJ: Princeton UP 2007).

⁸See especially Matthew Fuhrmann, 'Spreading Temptation: Proliferation and Peaceful Nuclear Cooperation Agreements,' *International Security* 34/1 (2009), 7–41; Matthew Fuhrmann, 'Taking a Walk on the Supply Side: The Determinants of Civilian Nuclear Cooperation,' *Journal of Conflict Resolution* 53/2 (2009), 181–208; Matthew Kroenig, 'Importing the Bomb: Sensitive Nuclear Assistance and Nuclear Proliferation,' *Journal of Conflict Resolution* 53/2 (2009), 161–180.

successfully produced the bomb.⁹ Iran, for instance, began a nuclear weapons program in the 1980s but it has not yet acquired the bomb in part because of technical challenges.

The most significant and technically difficult factor affecting a state's opportunity to develop nuclear weapons is its ability to produce adequate quantities of fissile material. There are two paths countries can take to acquire fissile nuclear material. One involves enrichment technology designed to produce highly enriched uranium (HEU). A second path toward fissile material production involves reactor-based technology oriented toward plutonium production.¹⁰ This means that key chokepoints in a nuclear weapons program are: (1) uranium enrichment facilities; (2) plutonium reprocessing facilities; and (3) reactors.¹¹

Attacks can delay a target state's ability to produce nuclear weapons if they make it more difficult for it to possess these chokepoint facilities and, in turn, produce fissile material. Below, we identify four possible mechanisms that might produce this outcome. The first affects the target's past progress; the others limit its future potential to produce fissile material.

The Direct Effects of Attacks against Nuclear Facilities

The most direct way that an attack can affect the target state's nuclear program is through the destruction of facilities crucial to weapons development. An attack could delay the target's nuclear ambitions if any of the chokepoint facilities we identify above were destroyed. The magnitude of this effect depends on how many of the target's chokepoint facilities are destroyed relative to those continuing to operate. If the target possesses numerous chokepoint facilities and the attack destroys all of them, the raid would have a comparatively large effect on the nuclear program. A raid would have a more modest impact if some chokepoint facilities are razed but others are left intact.

It is difficult to determine exactly how many years an attack could set back a program in the event that chokepoint facilities are destroyed. Such a calculation would depend on the types of facilities countries

⁹Jo and Gartzke, 'The Determinants of Nuclear Weapons Proliferation'.

¹⁰See Gary Gardner, *Nuclear Nonproliferation: A Primer* (London: Lynne Rienner 1994), 16–17.

¹¹Some scholars do not classify reactors as sensitive nuclear technology. We include it on our list since reactors produce plutonium in spent nuclear fuel that could be reprocessed into bomb grade material. See M.D. Zentner *et al.*, *Nuclear Proliferation Technology Trends Analysis, 2005* (Richland, WA: United States Department of Energy, Pacific Northwest National Lab 2005).

possessed, how much progress they had made toward building the bomb, and their level of indigenous knowledge. If a country does not possess any chokepoint facilities prior to an attack, it would be hard to classify a strike as ‘effective’ from a counterproliferation standpoint even if it razed nuclear infrastructure. In the absence of chokepoint facilities, the target would not have been able to produce fissile material at any point in the near future in the absence of a strike. On the other hand, if a country possesses numerous chokepoint facilities and the attack destroys all of them, the raid has a comparatively large effect on the nuclear program since the target would likely otherwise have been able to produce fissile material for a bomb in the near future.¹² In a best case scenario where a strike razed all chokepoint facilities an attacking country possessed, it could set the program back five to ten years, if we assume that the target country possessed chokepoint facilities that were near completion and continued its pursuit of the bomb at a rate similar to what it did prior to the attack. This estimate is lower than the amount of time it generally takes to construct chokepoint facilities¹³ because diminishing marginal costs enable countries to build a second facility quicker. For example, it took India more than a decade to develop its first uranium enrichment facility but it built the second such plant in only five years.¹⁴

Conversely, attempts to hit chokepoints can fail. An obvious cause of a failed strike would be poor intelligence.¹⁵ In other cases the attempt could end in operational failure due to an accident or the attackers coming under enemy fire. In the event that the attacker cannot locate or destroy targets, attacks would obviously not delay the target’s nuclear program and could actually accelerate it by increasing the state’s willingness to build nuclear weapons. Failed attacks could also lead to measures that make future strikes more difficult, for example by distributing the chokepoints so that they cannot be hit in one strike.

The Indirect Effects of Attacks against Nuclear Facilities

The mechanism we described above is based on the notion that an attack can directly delay a nuclear program by reversing past progress. An attack could also impact a target’s program more indirectly by affecting its future behavior in one of three ways.

¹²For a similar discussion, see Reiter, ‘Preventive Attacks against Nuclear Programs.’

¹³See M.D. Zentner *et al.*, *Nuclear Proliferation Technology Trends Analysis*.

¹⁴*Ibid.*

¹⁵Reiter, ‘Preventive Attacks against Nuclear, Biological, and Chemical Weapons Programs.’

Shift in the approach to fissile material production. A raid might alter a target state's priorities such that it values keeping its program covert above all else. This, in turn, could cause a target country to alter its approach to acquiring fissile material. The most likely such shift is from plutonium production to uranium enrichment. Proliferators pursuing the plutonium route may choose to focus on the uranium path following an attack because it is comparatively more difficult to conceal reactors and reprocessing facilities due to their sheer size. Target states might also perceive that some enrichment plants may be more difficult to keep covert than others. For instance, electromagnetic isotope separation (EMIS) facilities might arouse less suspicion because the technologies involved are less tightly controlled. Consequently, they might abandon plans to develop centrifuge or gaseous diffusion plants after an attack in favor of an EMIS plant that relies on less conspicuous technology.

While a target state may correctly perceive that changing its approach to acquiring fissile material provides greater secrecy, this shift can also delay its nuclear program if it chooses to pursue a technology with which it has little experience.¹⁶ Under such circumstances, the target would need to develop indigenous knowledge and procure or develop new technologies. This would take comparatively more time because it would not benefit from the favorable effects of learning. For example, rebuilding a reactor might take less than three years but building a centrifuge enrichment facility without having previously done so could take at least 14 years.¹⁷ Moreover, there is no guarantee that the target could successfully develop this facility. Of the 18 countries that have attempted to enrich uranium using the centrifuge method since the 1940s, only seven (39%) have successfully done so.¹⁸ This indicates that a program could be delayed even further if the target chose to pursue a technology that was easier to conceal but inefficient or difficult to master.

Reduction in willingness of foreign suppliers to provide assistance. The use of force is typically an instrument of last resort because it is potentially risky and expensive. Military force, therefore, represents a costly signal that the attacking country is committed to ending or delaying the target's nuclear program. This might make third parties less inclined to supply nuclear technology, materials, or know-how to the suspected proliferating state for two reasons. First, there are

¹⁶Jeremy Tamsett, 'The Israeli Bombing of Osiraq Reconsidered: Successful Counter-proliferation?' *The Nonproliferation Review*, 11/3 (2004), 70–85.

¹⁷Zentner *et al.*, *Nuclear Proliferation Technology Trends Analysis*.

¹⁸*Ibid.*

practical risks associated with constructing facilities that could be targeted. To build a nuclear facility such as a reactor, personnel from the supplier country would have to spend years on the ground in the recipient country.¹⁹ Many of these personnel could be killed if the facility they were constructing was attacked again. The prospect of military force against the same program might discourage states from engaging in the perilous business of nuclear supply.

Second, the use of force reveals information about the proliferating state. It signals that at least one state (i.e., the attacker) had reason to believe that the target was using, or planning to use, nuclear infrastructure not to develop energy, but to develop the bomb. In exposing these dangers, attacks affect the way that third parties – especially nuclear supplier countries – view the target’s development of nuclear facilities. Helping a country acquire the bomb could increase the risk of nuclear war, instigate regional instability, raise the possibility of nonstate actors getting their hands on nuclear weapons, and reduce the supplier’s ability to exert influence against the target state.²⁰ Supplying to a suspected proliferating state could also damage the supplier’s relations with the attacking state and other powerful states that champion nonproliferation. Each of these outcomes would harm the supplier’s interests and create incentives to discontinue its nuclear commerce.

An inability to obtain foreign assistance would have serious consequences because of its contribution to a target state’s nuclear program. Foreign assistance is typically supplied exclusively for peaceful purposes, but dual-use technology can also be used to build nuclear weapons.²¹ Additionally, nuclear assistance helps establish an indigenous infrastructure that can be drawn on to build facilities dedicated to a military program. For these reasons, nuclear aid lowers important barriers to proliferation, whereas the withdrawal of such assistance would increase the time necessary to develop a nuclear weapon.

Enhanced international inspections and safeguards. The nuclear Nonproliferation Treaty (NPT), which entered into force in 1970, entitles all non-nuclear-weapon states to nuclear technology for peaceful purposes on the condition that they accept a system of

¹⁹See, for example, Duane Bratt, *The Politics of CANDU Exports* (Toronto: U of Toronto P 2006).

²⁰See, for example, Scott Sagan and Kenneth Waltz, *The Spread of Nuclear Weapons: A Debate Renewed* (New York: W.W. Norton 2002); Fuhrmann and Kreps, ‘Targeting Nuclear Programs in War and Peace.’

²¹Fuhrmann, ‘Spreading Temptation.’

safeguards imposed by the International Atomic Energy Agency (IAEA). This safeguards system – and the nuclear nonproliferation regime more generally – is based on the notion that countries can have a peaceful nuclear infrastructure that does not contribute to a weapons program if certain technical and legal restraints are imposed. Although IAEA safeguards do not guarantee that a proliferator will not use nuclear technology for military purposes, rigorous inspections can make such diversions more difficult. It was IAEA inspections that detected irregularities in North Korea in 1992, for instance.²² Inspections, though not flawless, can help clarify the intentions of a nuclear program and add a level of scrutiny that may make it more difficult for a state to produce fissile material for bombs.

The use of force is not the only way to trigger enhanced international inspections, but there are two reasons to expect that it could lead to that outcome. First, the IAEA, with support from member countries, is likely to seek a greater presence in a country that has been attacked to counter the perception that it is incapable of fulfilling its mandate and to decrease the likelihood that additional attacks will occur. Second, the targeted country might encourage the IAEA's presence in order to demonstrate to the international community that its intentions are peaceful.

Peacetime Case Studies

Israeli Attacks Against Iraq's Nuclear Program, 1981

Beginning in the 1970s, Israel pursued a series of covert and later overt actions designed to delay the Iraqi nuclear program.²³ The Iran–Iraq war provided an opportunity for it to escalate its opposition to Baghdad's bomb campaign. Using eight Israeli F-16s flanked by eight F-15s for cover, the Israeli Air Force raided the Osirak facility in 1981. The Israeli strikes completely destroyed the reactor and caused minimal collateral damage.²⁴

Previous research has debated the effect of the 1981 strike on the Iraqi nuclear program. According to one view, the attack did little to affect the program because Osirak – a 70 MW light water reactor – was

²²David Albright and Kevin O'Neill (eds), *Solving the North Korean Nuclear Puzzle* (Washington DC: Inst for Science and International Security 2000).

²³Amos Perlmutter *et al.*, *Two Minutes over Baghdad* (London: Routledge 2003).

²⁴Schlomo Nakdimon, *First Strike: The Exclusive Story of How Israel Foiled Iraq's Attempt to Get the Bomb* (New York: Summit Books 1987); Rodger Claire, *Raid on the Sun: Inside Israel's Secret Campaign that Denied Saddam the Bomb* (New York: Broadway 2004).

not ideal for plutonium production. Skeptics of its ability to generate plutonium for bombs point to a Congressional Research Service report indicating that it would have taken 10–30 years to produce enough plutonium for a bomb.²⁵ Those advocating this position also suggest that French suppliers would have been ‘highly motivated to report any illegal weapons activity’ in the event that Iraq attempted to use a civilian facility to produce plutonium for bombs.²⁶ At the other end of the spectrum is the view that ‘the Israeli counterproliferation effort successfully prevented Iraq from building a nuclear weapon,’ destroying the most critical Iraqi nuclear facility and making it impossible for Iraq to produce more than six grams of plutonium by 1991.²⁷ Somewhere in between is the argument that the use of military force set back the Iraqi program at least several years; in 1981, French nuclear engineers estimated that it would take four and a half years to rebuild the facility.²⁸

We find evidence supporting the view that the raid both directly and indirectly delayed the Iraqi nuclear program. A report from French scientists familiar with the project estimated that the reactor could produce between three and ten pounds of plutonium annually, at about seven pounds per bomb; ‘the risk is self-evident,’ reported one of the scientists involved with the report.²⁹ Jeremy Tamsett argues that Osirak could have produced plutonium for 28 nuclear weapons by the end of the decade.³⁰ Yet another estimate suggested a production of about 8–10 kg of plutonium annually, enough for about one bomb a year.³¹

Moreover, the argument that Iraq could not have used Osirak for military purposes rests on some questionable assumptions. For example, the view that France would be motivated to report illegal weapons activity and therefore that Iraq would have been unable to produce enough plutonium is unconvincing. This assumes that France, and the international community more generally, would be aware of illicit activities in the event that they occurred. It is not clear that this would have been the case, however. Although Osirak was under IAEA

²⁵Reiter, ‘Preventive Attacks against Nuclear Programs,’ 358.

²⁶Reiter, *Preventive War*.

²⁷Tamsett, ‘The Israeli Bombing of Osiraq Reconsidered,’ 71–72.

²⁸Shai Feldman, ‘The Bombing of Osiraq – Revisited,’ *International Security* 7/2 (Autumn 1982), 126; Whitney Raas and Austin Long, ‘Osirak Redux? Assessing Israeli Capabilities to Destroy Iranian Nuclear Facilities,’ *International Security*, 31/4 (2007), 10–11; Tim Keeley, ‘Angry French Contend Osirak Couldn’t Have Served Weapons Purposes,’ *Nucleonics Week*, 18 June 1981, 3.

²⁹‘Warn Mitterrand about Iraqi Nuclear Reactor,’ *United Press International*, 18 Mar. 1982.

³⁰Tamsett, ‘The Israeli Bombing of Osiraq Reconsidered’.

³¹Keeley, ‘Angry French.’

safeguards, Iraq had devised crafty ways of misleading inspectors that verified compliance with the NPT.³² Inspectors did not have a permanent presence in Iraq, making it possible for Baghdad to elude detection. A final problem with this argument is that France was hardly the poster child for nonproliferation during this era. Paris knowingly helped Israel build nuclear weapons and refused to ratify the NPT until the 1990s. It is by no means obvious that it would have been sufficiently motivated to take action against Iraq in the name of nonproliferation. Thus, by destroying a facility suited to plutonium production, Israel removed Iraq's past nuclear progress, supporting the direct mechanism outlined above.

There is also evidence in favor of two of the indirect mechanisms specified. The attacks provoked a shift in Iraq's path toward the bomb. Iraq had considered uranium enrichment before the attacks, but accelerated those plans after the attacks, both because France did not rebuild the reactor, but also because the plutonium path would have been an easier target for subsequent attacks. Iraq did not completely abandon its plutonium program, but focused the majority of its efforts on the uranium path, with EMIS and to a far lesser extent gaseous diffusion emerging as the top candidates.³³

The problem with shifting courses is that Iraq lacked indigenous knowledge necessary to master the complexities of enrichment technology. The EMIS program faced technical challenges that limited its ability to produce sufficient enriched uranium for a bomb.³⁴ In part because of these challenges, Iraq began working on gas centrifuge technology. The centrifuge program required a sophisticated, foreign technology with which Iraqis were not familiar; they encountered many problems because of complexities of rotor dynamics that the Iraqi scientists did not understand. As one Tuwaitha engineer suggested, 'a centrifuge is like a delicate soufflé that will fall apart if anything is done incorrectly, and our chefs were woefully unprepared.'³⁵

The attack did provoke Saddam Hussein to intensify his support for the Iraqi program, adding additional scientists, increasing financial investment in the effort to produce the bomb.³⁶ Increased resources were not sufficient for an accelerated nuclear program, however, since

³²David Kay, 'Denial and Deception Practices of WMD Proliferators: Iraq and Beyond,' *Washington Quarterly*, 18/1 (Jan. 1995), 85.

³³David Albright and Robert Kelley, 'Massive Programs, Meager Results,' *Bulletin of the Atomic Scientists* (Nov./Dec. 1995), 56–64.

³⁴Ibid.

³⁵Mahdi Obeidi and Kurt Pitzer, *The Bomb in My Garden: The Secrets of Saddam's Nuclear Mastermind* (New York: Wiley 2004), 103.

³⁶Reiter, 'Preventive Attacks against Nuclear Programs,' 362.

the strikes led to insurmountable technical impediments. On the contrary, the attempt to fast-track the bomb was counterproductive, as the Iraqi scientists ‘tried to shortcut the difficult science of rotor dynamics’ and burned out the centrifuges, with one scientist concluding that ‘a little knowledge is dangerous indeed.’³⁷ Thus, despite Saddam attributing ‘a high value to the nuclear progress and talent that had been developed to the 1991 war,’ technical challenges prevented him from acquiring sufficient quantities of fissile material by the time of the 1991 Persian Gulf War.³⁸

The Israeli raid also made France – Iraq’s most important nuclear supplier – less likely to assist the program. France appears to have considered rebuilding the reactor or resupplying Iraq with nuclear fuel that posed less of a proliferation risk.³⁹ One French official, however, suggested that declarations about French willingness to assist Iraq in resuscitating its program were “‘living-room hypotheses” designed to save face for the Iraqis’ and that the reactor would never be rebuilt.⁴⁰ In any case, years passed and neither Mitterrand nor Chirac – despite allegations that the latter had confidentially promised Saddam that he would rebuild the facility – ever followed through.⁴¹ Mahdi Obeidi, a high-ranking Iraqi nuclear scientist, regretted that ‘months passed, and the promised French cooperation never materialized. For those of us who had once envisioned an Iraqi nuclear program ... the dream died on the vine.’⁴² Iraq signed bilateral civilian nuclear cooperation agreements with many countries including Brazil, France, Italy, and the Soviet Union prior to 1981 but it had incredible difficulty securing atomic assistance after the Israeli strike.⁴³

There are no indications that the strike delayed Iraq’s nuclear program by producing enhanced international inspections. IAEA officials certainly opposed the raid, as they viewed it as an indictment of the safeguards regime.⁴⁴ Inspectors did not necessarily have greater access to Iraqi officials following the strike, however.

³⁷Obeidi and Pitzer, *The Bomb in My Garden*, 104.

³⁸Iraq Survey Group, ‘Final Report’ 2004, <<http://www.globalsecurity.org/wmd/library/report/2004/isg-final-report>>.

³⁹Edward Cody, ‘France Plans to Bar Weapons-Grade Fuel for Iraq’s Reactor,’ *Washington Post*, 13 Jan. 1982.

⁴⁰Tim Keeley, ‘France Has Told Iraq it is Fully Willing to Rebuild,’ *Nucleonics Week*, 27 Aug. 1981, 2; Ann MacLachlan, ‘French-Iraqi Accord Makes No Provision for Rebuilding Reactor,’ *Nucleonics Week*, 24/35 (1983), 1.’

⁴¹Ann MacLachlan, ‘French-Iraqi Accord’.

⁴²Obeidi and Pitzer, *The Bomb in My Garden*, 52.

⁴³Fuhrmann, ‘Taking a Walk.’

⁴⁴See, for example, IAEA Director General Sigvard Edlund’s statement in ‘Peaceful Nuclear Development Must Continue,’ *IAEA Bulletin* 23/3 (Dec. 1981), 4–5.

Israeli Attack against Syria's Nuclear Program, 2007

Israel's September 2007 strike on a nuclear facility in Syria was undertaken under a shroud of secrecy. The attack destroyed a Syrian reactor at Al Kibar that was in the early phases of development, likely with assistance from North Korea.⁴⁵ Unlike the attention and censure surrounding the 1981 Osirak strike, the international reaction was comparatively silent and weeks passed before Israeli officials acknowledged that it occurred.⁴⁶ A US intelligence briefing in April 2008 confirmed suspicions that the facility had been a nuclear reactor camouflaged in order to minimize attention, but nonetheless had been 'irreparably damaged' by the September 2007 Israeli raid.⁴⁷

The Israeli strike destroyed a facility similar to the North Korean reactor at Yongbyon, which is well suited to plutonium production. Operating at full power, the Syrian reactor could have produced about one weapon's worth of plutonium annually.⁴⁸ Without a reprocessing facility, which has not been located, Syria would have been unable to extract plutonium from spent nuclear fuel, however. Moreover, while the reactor was nearing operational capacity at the time of the attack, full-scale operations would have been impossible in the absence of fuel to operate the reactor; such fuel was missing and would have 'required weeks or months of testing once inside the reactor.'⁴⁹ By destroying the physical plant, however, Israel negated about six years of progress toward nuclear development, the average time states have taken to build a gas-cooled graphite-moderated reactor.⁵⁰

In addition to the attack having the direct effect in terms of removing past progress, there is also evidence supporting two of the indirect theoretical mechanisms. The Israeli raid complicated Syria's efforts by triggering international investigations. Prior to the Al Kibar attack, Syria's program was largely unidentified and thus uninspected. After the strikes, the IAEA solicited information on Syria's program from NPT member states. Several months later, the United States responded

⁴⁵Bill Gertz and Sara Carter, 'US: Syria Hid N. Korea-Aided Nukes Plant,' *Washington Times*, 24 Apr. 2008.

⁴⁶Leonard Spector and Avner Cohen, 'Israel's Airstrike on Syria's Reactor: Implications for the Nonproliferation Regime,' *Arms Control Today*, 38/6 (2008), 15–21.

⁴⁷United States Director of National Intelligence, 'Background Briefing with Senior US Officials on Syria's Covert Nuclear Reactor and North Korea's Involvement,' 24 Apr. 2008, <www.dni.gov/interviews/20080424_interview.pdf> .

⁴⁸David Albright and Paul Brannan, 'The Al Kibar Reactor: Extraordinary Camouflage, Troubling Implications,' Inst. for Science and International Security, 2008.

⁴⁹Peter Crail, 'US Shares Information on NK-Syrian Nuclear Ties,' *Arms Control Today* (May 2008).

⁵⁰Zentner *et al.*, *Nuclear Proliferation Technology Trends Analysis*.

with a detailed display of satellite images and other previously classified evidence documenting the development of Syria's nuclear reactor over a period of years.⁵¹

The IAEA took several other steps. It demanded a visit to inspect Syria's suspected nuclear site. According to Mohamed ElBaradei, Syria had 'an obligation to report the planning and construction of any nuclear facility to the agency ... we are treating this information with the seriousness it deserves.'⁵² In May 2008, the IAEA stated its commitment to its safeguards responsibilities and informed Syria of its intentions to send inspectors to review information and inspect the site at Al Kibar. Syria responded with a letter that same month agreeing to the visit. According to the IAEA, Syria 'provided unrestricted access to all of the buildings on the site' during the June 2008 visit.⁵³ On-site inspections and imagery allowed the IAEA to conclude that the facility was 'similar to what may be found in connection with a reactor site.'⁵⁴ Additional inspections produced evidence of uranium particles from a second site, leading to questions about why 'material that was not previously declared to the IAEA was detected at two facilities in Syria, one of which was being constructed clandestinely.'⁵⁵ The results were sufficiently suspicious to land Syria on the IAEA's official meeting agenda and to keep the pressure on Syria after the attacks. As one IAEA diplomat anonymously indicated, 'the agency clearly thinks it has something significant enough to report to put Syria on the [nuclear safeguards] agenda right after North Korea and Iran.'⁵⁶ Prior to the inspection and investigation, information on Syria's nuclear program had been 'inconclusive' and Syria had remained off the official IAEA meeting agenda.⁵⁷ Syria has not been forthcoming in answering questions uncovered during inspections, but the additional intelligence

⁵¹Greg Miller and Paul Richter, 'US Offers Evidence of North Korea-Syria Nuclear Plant,' *New York Times*, 25 Apr. 2008; Yossi Melman, 'IAEA Asks for Information on any Syrian Plans,' *Haaretz*, 15 Oct. 2007.

⁵²Borzou Daragahi, 'IAEA to Send Inspectors to Syria's Alleged Nuclear Site,' *Los Angeles Times*, 3 June 2008.

⁵³International Atomic Energy Agency, *Implementation of the NPT Safeguards Agreement in the Syrian Arab Republic* (Vienna, Austria: IAEA Board of Governors 2008).

⁵⁴Ibid.

⁵⁵Peter Crail, 'IAEA Finds Uranium at Second Syrian Site,' *Arms Control Today*, Jul./Aug. 2009.

⁵⁶Damien McElroy, 'Uranium Found in Syria by UN Nuclear Inspectors,' *Telegraph*, 10 Nov. 2008.

⁵⁷Joby Warrick, 'Syrian Facility Looked like Reactor, UN Says,' *Washington Post*, 20 Nov. 2008; Reuters, 'Report: IAEA Finds Traces of Uranium at Suspected Syrian Nuclear Site,' 10 Nov. 2008.

from member states, the first independent investigation of the reactor in June 2008, and placement on the IAEA's meeting agenda all indicate that the IAEA is far more involved in scrutinizing Syria's program following the raid.

It is difficult to obtain comprehensive information on North Korea's post-attack intentions, but the raid appears to have made it less tenable for Pyongyang to assist Syria's nuclear program. Since Syria's indigenous capabilities are insufficient to build sophisticated nuclear facilities at this point in time, the withdrawal of North Korean assistance has frustrated the progress of its nuclear program.

Wartime Case Studies

Allied Attacks against Germany's Nuclear Program, 1942–1945

Between 1942 and 1944, the allies waged four separate attacks on the Norsk-Hydro heavy water facility in German-occupied Norway. In October 1942, a 34-person British sabotage team in two Horsa gliders crashed as it attempted to destroy stockpiles of heavy water at the facility.⁵⁸ This raid was a dismal operational failure and actually prompted Germany to defend the facility more heavily, mining all access points. In February 1943, skiers from the Royal Norwegian Army dressed in British uniforms parachuted into Rjukan, the site of the heavy water facility, and destroyed the heavy water.⁵⁹ This act of sabotage destroyed 18 electrolysis cells in the heavy water facility's chambers, flushed 500 kg of heavy water, and took the facility out of commission for about two months.

In November 1943 the allies followed-up by attacking the facility by air. Two hundred American B-17s dropped over seven hundred 1000-pound bombs on the plant.⁶⁰ Many of these bombs missed or inflicted only light damage on their targets, but 12 bombs successfully damaged the facility. These airstrikes dispensed of more heavy water and shut down the facility for months.⁶¹ Reports suggested that this attack was

⁵⁸John S. Craig, *Peculiar Liaisons in War, Espionage, and Terrorism in the 20th Century* (New York: Algora Pub 2005); Thomas Powers, *Heisenberg's War: The Secret History of the German Bomb* (New York: Penguin Books 1993).

⁵⁹Powers, *Heisenberg's War*; Knut Haukelid, *Skis against the Atom* (London: W. Kimber 1954); Jeremy Bernstein, *Hitler's Uranium Club* (Woodbury, NY: American Inst. of Physics 1996).

⁶⁰Powers, *Heisenberg's War*.

⁶¹Per F. Dahl, *Heavy Water and the Wartime Race for Nuclear Energy* (London: Taylor and Francis 1999).

one ‘of the most important and successful undertakings the Allied saboteurs have carried out as yet during the war.’⁶²

Germany was able to rebuild the facility quicker than the allies had anticipated but facing the prospect of additional attacks, the Germans decided to transfer materials involved in the production of heavy water to the continent in 1944.⁶³ A Norwegian saboteur who had been tipped off by British intelligence intercepted the ferry *Hydro* that was transporting heavy water and sank it into the bottom of Lake Tinnsjø in Norway.⁶⁴ This attack sank another 607 kg of heavy water and reinforced the perils of maintaining a nuclear facility in occupied territory.⁶⁵

Iraqi Attacks against Iran’s Nuclear Program, 1984–1988

The Iran–Iraq War provided the backdrop for a series of strikes against nuclear facilities. In 1980, Iranian F-4 Phantoms attacked Iraq’s Osirak plant en route home from a bombing raid. This strike was an operational failure and it caused little damage to Osirak, necessitating the Israeli raid one year later.⁶⁶

Later in the war, Iraq raided Iran’s Bushehr reactors in a series of attacks. The first strike took place in March 1984, and was followed by subsequent attacks in each year of the war until a final raid in 1988, a total of seven strikes over five years.⁶⁷ Iraq’s initial airstrikes did minimal damage to the reactors.⁶⁸ It was not until November 1987 that Iraqi airstrikes actually caused significant damage.⁶⁹ According to a German witness involved in the Iranian nuclear project, the 1987 raids were ‘very accurate’ and ‘destroyed the entire core area of both units’

⁶²Lesley Groves, *Now it Can be Told: The Story of the Manhattan Project*, New Ed. (Da Capo P 1983), 188.

⁶³Samuel Goudsmit, *Alsos* (American Inst of Physics 2006); Powers, *Heisenberg’s War*.

⁶⁴Groves, *Now it Can be Told*; Bernstein, *Hitler’s Uranium Club*.

⁶⁵The problem is that Germany had chosen heavy water as a moderator for its reactors in 1939, but the Norsk-Hydro plant, in occupied Norway, was the only source of heavy water for the German program. Dahl, *Heavy Water*.

⁶⁶‘The Ghosts that Hit Osirak,’ *The Economist*, 18 Oct. 1980, p.54.

⁶⁷Mark Hibbs, ‘Bushehr Construction Now Remote after Three Iraqi Air Strikes,’ *Nucleonics Week*, 28/48 (1987); Mark Hibbs, ‘Iraqi Attack on Bushehr Kills West German Nuclear Official,’ *Nucleonics Week*, 28/47 (1987); Andrew Koch and Jeanette Wolf, ‘Iran’s Nuclear Facilities: A Profile,’ Center for Nonproliferation Studies, 1998, <<http://cns.miis.edu/pubs/reports/pdfs/iranrpt.pdf>> .

⁶⁸Padraic Sweeney, ‘Iran Asks IAEA to Inspect Damage from Alleged Iraqi Attack on Bushehr,’ *Nucleonics Week*, 26/8 (1985); Associated Press, ‘Agency Iranian Complaint of Iraqi Attack on Nuclear Site,’ 30 May 1984.

⁶⁹Hibbs, ‘Bushehr Construction.’

and subsequently exposed them to a hostile climate of salt and extreme temperatures.⁷⁰ IAEA assessments found that the reactor was ‘certainly not completely destroyed’ though considerable damage had been done.⁷¹

Iraqi raids ultimately reversed a substantial amount of progress on the Bushehr projects. The German contractor Kraftwerk Union began constructing the facilities in 1974 and at the time of the first attack in 1984, the two reactors at Bushehr were 90 per cent and 50 per cent complete, respectively.⁷² The Iraqi strikes – especially the 1987 attacks – necessitated nearly a complete reconstruction of the facilities. Yet, Iraq needed to strike repeatedly over a period of four years in order to achieve this result.

US Attacks against Iraq’s Nuclear Program, 1991, 1993

Nuclear facilities were among the high priority targets during the 1990–91 Persian Gulf War.⁷³ In the initial stages of the war, coalition aircraft struck the Tuwaitha Research Facility near Baghdad and F-117s repeatedly bombed this plant throughout the campaign. The United States also struck a suspected uranium feedstock production facility near Mosul and a uranium extraction facility at Al Qaim. These attacks were mixed in terms of their damage to Iraq’s nuclear infrastructure. In 1991, the key chokepoints relevant to Iraq’s weapons program were the facilities related to the EMIS and gas centrifuge enrichment programs. The bombing raids destroyed several of the chokepoint facilities, especially those relevant to Iraq’s EMIS enrichment program. As the Iraq Survey Group (ISG), also referred to as the Duelfer Report, concluded in the aftermath of the 2003 Iraq War: ‘Nearly all of the key nuclear facilities . . . were bombed during Desert Storm . . . Many of the facilities located at Tuwaitha were devastated, and the EMIS enrichment plants at Tarmiya and Ash Sharqat were largely destroyed.’⁷⁴

Other key facilities were not destroyed, however, because the United States was unaware of their existence or their location. The yellowcake

⁷⁰Tony Walker, ‘Tehran Says 10 Die as Iraq Hits Nuclear Site,’ *Financial Times*, 18 Nov. 1987, 3.

⁷¹Mark Hibbs, ‘Bonn will Decline Teheran Bid to Resuscitate Bushehr Project,’ *Nucleonics Week*, 32/18 (1987); *Nuclear News*, ‘German Reactor Expert Killed in Bushehr Attack,’ Jan. 1998, 61.

⁷²Koch and Wolf, ‘Iran’s Nuclear Facilities: A Profile’.

⁷³Thomas A. Keaney and Eliot A. Cohen (eds), *Gulf War Air Power Survey: Summary Report* (Washington, DC: USGPO 1993), 80.

⁷⁴Iraq Survey Group, ‘Final Report’, 2004.

facility at Al-Qa'im, feed material plant at Mozul, and high explosives testing site (Al-Athir) were damaged, but the centrifuge facility at Rashdiya was 'neither found nor targeted in the 1991 war.'⁷⁵ The Gulf War Air Power Survey underscored the challenges associated with locating and targeting Iraqi nuclear facilities during the war. It stated, 'we now know that the Iraqis' program to amass enough enriched uranium to begin producing atomic bombs was more extensive, more redundant, further along, and considerably less vulnerable to air attack than was realized at the outset of Desert Storm.'⁷⁶ As inspections discovered soon after the Gulf War, Iraq had three times more nuclear facilities than military planners believed during the war.⁷⁷ The case of Ash Sharqat is representative of the coalition's targeting challenges. It was thought to be a rocket facility rather than one related to Iraq's nuclear program; the facility was the subject of a series of attacks and then dismissed, 'because intelligence did not suspect Ash Sharqat of nuclear activities.'⁷⁸

In the aftermath of the Gulf War, the United States again struck suspected nuclear facilities. On January 17, 1993, the US Navy used Tomahawk Land Attack Missiles against facilities that had largely escaped unscathed from the Gulf War: Facility 409 (Ma'malal'Rabia') that manufactured calutrons for the Iraqi EMIS program and Facility 416 (Al-Dijla) that produced power supplies for the EMIS project. These attacks were reasonably successful at the operational level. UNSCOM and IAEA teams found that the Navy Tomahawk Land Attack Missiles had successfully hit the buildings and destroyed sensitive machine tools in the 1993 raid and could be considered an operational success.⁷⁹

Discussion and Conclusion

The standard debate on whether military force delays proliferation is typically cast in stark terms. One side of the debate suggests that attacks offer the prospect of unequivocal success in delaying nuclear proliferation; the other counters that the use of force can actually backfire by accelerating the target state's nuclear programs. History tells a more complicated story. In this section we discuss the

⁷⁵Ibid.

⁷⁶Keaney and Cohen (eds), *Gulf War Air Power Survey: Summary Report*, 82.

⁷⁷Ibid., 431.

⁷⁸Ibid., 431, 434.

⁷⁹Federation of American Scientists, 'Zaafaraniyah,' 2000, <www.fas.org/nuke/guide/iraq/facility/zaafaraniyah.htm> .

conclusions that emerge from our analysis and comment on what the historical record says about the likely effect of an attack against Iran's nuclear program.

We theorized that strikes could delay progress through both direct and indirect mechanisms. Peacetime cases produced some support for the general argument that attacks delay states' acquisition of fissile material and for the specific mechanisms, but the size of this effect was generally modest.

The 1981 Osiraq raid offered support for three of the four mechanisms outlined. First, the Israeli attack destroyed a key chokepoint for Iraq's nuclear program (although the Israelis left the reprocessing facility intact), evidence supporting the direct mechanism. Second, the attack had an indirect effect by prompting Iraq to switch from reprocessing technology to centrifuge technology, which it hoped would be more easily concealed. Centrifuge enrichment proved technically challenging and ineffective for the Iraqis who knew little about the technology. Third, compounding matters further, France withdrew its support from the program after the strike. In the absence of indigenous know-how or materials, Iraq found uranium enrichment to be laborious and time-consuming since its scientists did not understand rotor dynamics and spent years either burning up the centrifuges or trying to make do with poor quality centrifuges.

Israel's raid on Syria in September 2007 likewise delayed Damascus' ability to build nuclear weapons both through the direct mechanism of removing past progress and through two of the indirect mechanisms. The Israeli raid destroyed a graphite-moderated reactor modeled after the North Korean facility at Yongbyon. This facility is a chokepoint because it could have been used to produce plutonium for nuclear weapons. That said, Syria does not appear to have been close to acquiring the bomb at the time of the raid. Future progress toward the bomb, however, has been made more difficult because the attack prompted IAEA attention and inspections to a program that had previously been unidentified and uninspected. Moreover, there is no evidence that Pyongyang has agreed to rebuild the reactor at Al Kibar.

Paradoxically, these two raids produced delays in part because the Iraqi and Syrian nuclear programs were in their relative infancy. In neither instance did the target state possess the means to produce fissile material for nuclear bombs at the time of the attack. Indeed, the Israelis struck before the Osirak and Al Kibar reactors had gone critical. But Baghdad and Damascus had critical chokepoints that were concentrated in a single area, making it easier for the Israelis to delay progress with one attack. Thus, it appears that attacking countries can achieve the most success before a program becomes 'a train without brakes,' to borrow a phrase from Iranian President Mahmoud Ahmadinejad. Yet,

the timeframe in which strikes might be most effective is also when they would be considered the least legitimate. Anything other than preemptive uses of force (i.e., striking to prevent an imminent attack) are considered illegal under international law and the international community might be less likely to endorse attacks when it is not obvious that the target was on the verge of acquiring nuclear weapons.⁸⁰

The wartime cases underscore the reasons why using military force to delay proliferation can encounter challenges. The dual-use nature of nuclear complexes and the relative inconspicuousness of centrifuge facilities make it possible for states to maintain a covert military nuclear program.⁸¹ As a result, states seeking to minimize proliferation might lack timely or clear indicators on the status or whereabouts of a proliferating state's nuclear facilities. The 1991 Persian Gulf War case illustrates this problem. Many key chokepoint facilities, particularly those relating to Iraq's gas centrifuge program, were not destroyed during US airstrikes because their locations were unknown. Importantly, this problem is not limited to the wartime cases. The 1981 Osirak strike is also suggestive of an intelligence gap because the reprocessing facility next to the reactor was not targeted. Either the Israelis thought the reprocessing facility was located beneath the reactor, or they were unaware that this chokepoint existed at all. Regardless, while the Israelis successfully destroyed the Osirak reactor, they altogether neglected the adjacent plutonium reprocessing facility.

What does the historical record suggest about the consequences of a potential American or Israeli strike against Iran's nuclear program? Although military force delayed proliferation in some previous cases, policymakers must remember that past may not be prologue. In particular, the three indirect mechanisms we identified are unlikely to 'work' in the Iranian case. Tehran received helpful nuclear assistance in the past, but it does not depend on external support today to sustain its military program. It currently receives civilian nuclear assistance from Russia but it is unclear that the withdrawal of this aid would have a major impact on its ability to produce fissile material for nuclear weapons. It is also unlikely that an attack would lead to a change in Iran's fissile material production strategy. Tehran is already relying primarily on centrifuge enrichment technology which is easier to conceal than facilities necessary for plutonium production (e.g., reactors and reprocessing centers). Centrifuges are likewise easier to

⁸⁰Michael Walzer, *Just and Unjust Wars: A Moral Argument with Historical Illustrations* (New York: Basic Books 2000).

⁸¹Michael S. Goodman and Wyn Q. Bowen, 'Behind Iran's Nuclear Weapons "Halt,"' *Bulletin of the Atomic Scientists*, 19 Feb. 2008.

hide than other enrichment technologies, such as gaseous diffusion plants. The third indirect mechanism could have a modest effect in delaying Iran's nuclear program. Inspectors from the IAEA have been on the ground in Iran for decades, but they have had only limited success in detecting transgressions in a timely fashion. If an attack caused Iran to enter the Additional Protocol (AP), which provides the IAEA the authority to visit any facility in a country, this could frustrate weaponization efforts. Potential attackers should not count on this outcome given that Syria granted the IAEA some additional access after being attacked but has still not committed to the AP.

This suggests that the direct, physical destruction of Iranian nuclear facilities would be the main route by which an attack could delay progress.⁸² The most critical facilities for Iran's nuclear program are (1) the uranium enrichment plants at Natanz and Qom, (2) the Arak heavy water production center, and (3) the Isfahan uranium conversion facility. Of these facilities, the most sensitive are the enrichment plants because they could provide a critical source of fissile material for nuclear weapons (i.e., HEU). The plants at Arak and Isfahan are significant but they are alone insufficient to provide Iran with bomb-grade materials. How much time could Israel or the United States buy by destroying the two uranium enrichment facilities? The history of nuclear programs reveals that it takes an average of 14 years to go from the initiation of a gas centrifuge program to the completion of the first full-scale facility.⁸³ Iran is already well behind the average time since it initiated its program in 1987 and it did not demonstrate operational capacity until 2004. It would not take 17 years to demonstrate operational capacity as it did before, since Iran has acquired a significant amount of indigenous knowledge that cannot realistically be taken away in an attack. But in all likelihood, a raid would still delay the program. Considering that it took India five years to construct a second centrifuge enrichment facility once it completed a pilot plant, we could assume that destroying Natanz and other related enrichment facilities could delay Iran's ability to produce fissile material by about the same amount of time. This is a relatively modest gain in light of the well-known risks associated with striking Iran's nuclear facilities.⁸⁴ Yet, policymakers who adopt short time horizons may calculate that a delay of up to five years would justify the dangers of preventive military strikes.

⁸²For more on when and why states target suspected proliferators' nuclear facilities, see Fuhrmann and Kreps, 'Targeting Nuclear Programs in War and Peace.'

⁸³Zentner *et al.*, *Nuclear Proliferation Technology Trends Analysis*.

⁸⁴See, for example, Caitlin Talmadge, 'Closing Time: Assessing the Iranian Threat to the Strait of Hormuz,' *International Security*, 33/1 (Summer 2008), 82–117.

Either way, it is critical to recognize that this assessment rests on two fairly ambitious assumptions. The first is that all of Iran's sensitive nuclear facilities are known to Israel and/or the United States. History provides good reason to doubt that this is true. For the last several years the IAEA has been 'unable effectively to monitor the R&D activities being carried out by Iran,' except at sites with safeguarded materials, meaning that the agency cannot address concerns about the existence of covert facilities.⁸⁵ Revelations of the second enrichment plant at Qom – also known as the Fordow Fuel Enrichment Plant – did not emerge until September 2009. It is unclear when Western intelligence agencies discovered this facility, but construction likely began in 2002.⁸⁶ The facility is located in an underground tunnel complex at a site controlled by the Islamic Revolutionary Guards Corps. Given that Iran managed to keep this facility secret for seven years, it is not implausible that there are other covert facilities that remain unknown even to intelligence services. Our analysis of the wartime cases further underscores this point. The United States was unaware of many critical nuclear facilities in Iraq prior to the 1990–91 Persian Gulf War, for example.

The second assumption deals with the operational feasibility of an attack, a question that has received excellent scholarly treatment elsewhere.⁸⁷ Although the affordability and ubiquity of precision weapons available means that targeting states are likely to hit known targets,⁸⁸ a factor that offsets improvements in military technology is that potential targets have learned from previous attacks and taken appropriate defensive measures. Just as Germany learned that it needed to better defend the Norsk-Hydro facility following the first Allied attack, Iran has learned from the Osirak and Al Kibar strikes that it should not concentrate its nuclear facilities in one location. Doing so

⁸⁵International Atomic Energy Agency, *Implementation of the NPT Safeguards Agreement in the Islamic Republic of Iran*, GOV/2006/8 (Vienna, Austria: IAEA Board of Governors 27 Feb. 2006). See also Michael Eisenstadt, 'Iran: The Complex Calculus of Preventive Military Action,' Washington Institute for Near East Policy, Policy Watch #1152, 25 Sept. 2006.

⁸⁶International Atomic Energy Agency, 'Implementation of the NPT Safeguards Agreement and Relevant Provisions of Security Council Resolutions 1737 (2006), 1747 (2007), 1803 (2008) and 1805 (2008) in the Islamic Republic of Iran,' Report by the Director General, International Atomic Energy Agency, 16 Nov. 2009. See also, Nuclear Threat Initiative, 'Iran: Nuclear Overview,' March 2010, <www.nti.org/e_research/profiles/iran/Nuclear/index.html> .

⁸⁷Raas and Long, 'Osirak Redux?'

⁸⁸See John E. Peters *et al.*, 'Allied Power Projection Capabilities,' in *Persian Gulf Security: Improving Allied Military Contributions* (Arlington, VA: Rand Corp 2001), 75; Ryan Hansen, 'JDAM Continues to be Warfighter's Weapon of Choice,' *Air Force Link*, 17 Mar. 2006, <www.af.mil/news/story.asp?storyID=123017613> .

makes it vulnerable to the possibility of a one-strike success, whereas disseminating the facilities makes each one less vulnerable. From a probabilistic standpoint, the more targets that attackers have to hit, the lower the likelihood of net success.

In sum, given that Iran already possesses the requisite knowledge to enrich uranium – and this knowledge cannot be taken away – the best possible outcome of military force would be delaying Tehran’s ability to build nuclear weapons by around five years. Based on our survey of the historical record, it is far from obvious that military force would yield even this modest return. Policymakers should also be aware that multiple attacks against Iran might be necessary. We now know that Iraq terminated its nuclear weapons program in the 1990s, but this happened only after three different countries (Iran, Israel, and the United States) had attacked its facilities.

With this cautious conclusion in mind, we propose a few next steps for research. One step is to undertake a systematic study of potential costs – diplomatic, economic, or military – of using force. This analysis bracketed the question of costs, since if military force does not delay the target state’s nuclear program, then the strategy has nothing to recommend it, even if the costs are negligible. However, the effectiveness question is just one side of the ledger and the overall utility of force is best assessed by taking into account the possible costs to the attacking state. For example, if the target state has the ability to launch counter strikes, the costs from attacking nuclear facilities might outweigh the benefits and justifiably deter the attacking state from using force. Indeed, the fear of high costs in part explains why the United States refrained from attacking China in the 1960s and North Korea in the 1990s⁸⁹ and may be one reason for caution even if removing the Iranian facilities through force is operationally feasible.

Having identified the reasons why striking nuclear programs can hinder the target state’s proliferation goals, we also suggest analyzing whether tools other than force can provoke the same mechanisms we discuss here. We also urge future research into why countries choose force to oppose proliferation, since we have confined our focus to the consequences, not causes of attacks. If raids delay proliferation and most countries highlight the spread of nuclear weapons as the greatest threat to their national security, why have strikes occurred relatively infrequently? At what point – whether relative to the target state’s nuclear program or to the instruments that have been tried – do states resort to force? What explains the ‘near misses,’ the cases where states

⁸⁹William Burr and Jeffrey Richelson, ‘Whether to Strangle the Baby in the Cradle,’ *International Security* 25/3 (Winter 2000/1), 54–99; Joel Wit *et al.*, *Going Critical: The First North Korean Nuclear Crisis* (Washington DC: Brookings Institution Press 2005).

considered force but decided against it? How do the perceived high costs of attacking, normative constraints, or other factors affect the calculus on using force? Based on the gravity of proliferation and military force, we conclude that these are all important avenues for future study.

Acknowledgments

We thank Avner Cohen, Alexander Downes, Bryan Early, Michael Horowitz, Matthew Kroenig, Austin Long, Sean Lynn-Jones, Martin Malin, Alexander Montgomery-Amo, Thomas Nichols, Bennett Ramberg, Etel Solingen, Leonard Spector, and anonymous reviewers for helpful comments and criticisms. Participants at the Center for Security Studies' workshop 'Uncovering the Sources of Nuclear Proliferation,' in Zurich, Switzerland and a research seminar at the James Martin Center for Nonproliferation Studies in Washington, DC also provided valuable feedback. Any remaining errors are our own.

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