By Alexander Glaser, Zia Mian, Seyed Hossein Mousavian, and Frank von Hippel

Building on the Iran Deal: Steps Toward a Middle Eastern Nuclear-Weapon-Free Zone

The July 14 agreement between Iran and the six-country group known as the P5+1 established a set of important limitations and related transparency measures on Iran's nuclear activities.

Approved unanimously by the UN Security Council on July 20, the agreement, formally known as the Joint Comprehensive Plan of Action, aims "to ensure that Iran's nuclear program will be exclusively peaceful" and thus to reduce the risk of nuclear proliferation. To this end, it imposes limits for a decade or more on Iran's use of the key technologies required to make highly enriched uranium (HEU) and to separate plutonium, the fissile materials that are the critical ingredients in nuclear weapons.

Other states in the Middle East, especially Egypt and Saudi Arabia, are planning to establish their own nuclear power programs during the period that the Iran deal is expected to be in force. This has led to concerns about how Iran and other countries in the region will act when restrictions on Tehran's nuclear program end. To address such concerns, this article proposes that the P5+1 and the states of the Middle East use the next decade to agree on region-wide restraints based on the key obligations of the Iran deal as steps toward establishing a Middle Eastern nuclear-weapon-free zone, preferably as part of a regional zone free of all weapons of mass destruction (WMD).[1] These measures would ban the separation of plutonium, limit the level of uranium enrichment, place enrichment plants under multinational control, and cap and reduce Israel's existing stocks of fissile materials available for use in nuclear weapons, in time eliminating its arsenal through a step-by-step process.

These are intermediate steps to a nuclear-weapon-free zone that would establish strong, new technical and political barriers to any future attempts by countries in the region to seek a nuclear weapons capability. Although different Middle Eastern states may favor different sequencing of these and other steps, all of the intermediate steps presented below have nonproliferation and disarmament value in their own right. Individually and in groups, states in the region should be encouraged to adopt these steps as way stations toward the larger goal of a nuclear-weapon-free Middle East. They also should be pursued globally as steps toward global nuclear disarmament, especially by the five permanent members of the Security Council (China, France, Russia, the United Kingdom, and the United States), who all have nuclear weapons and with Germany make up the P5+1.

As in the Iran deal, verification arrangements will be important. Covert proliferation has a long history in the Middle East, starting with Israel's nuclear program in the 1960s and continuing with the violations by Iraq, Libya, and Syria of their commitments under the nuclear Nonproliferation Treaty (NPT) and most recently the confrontation over Iran's nuclear program. Given this history and the deep mutual suspicions of countries in the region, a robust

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regional safeguards, monitoring, and verification regime may add to the confidence provided by the International Atomic Energy Agency (IAEA) nuclear safeguards system.

Principles and Building Blocks

A nuclear-weapon-free zone in the Middle East was first proposed in the UN General Assembly in 1974 by Iran and Egypt. In 1990, the proposal was broadened by Egypt to include a ban on chemical and biological weapons—that is, to create a WMD-free zone in the Middle East. A 1991 study commissioned by the UN secretary-general proposed that such a zone encompass "all States directly connected to current conflicts in the region, i.e., all States members of the League of Arab States..., the Islamic Republic of Iran, and Israel."[2] As of late 2015, all of these countries but two—Israel and Syria—had sent letters to the UN secretary-general confirming their support for declaring the Middle East a region free from nuclear, chemical, and biological weapons.[3]

Most of the states expected to join a Middle Eastern WMD-free zone have signed and ratified the Chemical Weapons Convention (CWC) and the Biological Weapons Convention (BWC), and all but Israel have joined the NPT as non-nuclear-weapon states. Many also have signed and ratified the Comprehensive Test Ban Treaty (CTBT). Some are members of the African nuclear-weapon-free zone, created by the Treaty of Pelindaba, which entered into force in 2009 (table 1).

Ban on the separation of plutonium. As part of the nuclear deal, Iran agreed that, for 15 years, it "will not, and does not intend to thereafter" carry out any separation of plutonium from spent nuclear fuel, an operation known as reprocessing. Iran also pledged not to build a facility capable of reprocessing or to carry out any research and development activities in that area. In addition, Tehran affirmed its intent to ship out to another country, presumably Russia, all spent nuclear fuel from all present and future power and research reactors.

Israel is the only country in the region that has separated plutonium from spent nuclear fuel. Its nuclear arsenal is based on plutonium that was produced by irradiating natural uranium fuel in a reactor that uses heavy water as a neutron moderator. The reactor, which Israel built with French assistance in the 1950s, is located at the Negev Nuclear Research Center near Dimona.[4]

Israel's plutonium has been separated from the irradiated uranium in an underground reprocessing plant adjoining the reactor. As its first step toward a Middle Eastern nuclear-weapon-free zone, Israel could shut down the Dimona reactor and end reprocessing of the accumulated discharged fuel. These steps could be verified with fair

Table 1: Weapons of Mass Destruction Treaties and Possible Members of a Middle Eastern Nuclear-Weapon-Free Zone

	CWC	BWC	NPT	CTBT	Treaty of Pelindaba
Algeria	1995	2001	1995	2003	1998
Bahrain	1997	1988	1988	2004	–
Comoros	2006	–	1995	1996	2012
Djibouti	2006	–	1996	2005	1996
Egypt	–	1972	1981	1996	1996
Iran	1997	1973	1970	1996	–
Iraq	2009	1991	1969	2013	–
Israel	1993	–	–	1996	–
Jordan	1997	1975	1970	1998	–
Kuwait	1997	1972	1989	2003	–
Lebanon	2008	1975	1970	2008	–
Libya	2004	1982	1975	2004	2005
Mauritania	1998	2015	1993	2003	1998
Morocco	1995	2002	1970	2000	–
Oman	1995	1992	1997	2003	–
Palestine	–	–	2015	–	–
Qatar	1997	1975	1989	1997	–
Saudi Arabia	1996	1972	1988	–	–
Somalia	2013	1972	1970	–	2006
Sudan	1999	2003	1973	2004	1996
Syria	2013	1972	1969	–	–
Tunisia	1997	1973	1970	2004	1996
United Arab Emirates	2000	2008	1995	2000	–
Yemen	2000	1979	1979	1996	–

Notes: Dates indicate ratification/accession or signature (gray shading) to the Chemical Weapons Convention (CWC), Biological Weapons Convention (BWC), nuclear Nonproliferation Treaty (NPT), Comprehensive Test Ban Treaty (CTBT), and Treaty of Pelindaba on an African nuclear-weapon-free zone.

Source: Organisation for the Prohibition of Chemical Weapons, Comprehensive Test Ban Treaty Organization, and UN Office for Disarmament Affairs.

Chavosh Homavandi/AFP/Getty Images

Iranian students form a human chain outside the site of the Fordow uranium-enrichment facility near the northern Iranian city of Qom during a demonstration to defend their country's nuclear program on November 19, 2013.

confidence at first without access to the site and later under an arrangement that would give IAEA inspectors what is known as managed access, which would allow them to determine that the facilities were indeed shut down while allowing Israel to protect sensitive facility information.

Even if Middle Eastern countries pursue ambitious civilian nuclear power programs, they need not develop reprocessing capabilities. No sound economic or environmental justification exists for separating and stockpiling plutonium.[5] Of the 30 countries with operational commercial nuclear power reactors, only six have active civilian reprocessing programs, and five of those six states are nuclear-weapon states. Japan is the only non-nuclear-weapon state with a civilian reprocessing plant, but the plant is not operating and is the subject of extensive debate over its utility, risks, and cost.[6]

Restrictions on uranium enrichment. Centrifuge enrichment plants pose significant proliferation concerns because they can be quickly reconfigured for HEU production.[7] This is why a major part of the nuclear deal focuses on Iran's gas-centrifuge uranium-enrichment facilities and activities. Iran agreed that it will keep its operating enrichment capacity limited to one site and to a total of 5,060 first-generation centrifuges for 10 years and limit for 15 years the enrichment of its product to less than 3.67 percent uranium-235 and its stock of low-enriched uranium hexafluoride, the gaseous form that could be fed into the centrifuge cascades for further enrichment, to a very low level (less than 300 kilograms). These limitations would extend the time it would take Iran to produce enough weapons-grade HEU for a first nuclear weapon from about two months to about a year.

After the limits expire, however, Iran plans to expand its enrichment capacity by a factor of more than 20 in order to produce at least the 27 metric tons per year of 3.7 percent-enriched uranium required to fuel the Russian-supplied Bushehr power reactor.

Weapons-grade HEU is typically enriched to a U-235 level of 90 percent or greater. For safeguards purposes, however, the IAEA treats uranium enriched above 20 percent as a direct weapons-usable material. Even 20 percent is a much higher level of enrichment than the less-than-5-percent-enriched uranium that is used to fuel commercial nuclear power reactors worldwide today.

The only operating uranium-enrichment plant in the United States is licensed to enrich up to 5 percent U-235.[8] France's Georges Besse II enrichment plant, which began operating in 2009 and supplies enriched uranium for France's nuclear power plants, is licensed to produce up to 6 percent U-235.[9] It also supplies France's nuclear submarines. Enrichment in a Middle Eastern nuclear-weapon-free zone therefore could be limited to less than 6 percent and still accommodate states wishing to develop nuclear naval propulsion. Some policymakers and officials in Iran have already expressed such ambitions.[10]

The United States, the UK, Russia, and India use HEU for naval fuel,

unlike France and, it is believed, China. They should be pressed to shift to low-enriched uranium (LEU) fuel as part of a strengthened global nonproliferation and disarmament regime.

Only three countries in the potential Middle Eastern WMD-free zone—Iran, Israel, and Syria—have reactors that use HEU as fuel. These are research reactors, all of which are under IAEA safeguards. Israel's U.S.-supplied Soreq reactor is scheduled to be shut down in 2018.[11] The HEU-fueled research reactors in Iran and Syria, supplied by China, contain only about 1 kilogram of HEU each, much less than the 25 kilograms of U-235 that is the figure the IAEA uses as a rough measure of the quantity required for a simple nuclear weapon. China has developed a new fuel for such reactors that could be used to convert them to LEU fuel.

Several other research reactors in Middle Eastern states, including the U.S.-supplied Tehran Research Reactor, use fuel enriched to 19.75 percent. Russia and the United States have enough excess HEU to down-blend and use to supply the fuel needs of these reactors and similar reactors worldwide for many decades. Iran already has agreed to import such uranium as other countries do.

Iran is the only country in the Middle East with plans for a significant commercial uranium-enrichment program. Israel may now have or might have had a small-scale, centrifuge-based uranium-enrichment capability.[12] No other state in the region is believed to have this technology. Saudi Arabia, however, has been unwilling to rule out seeking an enrichment capability.

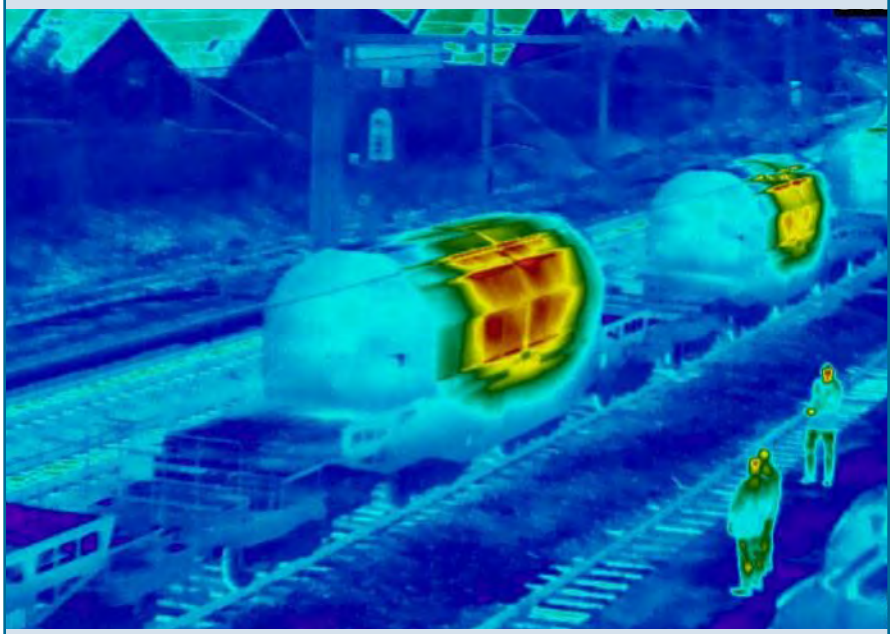
To address the latent proliferation capability of enrichment plants, uranium enrichment in the Middle East and preferably globally should be placed under multinational control.[13] One-third of global uranium-enrichment capacity, including the only commercial enrichment plants currently operating in two of the five NPT nuclear-weapon states (the UK and the United States), already is operated by Urenco, a company owned jointly by the Netherlands, the UK, and two German utilities, with senior management and an oversight body of government officials drawn from all three countries.[14]

A multinationally managed and operated enrichment plant, bringing together Iran and regional partners, would undercut incentives for Middle Eastern states to follow Iran and build national enrichment facilities. Senior Iranian officials have indicated that Iran is ready to partner with other countries in the region so that they do not have to build their own enrichment plants and to help set up a system to guarantee the fuel supply of nuclear power plants in the Middle East. A strategy of including as partners one or more members of the P5+1, all of whom already hold centrifuge enrichment technology, could maintain extra transparency with regard to Iran's enrichment operations, uranium acquisitions, and centrifuge manufacture after the extra transparency established under the nuclear deal expires. As a first step, Iran and the P5+1 could establish a working committee on multilateralization of Iran's enrichment program. They could invite other partners of the region to join and set a five-year deadline to reach agreement.

Declarations of fissile material stockpiles and step-by-step safeguards. Dealing with Israel's stockpiles of nuclear weapons and fissile materials will be a key part of achieving a Middle Eastern nuclear-weapon-free zone. Israel, the only non-NPT state in the region, keeps the existence of its stockpiles cloaked in secrecy.[15]

Figure 1: Remote Detection of Thermal Signatures

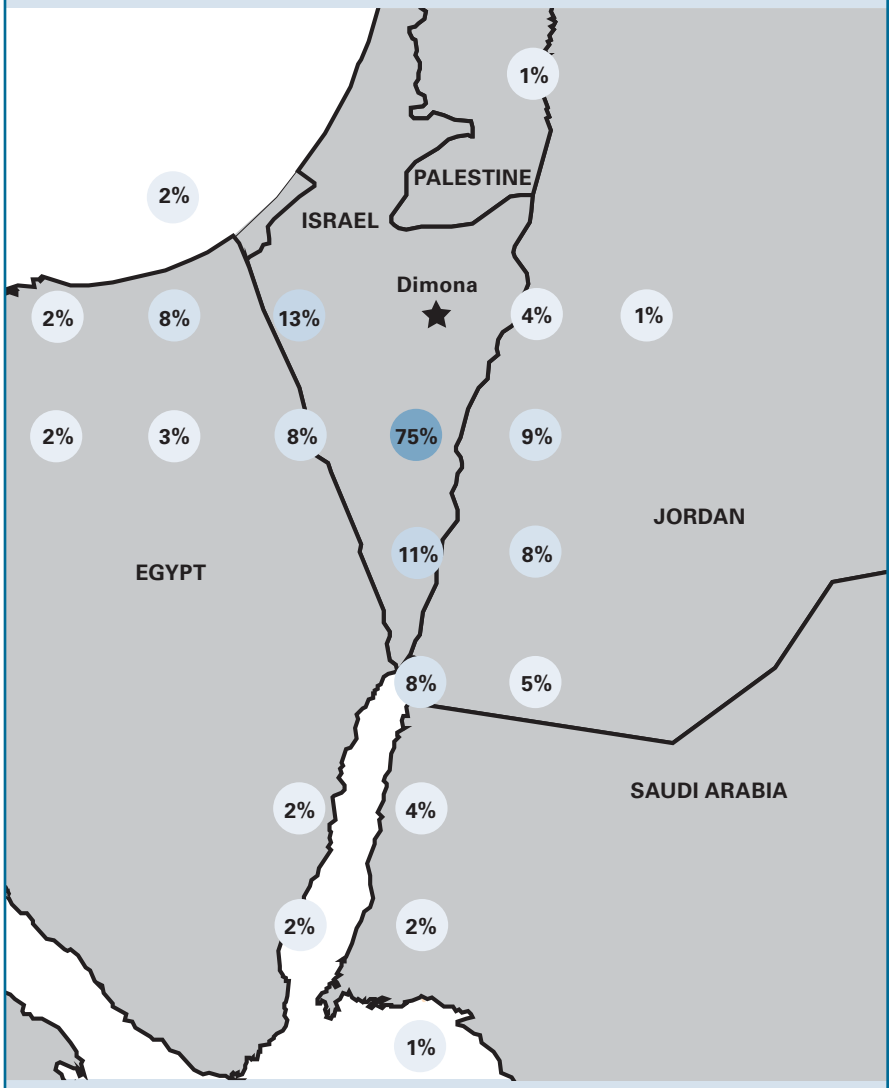
Infrared sensors on satellites, aircraft, or drones could reliably confirm the operational status of the Dimona reactor. Such sensors are allowed, for instance, as part of the 1992 Open Skies Treaty, an arms control and transparency agreement that has 34 states-parties and covers the United States, Russia, and Europe. The infrared picture shows a train carrying casks of high-level radioactive waste. The peak surface temperature indicated by the pattern on the leading cask was 30 degrees Celsius (86 degrees Fahrenheit).



Source: Greenpeace. The original color-coded version of this image with a temperature scale is available at http://news.nationalgeographic.com/news/2011/01/pictures/110119-nuclear-waste-train-castor-antinuclear-protest-germany-power-energy-pictures.

Figure 2: Detection of Krypton-85

Even a small number of krypton-85 detector stations in the Middle East could enhance confidence that Israel had ended reprocessing at its Dimona site. Based on computer simulations of atmospheric transport, the circles show the percentage of the time over the course of a year that sensors at the center of the circles could detect Kr-85 releases from Dimona associated with the separation of weapons-grade plutonium at a rate of 18 kilograms per year. Sensors located at the boundary of the Dimona site would detect releases of this scale whenever they occurred.



Source: Michael Schoeppner, Program on Science and Global Security, Princeton University

A step toward enabling a Middle Eastern nuclear-weapon-free zone and nuclear disarmament would be for Israel to declare the size of its stocks of unsafeguarded fissile materials. Israel initially need not disclose what portions reside in its nuclear weapons or any other information about its nuclear weapons program and arsenal. Israel would be called on to reduce and eventually eliminate the quantities of plutonium and HEU that it has available for use in weapons by placing increasing portions under international safeguards for verified disposal.

Verification Arrangements

Any Middle Eastern nuclear-weapon-free zone will need robust verification. The parties to a zone treaty almost certainly would want a regional monitoring regime to buttress IAEA inspections. Such an arrangement exists in Europe in the form of Euratom. In Latin America's nuclear-weapon-free zone, Argentina and Brazil have a joint organization, the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials, through which they monitor each other's nuclear activities.

Measures could go beyond standard IAEA safeguards to include the new transparency obligations accepted by Iran under the July 2015 agreement, such as monitoring of uranium mining and purification, uranium imports, and production of nuclear materials and nuclear-related technology such as centrifuges. Some other elements of a possible verification regime are discussed below.

Additional protocol and transparency measures. Under the July agreement, Tehran is to implement on a provisional basis an additional protocol to its IAEA safeguards agreement and to seek ratification of the protocol when the IAEA reaches the conclusion that all of Iran's nuclear material is in peaceful uses or after eight years, whichever comes first. An additional protocol requires parties to declare all of their nuclear-related activities, including centrifuge manufacture—not just those involving nuclear materials—and to give IAEA inspectors access to check those declarations.[16]

Thirteen of the 23 countries that could be part of a Middle Eastern nuclear-weapon-free zone (Egypt, Iran, Israel, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Somalia, Sudan, Syria, Tunisia, and Yemen) have not ratified an additional protocol.[17] Like Iran, all of these states could bring an additional protocol into force pending ratification.

Israel's safeguards agreement, which has been in force since 1975, covers only the Soreq research reactor. Once this reactor is shut down and the U.S.-origin fuel is returned, no IAEA safeguards of any kind will exist in Israel. As part of the confidence-building process, Israel and the IAEA could negotiate a

safeguards agreement that would cover all of Israel's peaceful nuclear-related activities and fissile material withdrawn from its nuclear weapons stockpile. Israel would not be the first nuclear-armed state to do so. The five NPT nuclear-weapon states and India have signed and ratified additional protocols with the IAEA that are much more limited in coverage than those signed by the NPT non-nuclear-weapon states.

Although full transparency and on-site inspections will be indispensable elements of a successful regional and IAEA verification system, some of the initial steps outlined above for moving toward a Middle Eastern nuclear-weapon-free zone could be verified initially with fair confidence without direct access to the sites in question. Among the conditions that could be verified with standoff detection methods could be the shutdown of the reactor and reprocessing plant at Dimona, as described below.

Shutdown of the plutonium-production reactor. Satellite or airborne infrared sensors should be able to verify the operational status of Israel's Dimona plutonium-production reactor by detecting the reduction of the temperatures of the outside of the reactor containment building or the reactor's cooling towers (fig. 1) once the reactor shuts down. Likewise, the sensors could help detect heat produced by any undeclared reactors in the region.

Shutdown of the reprocessing plant. The absence of reprocessing should be verifiable by off-site monitoring for the gaseous fission product krypton-85, which is released when irradiated nuclear fuel is cut open in the first stage of reprocessing. Because the gas is chemically nonreactive, reprocessing plants have not bothered to try to capture it. An analysis of measurements of krypton-85 at a distance of 60 kilometers from Japan's Tokai pilot reprocessing plant demonstrated a high detection probability.[18] Unless Dimona has installed a highly effective capture system, it should be possible to detect, with sensors placed around the Dimona site, any emissions of krypton-85 against the krypton background from reprocessing activities elsewhere in the world (fig. 2).

Shutdown of enrichment. Uranium enrichment using centrifuges is much more difficult to detect from a distance than reprocessing. There is very little leakage from centrifuge plants, so detecting undeclared uranium hexafluoride production might be a more promising approach.[19] The difficulty of detecting clandestine uranium enrichment highlights the potential role and importance of cradle-to-grave approaches to the nuclear fuel cycle.[20]

One immediate opportunity for collaborative efforts to build verification capacity could be for Middle Eastern countries to set up a regional data-sharing, analysis, and technical training process focused on existing or planned CTBT monitoring stations. Of special interest could be the radionuclide monitoring stations that look for radioxenon and other isotopes and particles from nuclear explosive tests. There currently are stations in Kuwait City; Misrata, Libya; and Nouakchott, Mauritania. A station is planned for Tehran. Mobile platforms could look for krypton-85 from reprocessing as part of the verification network for a nuclear-weapon-free zone.

One particularly important aspect of a verified nuclear-weapon-free zone in the Middle East will be to obtain

Thomas Coex/AFP/Getty Images

The Dimona nuclear reactor in the Israeli Negev Desert is shown in this September 2002 photo.

confidence in the completeness of Israel's fissile material declaration. This total could be checked after Israel had placed all of its declared fissile material under international safeguards. Israel's historical production of plutonium could be checked using techniques of "nuclear archaeology." These would include measurements of isotopic changes of certain trace elements in the permanent metal structures supporting the core of the Dimona reactor.[21] The measurements would reveal the cumulative flow, or fluence, of neutrons through the core over the lifetime of the reactor, which would provide the basis for an estimate of the total production of plutonium by the reactor. By committing publicly to this goal in advance, Israel could contribute to a regional confidence-building process and help set the basis for a verifiable Middle Eastern WMD-free zone.

Conclusion

The Joint Comprehensive Plan of Action provides an unprecedented opportunity for an international effort to make progress toward a Middle Eastern nuclear-weapon-free zone, possibly as part of WMD-free zone in that region. Building on the foundation created by that agreement, the measures proposed here constitute the essential technical steps toward a nuclear-weapon-free zone.

Although it is unlikely that such a zone can be established anytime soon, it should be possible to make progress on a number of the building blocks for it. Region-wide commitments to refrain from separating plutonium for any purpose, to limit uranium enrichment to the levels required for power reactors, and to conduct any enrichment activities only as part of a multinational arrangement would be major achievements. International and regional verification of such commitments would provide enhanced confidence against possible proliferation risks.

ENDNOTES

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14. The centrifuges used in Urenco plants, including the Urenco USA plant, and in Areva's plant in France are made on a "black-box" basis by the Enrichment Technology Company, which is jointly owned by Urenco and Areva.

15. Israel is believed to have clandestinely obtained about 300 kilograms of weapons-grade uranium from a U.S. naval fuel fabrication facility during the 1960s. Victor Gilinsky and Roger J. Mattson, "Did Israel Steal Bomb-Grade Uranium From the United States?" *Bulletin of the Atomic Scientists*, April 2014. See also Victor Gilinsky and Roger J. Mattson, "Revisiting the NUMEC Affair," *Bulletin of the Atomic Scientists*, Vol. 66, No. 2 (March 2010).

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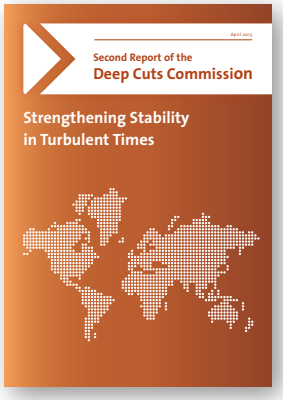

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