Should Israel Close Dimona? The Radiological Consequences of a Military Strike on Israel’s Plutonium-Production Reactor

Bennett Ramberg

Much ink has been spilled about apprehensions in Israel and the West that Iran could develop nuclear weapons, prompting calls in American, Israeli, and now even Arab circles for the application of military force to stop the mullahs. Yet, there is another, more immediate nuclear-related danger to the Jewish state that has received far less attention: the possibility that Israel's adversaries could use more easily acquired conventional weapons to force a deadly release of radioactivity from Israel's plutonium-production reactor at Dimona.

In Middle Eastern tit-for-tat, the concern generated currency when the London Sunday Times reported in late 2007 that Israel went on "red alert" 30 times as anxiety grew that Damascus would retaliate against Dimona for Israel's September 6 strike on a suspected Syrian nuclear site. On Israeli state television, a commander of a Patriot air defense missile battery stated, "Every civilian aircraft en route from Cairo to Amman, or from Jeddah to Cairo and vice versa, which deviates even slightly from its route, sets off an alarm and risks a missile being fired."[1]

Israel's fear reflects the Middle East's unique history: since World War II, the only military strikes on nuclear facilities have taken place in the region.[2] In 1980, Iranian aircraft attempted to destroy Iraq's Osirak reactor but missed the mark, hitting adjacent structures. In June 1981, Israel finished the job in a dramatic cross-regional raid. During the Iran-Iraq war in the 1980s, Iraqi aircraft mounted multiple attacks on Iran's two partially constructed power reactors at Bushehr.[3] In 1991, during the Persian Gulf War, the United States bombed a small Iraqi research reactor at Tuwaitha,[4] and Saddam Hussein launched several Scud-B rockets toward Dimona.[5] In 2003, a U.S.-led coalition invaded Iraq to halt its presumed nuclear, chemical, and biological weapons programs.

Yet, in no case did these raids on nuclear facilities cause radiological consequences. Either the plants were still under construction (Osirak and Bushehr), had radioactive elements removed prior to the strike (Tuwaitha), or the attacker simply missed the mark. The outcome of a successful strike on the decades-old Dimona reactor could be different. Today, multiple factors may drive Israel's adversaries to hit the plant: its perceived centrality to Israel's nuclear weapons program, revenge for Israeli strikes on neighboring states, Dimona's symbolic significance as one of the Jewish state's most valued assets, and, most disturbingly, an attack to intentionally release the radioactive contents of the plant as a weapon of war or terrorism.

This raises a question: given the likely and serious consequences of a successful attack for Israel's public health, economy, and society, should Israel close Dimona? Does the centrality of the reactor for Israel's nuclear arsenal argue otherwise? On balance, shutting down or mothballing the Dimona reactor would reap both important security and political benefits.

Radiological Consequences of an Attack on the Dimona Reactor

Situated in a relatively remote desert at the Negev Nuclear Research Center, the Dimona reactor,
also referred to as IRR-2, lies approximately 25 kilometers west of Jordan, 75 kilometers east of Egypt, and 85 kilometers due south of Jerusalem. Dimona is a heavy-water-moderated, natural-uranium-fueled reactor. Although the International Atomic Energy Agency (IAEA) estimates its power at 26 megawatts thermal (MWt),[6] most independent analysts believe that in the mid-1970s Israel upgraded the installation to generate between 70 and 150 MWt.[7] That output makes it not only the region's largest reactor for the moment—once Iran's Bushehr atomic power plant goes online, it will have more than 20 times the power[8]—but the sole evident producer of plutonium and tritium for nuclear weapons.[9]

Although Israel neither confirms nor denies its atomic arsenal, experts generally accept that it has been a nuclear-armed state for several decades. Its first prime minister, David Ben-Gurion, inaugurated the enterprise to compensate for the country's strategic vulnerability, a fledgling army, and the West's unwillingness to enter into a formal alliance to defend Israel's survival.[10] Estimates of the nuclear arsenal range from 75 to 200 weapons, comprising bombs, missile warheads, and possibly tactical weapons.[11] Since it went into operation in the mid-1960s with initial French assistance, the reactor has produced plutonium and tritium for these nuclear weapons, which Israel has fabricated in a nearby underground chemical separation plant and a nuclear component fabrication facility.[12]

To model the consequences of a successful missile attack on the installation, the U.S. Department of Defense's Hazard Prediction and Assessment Capability code (HPAC) was utilized. Described as a counterproliferation and counterforce modeling tool, HPAC estimates the effects of hazardous material discharges and of the use of weapons of mass destruction, including casualties. HPAC's Nuclear Facility model calculates the properties of radioactive material released during incidents at nuclear reactors and related facilities. For Dimona, HPAC provides an input data file that lists the reactor core inventory of radioactive materials (fuel and fission products) for each MWt of operating power.

Given the uncertainties in the precise operating power of Dimona, separate HPAC calculations were performed assuming the reactor generated 26, 70, or 150 MWt, although the lower power level of 26 MWt would have produced only plutonium for a few dozen nuclear warheads over Dimona's lifetime, a figure well below Israel's presumed weapons inventory. To estimate the radionuclide release from a military strike, the first day of the April 26, 1986, Chernobyl Unit 4 accident[13] served as a model, as characteristic of a catastrophic incident involving an explosion, fire, and the bypass of containment (Chernobyl Unit 4 did not have a containment structure). The consequences were scaled to the much smaller release Dimona could emit. It was hypothesized that a military strike could breach the reactor's containment dome, which is visible in ground photographs and satellite imagery; disperse the heavy water surrounding the reactor core; and create explosions and fire involving the nuclear fuel elements, ejecting radioactive material into a puff carried away from Dimona by prevailing winds.

In a military strike, like a reactor accident, two key radionuclides, iodine-131 and cesium-137, would constitute important components of the public impact of elevated cancer risk. Although a short-lived element with an eight-day half-life, iodine-131 poses unique, early health concerns because it concentrates in the thyroid. Cesium-137, with a 30-year half-life, poses a longer-term "ground shine" risk to populations resident or working in contaminated zones. The risk increases with the concentration of the element.

Of the many release scenarios HPAC could generate, three are displayed to communicate a reasonable range of outcomes. The chosen maps also illustrate the broad impact of different reactor power levels and seasonal prevailing winds. In general, estimates show that large populations could receive acute low doses within the first 24 hours, at or below the average total annual dose from natural background radiation and medical procedures. Nevertheless, these low doses slightly increase the cancer incidence. Closer to the Dimona reactor, the release could generate substantially higher doses, risking the health of the nearby communities and the thousands of workers at the site, in addition to the emergency response teams who, at Chernobyl, bore the brunt of the most acute radiological impacts.

Figure 1 (see print edition) characterizes a November attack on the reactor operating at 150 MWt
carrying the radioactive plume in the northwesterly direction over the city of Dimona (a community of 30,000 inhabitants) and then toward Beersheba before scattering toward Israel's heavily populated coastal plain housing approximately four million inhabitants. Statistically, this scenario could generate several hundred cancers above the expected natural rate for the exposed population. In a scenario exhibiting lesser impacts, were the reactor operated at only 26 MWt, an August attack would produce a narrower plume concentrated within Jordan's thinly populated south. Finally, in a February attack with the reactor generating 70 MWt, contaminants would settle in the West Bank. This scenario predicts the maximum number of excess cancers, exceeding 600 at the 70 MWt level and 1,000 at 150 MWt level, because of the more concentrated populations and collective doses that population would receive.

Given the secrecy shrouding Dimona, the maps and table provide rough probabilities that change with the input of different variables. Not factored into the calculations are such complicating but unascertainable factors as the age of the fuel (fresh fuel will have a lower buildup of radioactive elements, and as a matter of course, Dimona may not accumulate two-year-old fuel similar to that that blew apart at Chernobyl);[14] reductions in the quantity of iodine-131 in the reactor core were the plant shut down for weeks prior to an attack; operations at very low power to produce tritium; or the possibility that an attack would so fracture and scatter the reactor core that the absence of concentrated fires would diminish the release. Nor, due to the absence of data, do the calculations include the potentially significant contributions that could come from on-site spent fuel and high-level waste from reprocessing or separated plutonium. The modeling does suggest that were the Jewish state's adversaries bent on affecting the greatest number of Israelis, they would take advantage of late fall winds. To wait for winter would risk contaminating Palestinian communities in the West Bank.

In sum, because of Dimona's relatively small size and remote location, only in the worst cases are populations in the hundreds or more found to be at risk, distributed over a large fraction of the Israeli and Palestinian population. Israeli authorities have recognized the jeopardy to communities near Dimona in response to reactor accident concerns, particularly the vulnerability of the thyroid to iodine-131. To address the problem, they have distributed potassium iodide tablets to the nearby towns of Aruar, Dimona, and Yerham to block the absorption of iodine-131.

**Risk and Response**

These findings suggest that a successful strike on an operating Dimona reactor that breached containment and generated an explosion and fire involving the core would present effects similar to a substantial radiological weapon or dirty bomb. Although consequences would represent only a small fraction of the Chernobyl release, for Israel, a country the size of New Jersey with a population of some six million, the relative economic dislocation, population relocation, and immediate and lingering psychological trauma could be significant.[15]

Israel has not been unmindful of these challenges. From the outset of its nuclear program, it acted to reduce the dangers. It placed the reactor in the Negev. It placed critical facilities for manipulating nuclear material in deeply buried cells. It heavily defended the installations with anti-aircraft and missile defenses.[16] For some years, however, a hubris crept into the evaluation of the plant's vulnerability. Following decisive military defeats of its neighbors in past wars, some Israeli advisers disdained their ability to strike the plant. For example, in May 1984, after I published a book about the consequences of military attacks on nuclear power plants, an Israeli intelligence officer came to the United States to inquire about the book's conclusions regarding reactor vulnerability as Israel planned a nuclear power plant. The officer belittled the peril, arguing that no Arab air force had ever overcome Israeli air defenses and none ever would.

At that time, history provided odd support. Although Soviet reconnaissance aircraft flew over the reactor in May 1967 without incident,[17] during the June 1967 war, Israel shot down one of its own Ouragan jet fighters when it strayed over the facility.[18] In 1973, Dimona's defenders downed a wayward Libyan civilian airliner heading for the reactor, killing 108 people.[19] The 1991 Gulf War upset whatever solace Israel could take from the past. Iraqi Scud missiles rained on Tel Aviv, and one came close to striking Dimona. Hezbollah's bombardment of northern Israel in 2006 further demonstrated the country's vulnerability to crude rocket attack. Although Israel's Arrow ballistic
missile defenses, which surround Dimona today, may be superior to the Patriot system that failed in 1991, Syria's more advanced Scuds and Iran's Shahab-3 rocket present a more capable challenge than Saddam's projectiles.

Furthermore, interest in "taking out" the installation, which reached an early pinnacle during Gamal Abdel Nasser's Egypt in the 1960s, has now renewed. Following Israel's September 2007 strike, Syrian legislator Mohammad Habash said, "If Syria feels threatened by Israel, it will be hard to stop our missile operators from responding to the Israeli aggression by attacking the Dimona nuclear reactor." Iranian General Mohammad Baqer Zolqadr remarked in 2004 that "[i]f Israel fires one missile at Bushehr atomic power plant, it should permanently forget about Dimona nuclear center, where it produces and keeps its nuclear weapons, and Israel would be responsible for the horrifying consequence of this move." The March 2008 announcement by Israeli defense officials that Hezbollah had acquired rockets with the range to hit the plant raised further concerns that Dimona continues to be in the crosshairs of Israel's enemies.

The Costs and Benefits of Shutting or Mothballing Dimona

Given mounting regional tensions and the capacity of Israel's adversaries to strike Dimona, does prudence dictate closure of the plant? Certainly Israel would sustain costs. Its capacity to produce weapons-useable plutonium and tritium would end. Absent an enrichment program or nuclear-weapon design improvements, closure would freeze the total size of the Israeli nuclear arsenal based on its current inventory of plutonium. Israel's supply of tritium, which is a radioactive isotope of hydrogen with a half-life of 12.5 years, would decrease, but that element could be produced in an accelerator.

Israel could manage these challenges and take advantage of substantial benefits by closure. Dimona has produced all the plutonium Israel's armed forces could possibly utilize. The numbers of nuclear weapons in the arsenal, even if the weapons were not tritium boosted, suffice to destroy any collection of adversaries multiple times over and are therefore sufficient for deterrence. Closure would eliminate a radiological hostage and a reactor, which is among the world's oldest and which has already suffered minor mishaps, that Israel should shut because it is nearing the end of its life expectancy of safe operation.

In addition, Israel could derive political and strategic benefits. It could demand compensatory security guarantees from the United States and NATO. More broadly, in the public relations war, it could claim that closure marks a step toward a regional fissile material cutoff treaty in the effort to demonstrate its commitment to reducing regional nuclear tensions.

Alternatively, the Jewish state could mothball the plant, removing all radioactive elements from the site while keeping the facility in cold standby in the event circumstances required a restart.

Israel may conclude that avoiding the squeeze a shutdown would impose on weapons production outweighs the environmental threat posed by a successful attack. It may bank on the effectiveness of its defenses, the ineffectiveness or poor accuracy of enemy munitions, or the reluctance of adversaries to risk contamination of Arab populations in Jordan and the West Bank. It may also take solace from the failure of adversaries to effectively attack the plant in past conflicts. Were Israel to anticipate a strike, it could shut the plant and, as Iraq did in 1991, remove the "hot" material to a safe location. A shutdown alone could reduce the inventory of iodine-131.

Public banter about striking Dimona and Iran's nuclear plants raises a host of other troubling questions. Looking to the future, should atomic installations expand through the Middle East-Iran's Bushehr power reactor will be the first to fire up, possibly later this year-Israel's neighbors will see in the mirror their own reactors' vulnerability to military attack. Like Israel, they may take comfort in reactor defenses. Additionally, similar to India and Pakistan, they could replicate the 1990 treaty that the South Asian adversaries negotiated forbidding attacks on nuclear sites.

Nonetheless, such an accord, defenses, or mutual vulnerability acting as a deterrent to attack would not provide a guarantee that plants will be immune from military or even terrorist strikes in such an unstable part of the world. This ought to raise the question whether the planned growth of plants,
many orders of magnitude larger than Dimona, should go forward. Until the region resolves its political differences, nuclear energy planners ought to take a second look. In the meantime, Israel would do well to reflect whether, given its own reactor vulnerability, keeping Dimona operating is worth the risk. I believe it does not.

Corrected online September 3, 2008. See explanation.

The Radiological Dangers of an Israeli Attack on Iran's Nuclear Facilities

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In a region where an "eye for an eye" has defined adversarial relations for millennia, it merits examining what response Israel could exact for an attack on Dimona. Although Syria has the capacity to strike the plant, which it has threatened to do, Syria's proximity to the Jewish state makes it an easy target for reprisal. Given Israel's September 2007 attack on Damascus's suspected nuclear site, Israel would have to apply any revenge on Syria to other, non-nuclear targets.

Iran, Israel's most capable adversary, is another matter. Clearly, a successful blow on Dimona by Iran or Hezbollah surrogates would generate an Israeli public outcry for revenge even were Tehran's attack in response to Jerusalem's destruction of Iran's enrichment facilities.

Although Iran operates several small nuclear research reactors, two larger plants would dominate the attention of Israel's military planners, the 40-megawatt thermal heavy-water reactor at Arak and the 1,000-megawatt electric Russian-supplied nuclear power plant at Bushehr. The Arak installation shares many of Dimona's features as a dedicated plutonium generator but is years away from completion. Obviously, were Israel to strike before the plant commenced operations, as it did in the 1981 bombing of Iraq's Osirak reactor, no radiological consequences would ensue.

Bushehr is quite another matter. The plant may go critical in a matter of months. It is evidently a nuclear power plant, the first of many Iran plans to build over the next decades. Nonetheless, some warn that it could serve as a plutonium mine for nuclear weapons despite the inefficiency of civil-reactor plutonium for bombs. Iran could have such an option once its enrichment program is up and running. At that point, it could rely on its own fuel rather than its current practice of relying on Russian fresh fuel. Moscow has insisted that it will only provide such fuel if the spent fuel and its plutonium content is remitted back to Russia.

Relying on its own fuel would allow Tehran to conduct reprocessing without international encumbrance, unless it violated International Atomic Energy Agency safeguards. This risk could also make Bushehr a target for Israeli military action.

Given Bushehr's size and some recent analyses concluding that Israel has the capacity to destroy any Iranian nuclear plant, the radiological releases from Bushehr's destruction could approach the scope of Chernobyl. Fortunately, however, the plant's remote location along the Persian Gulf coupled with prevailing northwesterly
winds would carry the most concentrated radioactive plumes south into lightly inhabited parts of Iran and the waters of the gulf, likely limiting public health impacts.

Still, as one of the most valued assets in Iran's economy and one that could contaminate vast regions of the Iranian countryside and beyond, Tehran could not treat the plant's loss lightly. Arguably, the radiological mutual hostage relationship in which Israel and Iran would find themselves could discourage attacks. India's decision not to strike Pakistan's nuclear weapons complex, fearful that retribution would include attacks on its civil nuclear sector, and the subsequent agreement the two countries negotiated provides a precedent that Israel and Iran should consider.[3]

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Lessons From Chernobyl for Dimona

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The 1986 Chernobyl accident marks the most significant release of radiation from a nuclear reactor mishap to date. The radiological consequences of a successful military strike on Dimona, a reactor with an output of well under 5 percent that of the Soviet plant, would pale in comparison. Still, because a successful attack could generate harmful radiological contamination, Israel could learn much from how the Soviet Union and successor states coped with the tragedy.

Similar to Chernobyl, the heaviest radiological consequences likely would fall within the immediate vicinity of Dimona, although downwind hotspots could emerge. At Chernobyl, Soviet emergency responders performed heroically, but they were ill prepared to deal with the disaster. Many hours elapsed before authorities provided radioiodine blocking tablets to nearby populations. That interval increased the number of thyroid cancers. The additional 40 hours it took authorities to evacuate the nearby community of Pripyat and the weeks it took to remove 100,000 inhabitants residing in more distant but heavily contaminated zones added to the problem.

Still, postmortem analyses concluded that what evacuation did occur "substantially reduced radiation exposures and the radiation-related health impacts of the accident."[1]

Israel can learn from this finding. It should have in place sheltering and evacuation protocols for all potential radiological impact zones. Future national civil defense exercises, such as the April 2008 exercise that tested the country's response to a missile and chemical weapons attack, must include the radiological risks presented by Dimona. Also, authorities should consider a much wider distribution of radioiodine blocking tablets beyond the communities near the plant.

Contaminated foodstuffs, particularly radioiodine-laced milk that impacts the thyroid of its principal consumers—children—posed an additional problem during and following the
Chernobyl releases. Israel must prepare to address this and other contaminated-produce risks by stocking food, e.g., powdered milk, in secure warehouses for distribution. Replicating Chernobyl, agriculture will require monitoring for years. In time, natural processes such as rain and soil migration will concentrate radionuclides in some areas and remove some elements from others. Human intervention will help. Land and urban reclamation, along with population relocation and medical monitoring, proved costly in the former Soviet states, running into the hundreds of billions of dollars. The relatively small radionuclide release Dimona could generate should make meeting Israel's challenge and costs somewhat more bearable.

Finally, the failure of Soviet public officials to tell the public the truth about Chernobyl marked one of the most grievous errors in the handling of the accident.[2] The result contributed to a rate of long-term psychosomatic illness three to four times greater than unaffected control groups. The sense of victimization and associated depression continues to be the largest lingering impact on the broadest population. Israeli authorities could reduce needless fears by educating citizens that Dimona is no Chernobyl and that they are well prepared to manage the radiological challenge that destruction of the country's nuclear reactor may pose.

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2. For the history of the use and contemplation of force to halt nuclear weapons programs from World War II to the present, including in the Middle East, see Bennett Ramberg, "Preemption Paradox," Bulletin of the Atomic Scientists, July/August 2006, pp. 48-56.


6. The IAEA provides multiple citations establishing Dimona's operating power of 26 MWt. For example, see IAEA, Safe Decommissioning for Nuclear Activities: Proceedings of an International Conference (Vienna: IAEA, 2003) (held in Berlin, October 14-18, 2002). Megawatt thermal (MWt) refers to the thermal or heat output of a reactor in contrast to megawatt electric (MWe), which measures the electrical output from the reactor.

7. For a discussion of the range of values for Dimona's thermal power and implications for plutonium production, see David Albright, Frans Berkhout, and William Walker, Plutonium and Highly Enriched


9. Research reactors elsewhere in the Middle East include Algeria's reactors at Es Salam (15 MWt) and Nur (1 MWt); Egypt's ETRR-1 and ETRR-2 at the Inshas Complex (2 MWt and 22 MWt, respectively); Iran's research reactors at the Esfahan Nuclear Technology Centre (.03 MWt) and Tehran Nuclear Research Center (5 MWt); Israel's IRR-1 at Soreq Nuclear Research Center (5 MWt); Libya's IRT-1 at the Tajoura Nuclear Research Center (10 MWt); Morocco's MA-R1 at the National Center for Science and Engineering (2 MWt); Syria's SRR-1 Reactor in Dayr al-Hajar (0.03 MWt); and Turkey's ITU-TRR at the Technical University of Istanbul (0.25 MWt). See IAEA, "Nuclear Research Reactors of the World," www.iaea.org/worldatom/rrdb/.

10. For an excellent history of Israel's nuclear weapons program, see Avner Cohen, Israel and the Bomb (New York: Columbia University Press, 1998).


13. To estimate the magnitude of a radiation release following an attack on Dimona, the fractions of various radionuclides released during the first day of the Chernobyl accident were multiplied by the Dimona core inventory of radionuclides assuming the 26 MWt, 70 MWt or 150 MWt power levels. Radiation releases from Chernobyl Unit 4 occurred over a 10-day period before the reactor fire was extinguished. During this period, 20 percent of the core inventory of iodine-131 was released along with 13 percent of the cesium-137 inventory. On the first day, beginning with two explosions involving the reactor core, 5.1 megacuries (MCi) of iodine-131 and 0.6 MCi of cesium-137 were emitted, accounting for 8 percent of the iodine-131 and 4 percent of the cesium-137 core inventory. The Chernobyl releases were estimated for Dimona operating powers of 26 MWt, 70 MWt and 150 MWt, respectively. Cesium-137 releases of 0.2 percent, 0.4 percent, and 1.1 percent of the Chernobyl releases were estimated for Dimona operating powers of 26 MWt, 70 MWt and 150 MWt, respectively. Other categories of reactor-core radionuclides were also scaled accordingly from Chernobyl to Dimona. The calculations also assume the reactor's discharge occurs over a one-hour period (one surmises that Israeli emergency response and fire-fighting at the Negev Nuclear Research Center would be more effective than the Soviet response at Chernobyl). Once the radioactive source term is calculated by the HPAC system, HPAC's atmospheric dispersion model calculates the path of the radiation plume from the site, the degree of contamination, and doses to exposed populations based on historical weather and population databases in the code. The radiation dose for a 24-hour exposure to the plume was then tallied (the duration of evacuation or sheltering may be more or less rapid).


15. The Chernobyl accident has generated much debate about the extent of its consequences. Current documentation finds that several thousand often treatable thyroid cancers dominated evident physical impacts, apart from the 28 people who perished from acute radiation syndrome at the time. However, the mental health effects may have impacted the most people by increasing the rates of serious depressive anxiety and unexplained physical symptoms by 100-300 percent as compared to control groups. Projections out to 2065 suggest that Chernobyl will generate tens of thousands of additional cancers across Europe and the former Soviet states resulting in fatalities that could exceed 15,000. In addition, combating the accident, evacuation, relocation, cleanup, and lost productivity cost hundreds of billions of dollars. Future costs include construction of a new protective


20. Ginor and Remez, Foxbats Over Dimona, pp. 30-31, 38, 123.


25. Mordechai Vanunu told the London Sunday Times in September 1986 that Dimona, which normally stored high-level waste in liquid form above ground, had the capacity in an emergency to pipe the material into storage tanks in the bottom floor of the six-story underground reprocessing plant. Barnaby, Invisible Bomb, p. 38.

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