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Preventing Iranian Nuclear Weapons—Beyond the "Comprehensive Solution"

Summary and Conclusions

Negotiations on Iran's nuclear program are continuing in an effort to produce a follow-on agreement, termed the "Comprehensive Solution," to the November 2013 "Joint Plan of Action" (JPA). Much of the discussion of the Comprehensive Solution has focused on the terms such an agreement should include to prevent Iran from being able to produce nuclear weapons. However, this objective will not be attainable unless the agreement addresses key aspects of Iran's nuclear program, fixes the flaws in the JPA which seriously constrain any agreement and recognizes fundamental problems with International Atomic Energy Agency (IAEA) safeguards as currently implemented.

First, Iran's ability to quickly produce Highly Enriched Uranium (HEU) means that Iran is already a de facto nuclear weapon state. The Obama Administration, unwilling to face this U.S. policy failure, continues to try to say otherwise. The Administration has turned conventional nuclear nonproliferation wisdom on its head and implausibly claims that it is the nonnuclear weapon components, not the HEU, that are the great barrier to a country producing nuclear weapons. Any successful nuclear agreement with Iran would need to deny it easy access to HEU, not only in the short-term but in the long-term as well. Similarly, any fix for Iran's Arak plutonium production reactor would need to address the possibility that the reactor could be reconverted to produce significant amounts of plutonium.

Second, several key elements of the Comprehensive Solution have already been determined by the JPA. These are that the Comprehensive Solution will "have a specified long-term duration to be agreed upon," that Iran will be allowed to retain some amount of centrifuge enrichment capability and, once the Comprehensive Solution has lapsed, Iran's nuclear program will be under no special restrictions but rather "will be treated in the same manner as that of any non-nuclear weapon state." Many analysts have mistakenly referred to the Comprehensive Solution as a "final" nuclear agreement but clearly it will only be a long-term interim agreement. The terms of the final agreement have already been enunciated in the JPA, namely that Iran will have an unrestricted centrifuge enrichment program. A "Comprehensive Solution" based solely on the terms of the JPA will not only enhance Iran's nuclear weapon capability in the long-term but also lay the groundwork for the further spread of nuclear weapons by legitimizing any country's desire for a centrifuge enrichment program.

Third, it is necessary to delegitimize the possession of centrifuge enrichment by *any* non-nuclear weapon state. To do this the U.S. must insist that IAEA safeguards do what they say they do, not only provide the detection of the diversion of nuclear material but also provide the *timely*

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detection of that diversion. Commercial-scale centrifuge enrichment facilities can produce HEU so quickly that these facilities are unsafeguardable as timely detection of diversion is impossible. (Appendix 2) Nor is the problem restricted to just centrifuge enrichment. Recently, China has expressed concern about Japan's large and soon to be rapidly expanding plutonium stockpile. The U.S., instead of taking this opportunity to try to strengthen IAEA safeguards, supported the IAEA's position that because this plutonium had not been diverted in the past, there is no danger that it will be diverted in the future. If this were really true, there would be no need for IAEA safeguards at all.

Only by facing the inherent dual peaceful/military nature of nuclear technology is it evident what the terms of any agreement with Iran should be, namely that Iran should have no centrifuge enrichment capability and that it should not be possible to reconvert the Arak reactor to natural uranium fuel for large-scale plutonium production. This latter requirement means that at a minimum, Iran would need to export all of its current heavy water stocks and shut down and dismantle its heavy water production facility. Better still, the reactor should never be finished and its components should be destroyed.

A Comprehensive Solution based solely on the terms of the JPA would do more harm than good. It would legitimize Iranian possession of centrifuge enrichment, allowing Iran in the long-term to have a larger, more robust centrifuge enrichment program than it would otherwise possess. At the same time it would allow any country to claim the "right" to centrifuge enrichment, enabling it to get very close to possessing nuclear weapons.

However, if IAEA safeguards are to truly provide for timely detection of diversion of nuclear material then all non-nuclear weapons states, not just Iran, would be prohibited from possessing any materials or facilities that can quickly provide fissile material for nuclear weapons. This includes prohibiting not only enrichment and reprocessing facilities but also separated HEU, plutonium or U-233; and HEU, plutonium or U-233 that is contained in unirradiated reactor fuel (such as HEU fuel for research reactors or mixed oxide fuel for power reactors).[2]

These restrictions would go a long way to seriously impeding the proliferation of nuclear weapons. At the same time, Iran would no longer be able to quickly produce nuclear material for nuclear weapons, yet it would "be treated in the same manner as that of any non-nuclear weapons state" as specified by the JPA. Without these restrictions the ability to produce nuclear material for nuclear weapons will continue to spread from country to country and we should expect additional "Irans" in the future.

Iran as a De Facto Nuclear Weapon State

Currently Iran can produce the HEU for a nuclear weapon in just six weeks from the time it decides to do so (see Table 1 and Appendix 1) and can produce the HEU sufficient for three nuclear weapons in just four months. Even come July 20, 2014, when the JPA is to take full effect, Iran will still be able to produce the HEU for a nuclear weapon in eight weeks from the time it decides to do so and the HEU for three nuclear weapons in four and one half months.

[2] U-233, like plutonium and HEU, can be used to manufacture nuclear weapons. It is produced by the irradiation of thorium. Mixed oxide power reactor fuel is a mixture of uranium and plutonium oxides.

At one time, my estimates regarding how rapidly Iran could produce HEU were controversial but now most independent analysts' estimates are very similar to my own. Recently Secretary of State John Kerry confirmed that Iran could produce the HEU for nuclear weapons quickly should it decide to do so. His estimate is two months.[3]

Table 1

Time Required For Iran to Produce Various Amounts of HEU For Nuclear Weapons Should Iran Decide to Do So Quickly

Number of Nuclear Weapons (HEU)	As of March 20, 2014	As of July 20, 2014 when JPA takes full effect
One (20 kg)	6 weeks	8 weeks
Three (60 kg)	4 months	4 and one half months

However, Secretary Kerry is unwilling to concede that Iran is a de facto nuclear weapon state, claiming that Iran would be "without any necessary capacity to put it [the HEU] in anything, to deliver it, to have any mechanism to do so."[4] What Secretary Kerry is saying it that even if Iran produced the HEU required for a nuclear weapon, it would not have the nonnuclear components required to produce a nuclear weapon and even if it did, it would not have the means to deliver the nuclear weapon.

Kerry's argument stands conventional nuclear non-proliferation wisdom on its head. It is widely acknowledged that it is the lack of nuclear material (HEU or plutonium) that is the main barrier to a country being able to produce nuclear weapons. The nonnuclear components consist of nothing more than high explosives, detonators and fuses—items that are well-known to any half-decent military organization. The whole focus of IAEA safeguards is nuclear material. Similarly the current negotiations with Iran are focused exclusively on its ability to produce nuclear material, not on its conventional explosives capabilities.

There have been some (including some in the U.S. government) who contended that it would take years for Iran to produce the non-nuclear components of a nuclear weapon. This would run counter to historical experience, even if Iran were to start from scratch. However, given the significant aid that Iran has received from a Russian nuclear weapon designer, Iran is not starting from scratch. In December 2011, I estimated that Iran could produce an implosion-type nuclear weapon (the design of most nuclear weapons) in just two to six months and that the development of the non-nuclear components of this weapon could take place in parallel with or prior to the

[3] Patricia Zengerie, "Kerry says Iran nuclear 'breakout' window now seen as two months," *Reuters*, April 8, 2014.
[4] *Ibid.*

production of the HEU.[5] Since 2011, Iran's continuing efforts have shortened this time. In July 2012 John Sawers the chief of British intelligence MI6 said: "The Iranians are determinedly going down a path to master *all* aspects of nuclear weapons; all the technologies they need."[6] [Emphasis added.] In early 2013, even Secretary Kerry had to agree that Iran was getting "closer and closer" to a nuclear weapon.[7] Reports that senior Iranian officials attended North Korea's February 2013 nuclear test indicate that Iran may be receiving nuclear weapon design assistance from more than just the Russians.[8]

Further, if it were actually so time consuming to produce the traditional implosion-type nuclear weapon, Iran could always just produce a gun-type nuclear weapon instead. This was the weapon type that the U.S. used to destroy Hiroshima. This type of nuclear weapon is very simple to design and produce, so much so that it does not require prior nuclear testing. Such a weapon would require the 20 kilograms of HEU that I assumed was needed for an implosion-type weapon and would produce a yield of 2 to 4 kilotons.[9]

The bottom line is that should it choose to do so, Iran could produce enough HEU for a nuclear weapon in no more than two months and, by using either implosion- or gun-type nuclear weapon designs, Iran could likely produce a complete nuclear weapon rather quickly (within days or weeks) after producing the required HEU.[10] Olli Heinonen, former head of the IAEA's safeguards division, has come to the same conclusion, saying that Iran can now produce a nuclear weapon in "a month or two."[11]

On Secretary Kerry's claim that Iran would not have any means to deliver a nuclear weapon even if it had one, note that there are a variety of possible methods to deliver a nuclear weapon. In addition to the commonly discussed ballistic missile, nuclear weapons can be delivered by trucks or ships.[12] Notwithstanding Secretary Kerry's claim that Iran has no means to deliver a nuclear weapon, Iran surely possesses trucks and ships which could do so.

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[5] Gregory S. Jones, "Iran's Efforts to Develop Nuclear Weapons Explicated, Centrifuge Uranium Enrichment Continues Unimpeded, the IAEA's November 8, 2011 Safeguards Update," December 6, 2011, http://npolicy.org/article_file/Iran_Efforts_to_Develop_Nuclear_Weapons_Explicated.pdf

[6] Christopher Hope, *The Telegraph*, July 12, 2012, http://www.telegraph.co.uk/news/uknews/terrorism-in-the-uk/9396360/MI6-chief-Sir-John-Sawers-We-foiled-Iranian-nuclear-weapons-bid.html

[7] "John Kerry Concedes Iran is Moving Closer to Possessing Nuclear Weapon," Secretary of State Interviewed by Martha Raddatz in Qatar, ABC News, March 5, 2013.

[8] "Iranian nuclear chief observed Korean nuke test," *Jerusalem Post*, February 17, 2013.

[9] J. Carson Mark, "Some Remarks on Iraq's Possible Nuclear Weapon Capability in Light of Some of the Known Facts Concerning Nuclear Weapons," *Nuclear Control Institute*, May 16, 1991, p.23. This nuclear weapon could be easily fitted onto an Iranian ballistic missile. Further, it is important to note that the lethal area of a nuclear weapon does not scale linearly with yield, especially at low yields. Though two to four kilotons is only one-eighth to one-quarter (13% to 25%) of the yield of the Hiroshima bomb, the lethal area of such a weapon would still be about 3 km^2 (over one square mile). This is about three-eighths (38%) the lethal area of the Hiroshima bomb and such a weapon would kill tens of thousands if exploded over a city.

[10] The development of the non-nuclear components for the nuclear weapon could take place in parallel with or prior to the production of the HEU.

[11] David Feith, "How Iran Went Nuclear," *The Wall Street Journal*, March 2, 2013, p.A13.

[12] In his September 2012 speech to the UN, Israeli Prime Minister Netanyahu suggested that Iran might deliver a nuclear weapon by "container ship."

In March 2013, the Director of National Intelligence James Clapper reported the U.S. intelligence assessment that Iran's preferred nuclear delivery mode will likely be by ballistic missile.[13] Apparently in an effort to define the problem away, Secretary Kerry is saying that Iran would only be able to deliver a nuclear weapon by ballistic missile. It appears that U.S. intelligence believes that it would take Iran some time to develop a nuclear weapon small enough to fit onto its ballistic missiles and to conduct the flight tests needed to assure that the warhead was functional. This assessment may be the basis for President Obama's statement that "it would take over a year or so for Iran to actually develop a nuclear weapon."[14]

However, there are several problems with this intelligence assessment. The nuclear weapon design that the Russian nuclear weapon expert provided to Iran was specifically designed to fit upon Iran's ballistic missiles. North Korea may have already developed such a lightweight nuclear warhead. Pakistan with Chinese assistance most certainly has and has flight tested North Korean provided ballistic missiles of the type that Iran also has received from North Korea. Either of these countries may be providing aid to Iran. In addition, a small gun-type nuclear weapon, which would be easy to develop and would require no prior nuclear testing, could fit upon a ballistic missile. Thus it is not clear that Iran would require anywhere close to a year to develop a nuclear-armed ballistic missile.

Furthermore as was stated above, Iran is not restricted to using only ballistic missiles for nuclear weapon delivery but could use trucks or ships instead. Given the missile defenses of the U.S. and Israel, it is not clear that Iran's preferred delivery method would be ballistic missiles or why U.S. intelligence should believe that it is. Truck or ship delivery could be particularly effective against U.S. military forces in the region.

However, this does not mean that I think Iran will become an overt nuclear weapons state in the near future. As I stated in September 2011:

> That is not to say that I expect Iran to divert nuclear material from IAEA safeguards anytime soon. After all, why should it? It can continue to move ever closer to the HEU required for a nuclear weapon with the blessing of the IAEA. Iran would only need to divert nuclear material from safeguards when it would want to test or use a nuclear weapon. Recall that the U.S. was unable to certify that Pakistan did not have nuclear weapons in 1990, but it was only in 1998 that it actually tested a bomb. Similarly, though it could be many years before Iran becomes an overt nuclear power, it needs to be treated as a de facto nuclear power simply by virtue of being so close to having a weapon.[15]

Any nuclear agreement with Iran needs to focus on preventing nuclear weapons in the long-term. Too much of the current focus is mistakenly on the short-term. Consider the 1994 Agreed

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[13] James Clapper, "Statement for the Record, Worldwide Threat Assessment of the US Intelligence Community," Senate Select Committee on Intelligence, March 12, 2013, p.7.

[14] Michael D. Shear and David E. Sanger, "Iran Nuclear Weapon to Take Year or More, Obama Says," *The New York Times*, March 14, 2013. Note that it is unclear whether Obama meant "over a year," or "a year or so."

[15] Gregory S. Jones, "No More Hypotheticals: Iran Already Is a Nuclear State, *The New Republic*, September 9, 2011, http://www.tnr.com/article/environment-and-energy/94715/jones-nuclear-iran-ahmadinejad

Framework with North Korea. It was deemed a success at the time as it was able to push the prospect of North Korean nuclear weapons off for at least five or ten years. However, after three North Korean nuclear tests (the first of which occurred twelve years after the Agreed Framework), the Agreed Framework seems far less successful from the perspective of 2014.

Key Terms of Comprehensive Solution Already Determined by JPA

Even if Iran is currently a de facto nuclear weapon state, it is always possible for this condition to be reversed, just as South Africa was able to give up its nuclear weapons. However, the current negotiations with Iran will not be able to accomplish this objective in the long-term as several key elements of the Comprehensive Solution have already been determined by the JPA.

The JPA indicates that under the Comprehensive Solution Iran will be permitted to retain centrifuge enrichment. This fact has been denied by Secretary Kerry[16] but in two separate places in the Joint Plan of Action it says "This comprehensive solution would involve a mutually defined enrichment programme…." Note that the text says "would," not "might" or "could." That the follow-on Comprehensive Solution will permit Iranian centrifuge enrichment was later confirmed by the U.S. national security spokeswoman Bernadette Meehan who said, "We are prepared to negotiate a strictly limited enrichment program."[17]

It has long been the policy of the U.S. and other countries to prevent the acquisition of enrichment and reprocessing technologies by non-nuclear weapon states. Indeed, the JPA flatly prohibits Iran from developing reprocessing, so it is even more puzzling that this deal gives its approval to Iran's continuing possession of centrifuge enrichment. Centrifuge technology puts any country within an arm's reach of highly enriched uranium for nuclear weapons. (See Appendix 2)

Another key element of the Comprehensive Solution as determined by the JPA is that it "have a specified long-term duration to be agreed upon," that is the Comprehensive Solution will have a limited duration. The need for permanent restrictions on Iran's nuclear program has been implicitly recognized by a number of analysts who have proposed that certain of the conditions of the Comprehensive Solution should be permanent, ignoring or not recognizing that permanent restrictions on Iran's nuclear program violate the terms of the JPA. Western analysts have suggested that the term of the Comprehensive Solution should be at least twenty years but it is unlikely that Iran will agree to more than five or ten years. Should a negotiated "Comprehensive Solution" be reached with Iran, the length of its term will be one of its most important parameters.

A number of analysts have mistakenly referred to the Comprehensive Solution as the "final" agreement with Iran, when in fact it is only a long-term interim agreement. Again the JPA has already laid out what the terms of the true final agreement with Iran will be, namely that when the Comprehensive Solution has expired, Iran "will be treated in the same manner as that of any

[16] Aaron Blake, "Kerry on Iran: 'We do not recognize a right to enrich,'" *The Washington Post*, November 24, 2013.
[17] Jim Acosta, "White House prepared to allow limited Iran nuclear enrichment," CNN Political Ticker, December 4, 2013.

non-nuclear weapon state party to the NPT." This means that in the long-term, Iran's nuclear program will be under no special restrictions.

Even if Iran agrees under the Comprehensive Solution to greatly restrict its centrifuge enrichment program, after the Comprehensive Solution has expired, Iran will not only be able to build as many centrifuges as it wants, it could also import centrifuges as part of normal nuclear trade. Iran could then have a larger, more robust centrifuge program and be much closer to acquiring nuclear weapons than it currently is.

Iranian President Rouhani has already begun to lay the groundwork for a massive expansion of Iran's centrifuge enrichment program. In January 2014 he said, "…we will not accept any limitations and, in accordance with Majlis, or parliament law, in the future we are going to need 20,000 megawatts of nuclear power. We're are [sic] determined to provide for the nuclear fuel of such plants inside the country at the hands of local Iranian scientists. We're going to follow on this path."[18] When asked if there would be any destruction of centrifuges, Rouhani said, "No, no, not at all."

Though most observers focused on Rouhani's assertion that Iran would not destroy any centrifuges, his statement that Iran would need to provide the fuel for 20,000 megawatts of nuclear power is as least as significant. If this were really the case, Iran would require the equivalent of about two million of its current IR-1 type centrifuges, which is far greater than its current 19,000 centrifuges.

Even if Iran were to acquire the equivalent of only 100,000 of its current centrifuges (enough to provide the fuel for just one nuclear power reactor) and had no stockpile of 20% enriched uranium, it could acquire the HEU for a nuclear weapon in just two weeks or enough HEU for five nuclear weapons in just five weeks. (See Appendix 2)

What is worse, a Comprehensive Solution based on the terms of the JPA will be setting a precedent for all other non-nuclear weapon countries. After all, if Iran is to be treated in the same manner as that of any non-nuclear weapon state party to the NPT, then the reverse would be true as well and these countries could claim the same treatment afforded to Iran. If Iran which has violated its IAEA safeguards by conducting clandestine centrifuge enrichment and which has defied multiple U.N. Security Council resolutions demanding that it halt centrifuge enrichment, is allowed to retain this capability, on what basis can any country that has abided by its IAEA safeguard obligations be denied centrifuge enrichment? A Comprehensive Solution based on the terms of the JPA will set the stage for many countries to acquire centrifuge enrichment, making it easy for them to produce the HEU for nuclear weapons whenever they desire to acquire such weapons.

In addition to its centrifuge enrichment program, Iran is constructing a plutonium production reactor near Arak which would use natural uranium fuel, use heavy water as both the moderator and coolant and have a thermal power output of 40 MW. Iran has claimed this will be a research reactor and the IAEA has used this terminology as well. However, natural uranium fueled reactors make relatively poor research reactors due to the low density of U-235 in the fuel. Of

[18] Transcript, "Fareed Zakaria GPS," CNN, aired January 26, 2014.

the five non-electric power producing, natural uranium fueled, heavy water reactors with thermal power outputs of greater than 1MW currently in operation outside of the P5,[19] all five are plutonium production reactors supporting nuclear weapons programs. (Appendix 1) Clearly Iran's main intention in building the Arak reactor was for it to function as a plutonium production reactor and not a research reactor.[20] Iran already has a research reactor (the Tehran Research Reactor, TRR) to provide for its legitimate nuclear research needs. If Iran were to need a second research reactor (which seems unlikely), Iran could build a copy of the TRR.

Some have suggested that the Arak reactor's fuel and power level be changed to greatly reduce the amount of plutonium that this reactor would produce. Even then there would be the danger that the reactor could be reconverted to plutonium production using natural uranium fuel and heavy water once the Comprehensive Solution has expired. At a minimum it would be necessary to have Iran shut down and dismantle its heavy water production facility and export its stocks of heavy water. Better still, the reactor should never be finished and its components should be destroyed.

IAEA Safeguards Need to Provide Timely Detection of Diversion

For a number of years I have pointed out that Iran's centrifuge enrichment program raises broader concerns about the adequacy of IAEA safeguards regarding various fuel cycle facilities and stocks of HEU and separated plutonium.[21] According to the IAEA "…the objective of safeguards is the timely detection of diversion of significant quantities of *nuclear material* from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown and deterrence of such diversion by the risk of early detection."[22] [Emphasis in original] Presumably, "timely detection" allows sufficient time not only for a diversion to be detected but also for action to be taken to prevent safeguarded nuclear material or facilities from being used to produce the fissile material (HEU or plutonium) that could be used for nuclear weapons. To allow sufficient time for counteraction, the detection time should be at least many months.

The IAEA has never been willing to admit that there are nuclear materials and facilities that are inherently unsafeguardable in the sense that timely detection of diversion is impossible. To take an extreme case, imagine that a country has produced large spheres of HEU or plutonium metal. The country might claim these spheres are for peaceful criticality experiments but they could also be used as the cores for nuclear weapons. These spheres could be inserted into the nonnuclear components of a nuclear weapon and used in combat in a matter of hours. Obviously

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[19] These are the five permanent members of the UN Security Council, China, France, Russia, the UK and the U.S. which are also the five major nuclear weapon powers.

[20] In 2003, Ghalamreza Aghazadeh, the head of the Atomic Energy Organization of Iran, made statements implying that he viewed the centrifuge enrichment effort and the building of the research reactor as parallel efforts and it was important that one of them succeed. Such a view would only make sense if these undertakings were part of a nuclear weapons effort, where they would be parallel sources of fissile material (either HEU or plutonium). See: David Albright, *Peddling Peril*, Free Press, New York, 2010, pp.192-193.

[21] Gregory S. Jones, "An In-Depth Examination of Iran's Centrifuge Enrichment Program and Its Efforts to Acquire Nuclear Weapons," August 9, 2011, pp.16-23, http://npolicy.org/article.php?aid=1092&rid=4

[22] *The Structure and Content of Agreements Between The Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons*, INFCIRC/153, International Atomic Energy Agency, June 1972, p.9.

any detection of the diversion of these spheres could hardly be timely. Some boundary lines are necessary between nuclear materials and facilities that can be effectively safeguarded and those that cannot.

Thirty five years ago my colleagues at Pan Heuristics and I analyzed where the boundary lines should be.[23] For safeguards to be able to provide timely detection of diversion, non-nuclear weapon countries must be prohibited from possessing any materials or facilities that can quickly provide nuclear material for nuclear weapons. This includes prohibiting not only enrichment and reprocessing facilities but also separated HEU, plutonium or U-233; and HEU, plutonium or U-233 that is contained in unirradiated reactor fuel (such as HEU fuel for research reactors or mixed oxide fuel for power reactors).

For several years, I have noted that such restrictions would require shutting down enrichment facilities not only in Iran but also in Germany, the Netherlands, Brazil and Japan, as well as reprocessing facilities in Japan.[24] Such restrictions would also require the removal of Japan's massive plutonium stockpile of 9 metric tons (enough to produce thousands of nuclear weapons). This stockpile was created as a result of its civil nuclear power program. Japan has an additional 35 metric tons of separated plutonium that are stored overseas.[25]

Since January 2014, there has been much public discussion regarding Japan's plutonium stockpile. A small part of Japan's stockpile was provided to Japan in the 1960s by the U.S. This material consists of 331 kilograms of plutonium with a near weapons-grade composition. This plutonium could be used to produce at least sixty nuclear weapons. Some time ago the U.S. became concerned that this material could be stolen by terrorists from the poorly protected Fast Critical Assembly (FCA) in Japan where this material is used. The U.S. requested that Japan return the plutonium. Japan apparently initially resisted this request but on March 24, 2014 Japan and the U.S. announced that Japan would be returning this plutonium. The FCA also houses over 200 kilograms of HEU provided by the UK, which could be used to produce at least ten nuclear weapons. This material will also be removed from Japan.

These actions have focused greater attention on the rest of Japan's plutonium stockpile, with China in particular raising questions regarding why Japan has such a large stockpile and why it plans to begin to substantially increase the stockpile by starting a large reprocessing plant later this year. The U.S. though concerned that terrorists might steal some of Japan's plutonium, said "We are not at all concerned that the plutonium is either being handled improperly or that there isn't a plan for disposition."[26] At almost the same time, IAEA Director General Yukiya Amano said, "We have drawn (the) conclusion that all nuclear materials in Japan stay in peaceful

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[23] Albert Wohlstetter, Thomas A. Brown, Gregory Jones, David C. McGarvey, Henry Rowen, Vince Taylor and Roberta Wohlstetter, *Swords from Plowshares*, The University of Chicago Press, 1979.

[24] Gregory S. Jones, "Facing the Reality of Iran as a De Facto Nuclear State: Centrifuge Enrichment and the IAEA February 24, 2012 Safeguards Update," March 22, 2012, p.11. http://npolicy.org/article_file/Facing_the_Reality_of_Iran_as_a_De_Facto_Nuclear_State.pdf

[25] *Global Fissile Material Report 2011: Nuclear Weapon and Fissile Material Stockpiles and Production*, Sixth annual report of the International Panel on Fissile Materials, January 2012, p.23.

[26] Statement of Joseph Macmanus, U.S. ambassador to the IAEA, see: Frank Dahl, "U.S. says 'not at all concerned' about Japan's plutonium," *Reuters*, March 5, 2014.

purposes. Therefore, I do not have (a) reason to have concern that this (material)…will be diverted."[27]

These are remarkable statements. They say that because Japan has not diverted its plutonium stockpile up to now, there is no reason to be concerned that Japan might divert the plutonium in the future. Implicitly, these statements involve predictions about what Japan's government might do many years in the future. Predicting the future actions of governments is a highly uncertain exercise, as has been illustrated by the unforeseen use of chemical weapons by Syria and Russia's annexation of the Crimea. Indeed, Japan has been aware of the nuclear weapons potential of its acquisition of separated plutonium since the beginning of its program to stockpile this material.[28] More recently, a number of Japanese political figures have openly argued that Japan should continue its plutonium program as a nuclear weapon hedge and Japan's parliament has amended its atomic energy act to explicitly include "national security" as one of the prime missions of Japan's civilian nuclear energy program. Therefore there is no guarantee that one day Japan might not want to use its nuclear assets for nuclear weapons.

It is well past time for the IAEA to stop pretending that it can effectively safeguard such dangerous nuclear materials and activities. Nuclear safeguards are supposed to be more than just an accounting system. Rather than relying on clairvoyance, the IAEA safeguards should do what they are supposed to do, deter the diversion of nuclear materials by providing *timely* detection of that diversion. The IAEA needs to delineate those nuclear materials and facilities for which it cannot provide timely detection of diversion.

The U.S. needs to stop supporting the IAEA's claims to be able to safeguard any nuclear materials and facilities, regardless of how quickly they could be used to produce a nuclear weapon, and urge the IAEA to take the necessary steps to clarify the limits of its safeguards. By clarifying that centrifuge enrichment facilities in nonnuclear weapon states are unsafeguardable, it will be possible to fulfill the JPA's long-term promise that Iran "will be treated in the same manner as that of any non-nuclear weapon state," while denying Iran the "right" to centrifuge enrichment facilities. Unless nuclear facilities and materials in nonnuclear weapon countries are restricted to only those that are truly safeguardable, the ability to produce nuclear material for nuclear weapons will continue to spread from country to country and we should expect additional "Irans" in the future.

[27] Fredrik Dahl, "Japan's plutonium stocks no reason for concern—IAEA chief," *Reuters*, March 3, 2014.
[28] Toshihiro Okuyama, Yumi Nakayama, Douglas Birch, Jeffery Smith and Jake Adelstein, "Plutonium fever blossoms in Japan," Center for Public Integrity, March 19, 2014.

Appendix 1

Detailed Analysis of the IAEA February 20, 2014 Safeguards Report and the IAEA March 20, 2014 Update Regarding the Implementation of the Joint Plan of Action Methods Whereby Iran Could Produce HEU and/or Plutonium for Nuclear Weapons

Iranian Centrifuge Enrichment of Uranium

Iran has three known centrifuge enrichment facilities. Iran's main facility is the Fuel Enrichment Plant (FEP) at Natanz. The basic unit of Iran's centrifuge enrichment effort is a cascade which originally consisted of 164 centrifuges but Iran has now modified the majority of the cascades by increasing the number of centrifuges to 174. (All centrifuges operated up to now have been of the IR-1 type.) Each cascade is designed to enrich natural uranium to 3.5% enriched uranium.

As of February 10, 2014, Iran had installed a total of 90 cascades of IR-1 type centrifuges at the FEP. Of these 90 cascades, 54 were declared by Iran as being fed with uranium hexafluoride and therefore were producing 3.5% enriched uranium. In addition Iran has begun to install some of the more advanced IR-2m centrifuges at the FEP. Iran has installed six cascades of IR-2m type centrifuges. Thus far no IR-2m cascade has begun to enrich uranium. In March 2013, Iran stated that it would install 3,000 of these more advanced centrifuges though the JPA has put those plans on hold.[29] Iran began producing 3.5% enriched uranium at the FEP in February 2007 and as of February 9, 2014 Iran had produced a total of 7,498 kilograms (in the form of 11,091 kilograms of uranium hexafluoride) at this location. During the interval since the last IAEA report, the FEP's production rate of 3.5% enriched uranium has been 158 kilograms per month.[30] (See Table 2)

Iran also has the Pilot Fuel Enrichment Plant (PFEP) at Natanz, which is used to test a number of more advanced centrifuge designs. These are usually configured as either single centrifuges or test cascades containing various numbers of centrifuges. Two of these test cascades are complete cascades. One contains 164 IR-4 centrifuges and one contains 162 IR-2m centrifuges. Up to now no enriched uranium has been produced by these test cascades and no production will be permitted as long as the JPA is in force.

In addition, there are two full cascades each with 164 IR-1 type centrifuges at the PFEP. These two cascades were interconnected and used to process 3.5% enriched uranium into 19.7% enriched uranium. In February 2010, Iran began producing 19.7% enriched uranium at the PFEP using one cascade. It added the second cascade in July 2010. Under the terms of the JPA, Iran ceased production of 19.7% enriched uranium at the PFEP on January 20, 2014 and disconnected the interconnection between the two cascades. As of that date, Iran had produced 136.5 kilograms of 19.7% enriched uranium (in the form of 201.9 kilograms of uranium hexafluoride) at this facility. Since January 20, 2014, these two cascades have produced 3.5% enriched uranium from natural uranium feed. As of February 9, 2014, these two cascades had produced 2.8 kilograms of 3.5% enriched uranium at a rate of 4 kilograms per month.

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[29] Yeganeh Torbati, "Iran says building 3,000 advanced centrifuges," *Reuters*, March 3, 2013.
[30] To avoid problems with the fact that the length of a month is variable, I have adopted a uniform month length of 30.44 days.

Table 2

Average Iranian Production Rate of 3.5% Enriched Uranium
November 2008 to February 2014

IAEA Reporting Interval	Average 3.5% Enriched Uranium Production Rate (Kilograms Uranium per Month)
11/17/08-1/31/09	52
2/1/09-5/31/09	53
6/1/09-7/31/09	57
8/1/09-10/31/09	57
11/22/09-1/29/10	78
1/30/10-5/1/10	81
5/2/10-8/6/10	80
8/7/10-10/17/10	95
10/18/10-2/5/11	88
2/6/11-5/14/11	105
5/15/11-8/13/11	99
8/14/11-11/1/11	97
11/2/11-2/4/12	115
2/5/12-5/11/12	158
5/12/12-8/6/12	161
8/7/12-11/11/12	156
11/12/12-2/3/13	162
2/4/13-5/4/13	158
5/5/13-8/10/13	156
8/11/13-11/5/13	154
11/6/13-1/20/14	158
1/21/14-2/9/14	178

Finally, Iran has constructed an enrichment facility near Qom. Known as the Fordow Fuel Enrichment Plant (FFEP), Iran clandestinely started to construct this plant in violation of IAEA safeguards. Iran only revealed the existence of this plant in September 2009, after Iran believed that the West had discovered the plant.

The FFEP is designed to hold a total of 16 cascades (each cascade holds 174 IR-1 type centrifuges for a total of 2,784 centrifuges). Fifteen of the sixteen cascades have been vacuum tested and could operate at any time. The sixteenth cascade had been fully installed in November 2012 but for some reason, some of the centrifuges in this cascade have since been removed.

Only four of the fifteen cascades are producing enriched uranium. Until January 20, 2014, they were configured as two sets of two interconnected cascades so as to produce 19.7% enriched uranium from 3.5% enriched uranium as was done at the PFEP. The first of these two sets began production on December 14, 2011 and the second set began operation on January 25, 2012. As of January 20, 2014, Iran had produced 166.3 kilograms of 19.7% enriched uranium (in the form of 245.9 kg of uranium hexafluoride) at this facility. Under the terms of the JPA, Iran ceased production of 19.7% enriched uranium at the FFEP on January 20, 2014 and disconnected the interconnection between the two sets of cascades. Since that date, these four cascades have produced 3.5% enriched uranium from natural uranium feed. As of February 9, 2014, these four cascades had produced 10.7 kilograms of 3.5% enriched uranium at a rate of 16 kilograms per month.

Combining the output from the PFEP and the FFEP, Iran had produced a total of 302.7 kilograms of 19.7% enriched uranium when such production was ended on January 20, 2014. (See Table 3) Since the end of 2011, Iran has converted some of the 19.7% enriched uranium from a hexafluoride into an oxide so that it could be used to produce fuel for the Tehran Research Reactor (TRR). Iran had also blended down a small quantity of this material in early 2012. As a result on January 20, 2014, Iran had 141.4 kilograms of 19.7% enriched uranium in the form of 209.1 kilograms of uranium hexafluoride.

Under the terms the Joint Plan of Action half of Iran's stockpile of 19.7% enriched uranium in the form of uranium hexafluoride (70.7 kilograms) on January 20, 2014 should be converted into an oxide form by July 20, 2014 and the other half should be blended down to an enrichment of less than 5% by April 20, 2014. As of March 12, 2014 Iran had fed 21.4 kilograms into the oxide conversion process since January 20, 2014 which gives a rate of 12.8 kilograms per month. At this rate Iran should be able to meet the July 20, 2014 deadline. Combined with 19.7% enriched uranium that had been fed into the oxide conversion process prior to January 20, 2014, Iran would then have fed 230.6 kilograms into this process by July 20, 2014. As of March 15, 2014 Iran had blended down 50.4 kilograms since January 20, 2014 which gives a rate of 28.4 kilograms per month. At this rate Iran should be able to meet the April 20, 2014 deadline. As of mid-March 2014, Iran had 69.6 kilograms of 19.7% enriched uranium in the form of hexafluoride. Press reporting as of mid-April 2014 indicates that both the blend down and oxide conversion are continuing on schedule.

As of February 9, 2014 Iran had produced 7,498 kilograms of 3.5% enriched uranium at the FEP, 3 kilograms at the PFEP and 11 kilograms at the FFEP for a total of 7,512 kilograms. Subtracting the amounts of 3.5% enriched uranium fed into the PFEP and FFEP prior to January 20, 2014 to produce 19.7% enriched uranium and a small amount of 3.5% enriched uranium used to fuel the TRR would leave 5,153 kilograms. Assuming that Iran is blending down its 19.7% enriched uranium to 3.5% enriched uranium, one would need to add 127 kilograms to this amount, which gives Iran a total stockpile of 3.5% enriched uranium on February 9, 2014 of 5,280 kilograms.

Since January 20, 2014, using centrifuges at the FEP, PFEP and FFEP, Iran was producing 3.5% enriched uranium at the rate of 178 kilograms per month. It is easy to calculate that Iran has an enrichment capacity of about 7,800 SWU per year. Assuming that Iran continued producing 3.5% enriched uranium at this same rate by mid-March its stockpile, including material produced by blend down, would be about 5,680 kilograms. By July 20, 2014 its stockpile of 3.5% enriched uranium will be about 6,570 kilograms.

Table 3

Iranian 19.7% Enriched Uranium
April 2010 to March 2014

IAEA Reporting Interval	Average Monthly* Production at PFEP (kg U)	Average Monthly* Production at FFEP (kg U)	Total Average Monthly* Production (kg U)	Cumulative Production (kg U)	Cumulative 20% U Fed into Oxide Conversion Process (kg U)	Cumulative 20% U Blended Down to Less Than 5% (kg U)	Total Net 20% U in Form of UF_6 (kg U)
2/9/10-4/7/10	2.0	0	2.0	3.9	0	0	3.9
4/8/10-8/20/10	2.5	0	2.5	14.9	0	0	14.9
8/21/10-11/19/10	2.5	0	2.5	22.3	0	0	22.3
11/20/10-2/11/11	2.6	0	2.6	29.5	0	0	29.5
2/12/11-5/21/11	2.7	0	2.7	38.3	0	0	38.3
5/22/11-8/20/11	3.2	0	3.2	47.9	0	0	47.9
8/21/11-10/28/11	2.7	0	2.7	53.9	0	0	53.9
End 10/11-Mid 2/12**	3.1	6.5***	9.6	73.8	7	0	66.8
Mid 2/12-Mid 5/12	3.1	5.2	8.3	98.4	29.1	1.1	68.2
Mid 5/12-Mid 8/12	3.0	6.7	9.7	128.0	48.2	1.1	78.7
Mid 8/12-Mid 11/12	3.3	6.9	10.2	157.4	55.9	1.1	100.4
Mid 11/12-Mid 2/13	2.8	7.7	10.5	189.1	75.0	1.1	113.0
Mid 2/13-Mid 5/13	3.1	7.3	10.4	219.3	95.2	1.1	123.0
Mid 5/13-Mid 8/13	3.1	7.0	10.1	251.8	125.1	1.1	125.6
Mid 8/13-End 10/13	3.3	7.1	10.4	277.5	144.3	1.1	132.1
End 10/13-1/20/14	3.1	6.3	9.4	302.7	160.2	1.1	141.4
1.20/14-Mid 3/14	0	0	0	302.7	181.6	51.5	69.6

*In order to avoid the problem of the variable length of a month I use a uniform 30.44 day month
**IAEA inspections are carried out at the PFEP and the FFEP on slightly different dates
***The first set of interconnected cascades began operation on 12/14/11. The second set began operation on 1/25/12.

Iranian Options for Producing HEU

Given that Iran currently has in operation a total enrichment capacity of about 7, 800 SWU per year at the FEP, FFEP, and PFEP and in mid-March had stockpiles of 5,680 kilograms of 3.5% enriched uranium and 69.6 kilograms of 19.7% enriched uranium in the form of hexafluoride, Iran has a number of options for producing the 20 kilograms of HEU required for a nuclear weapon.

The most straightforward method Iran could use to produce HEU would be batch recycling. In this process, no major modifications are made to Iran's enrichment facilities but rather enriched uranium is successively run though the various enrichment facilities in batches until the desired enrichment is achieved. Iran could use a two-step process to produce HEU. This process is illustrated in Table 4.

Table 4

Time, Product and Feed Requirements for the Production of HEU by Batch Recycling at the FEP, PFEP and FFEP (Iran's Mid-March 2014 Uranium Stockpiles)
Cycles Carried out Simultaneously

Enrichment Plant	Product Enrichment and Quantity	Feed Enrichment and Quantity	Time for Cycle (Days)
FEP	19.7% 91.4 kg	3.5% 1,079 kg	25***
PFEP and FFEP*	90.0% 20 kg	19.7% 160 kg**	42***
Total			42****

* The combined plant inventory at the PFEP and FFEP is 0.8 kilogram.
** Includes 69.4 kilograms of 19.7% enriched uranium that Iran has already stockpiled.
*** Includes two days to account for equilibrium and cascade fill time.
**** Cycle times *not* additive since cycles are simultaneous.

This calculation assumes that the cascades at the PFEP and FFEP can be reconnected to form tandem cascades and start operation almost immediately and that the tandem cascades can be adjusted so as to produce 90% enriched uranium from 19.7% enriched feed.[31] It takes 160 kilograms of 19.7% enriched uranium to produce the 20 kilograms of 90% enriched uranium needed for a nuclear weapon. The 160 kilograms required is greater than Iran's current stockpile of 19.7% enriched uranium (counting only the 69.4 kilograms which is in the form of 102.7 kilograms of uranium hexafluoride.) However, Iran can produce additional 19.7% enriched uranium by using 3.5% enriched uranium as feed to the cascades at the FEP. Iran produced 19.7% enriched uranium at the PFEP using a cascade identical to the ones at the FEP between February and July 2010.

[31] William C, Witt *et al.*, "Modeling Iran's Tandem Cascade Configuration for Uranium Enrichment by Gas Centrifuge," INMM 54th Annual Meeting, July 14-18, 2013.

Nor would Iran need to stop at producing only one nuclear weapon's worth of HEU. After using 1,079 kilograms of 3.5% enriched uranium required to produce 20 kilograms of HEU, Iran would still have 4,600 kilograms of 3.5% enriched uranium left over. This material could be enriched to produce an additional 390 kilograms of 19.7% enriched uranium. This could be used at the PFEP and FFEP to produce an additional 49 kilograms of 90% enriched uranium. The FEP could produce the 19.7% enriched uranium at a rate sufficient so that the PFEP and FFEP could produce 60 kilograms of enriched uranium (enough for three nuclear weapons) in a total of about four months.

Though much attention has been focused on Iran's stockpile of 19.7% enriched uranium, most of the reason why Iran can produce the HEU for a nuclear weapon as quickly as it can is because of its enrichment capacity and not its 19.7% enriched uranium stockpile. As is shown in Table 5, even come July 20, 2014 when Iran's stockpile of 19.7% enriched uranium in the form of hexafluoride should no longer exist, it will still be able to produce a weapon's worth of HEU in just eight weeks which is only somewhat longer than the six weeks that would be required given Iran's current stockpile of 19.7% enriched uranium (Table 4). As is shown in Appendix 2, if Iran were to have an even larger centrifuge enrichment capacity, the time required for it to produce the HEU for a nuclear weapon could be quite short even if Iran does not have a stockpile 19.7% enriched uranium. At current production rates, by July 20, 2014 Iran's stockpile of 3.5% enriched uranium will have grown to 6,570 kilograms which would allow Iran to produce a total of 69 kilograms of HEU. Iran could produce 60 kilograms of HEU which is enough for three nuclear weapons in just four and one half months.

Table 5

Time, Product and Feed Requirements for the Production of HEU by Batch Recycling at the FEP, PFEP and FFEP
No Iranian Stockpile of 19.7% Enriched Uranium

Enrichment Plant	Product Enrichment and Quantity	Feed Enrichment and Quantity	Time for Cycle (Days)
FEP	19.7% 160.8 kg	3.5% 1897 kg	44**
PFEP and FFEP*	90.0% 20 kg	19.7% 160 kg	42**
Total			54***

* The combined plant inventory at the PFEP and FFEP is 0.8 kilogram.
** Includes two days to account for equilibrium and cascade fill time.
*** Cycle times *not* additive. The FEP starts producing 19.7% enriched uranium 10 days in advance of the start of HEU production at the PFEP and FFEP.

This analysis has thus far ignored the 19.7% enriched uranium that has been fed into the oxide conversion process. As of February 16, 2014, Iran had fed 177.4 kilograms into the oxide conversion process, of which 120.6 kilograms had been converted into oxide (U_3O_8) and 36.8 kilograms were contained in solid and liquid waste. This indicates a conversion efficiency of 76.6%. Presumably the remaining 20 kilograms was still in process. Assuming Iran maintains the same conversion efficiency by July 20, 2014 Iran will have produced around 177 kilograms of 19.7% enriched uranium in oxide form. As of February 2014 Iran had irradiated about 11 kilograms and over time Iran will irradiate increasing amounts of this material. By July 2014, Iran is unlikely to have irradiated more than about 17 kilograms in total so that Iran would still have about 160 kilograms of unirradiated 19.7% enriched uranium oxide. This is enough to further enrich to produce one nuclear weapon's worth (20 kilograms) of HEU.

The chemistry required to convert this material back into hexafluoride is fairly simple. Uranium ore is in oxide form and Iran has facilities to convert the ore into hexafluoride and has done so on a large scale (hundreds of tons) to provide feed for its enrichment program. However, due to criticality concerns, Iran could not use these facilities to convert 19.7% enriched uranium oxide into hexafluoride. Rather Iran would need to build a new small, critically safe facility to carry out this conversion. It would probably take Iran a few months to build such a facility and get it running. The JPA prohibits Iran from possessing such a facility which means that Iran could only start its construction once the JPA had lapsed or Iran decided to be no longer bound by its restrictions.

Once the facility was running its throughput would probably be fairly low due to the need to limit batch size for criticality reasons. Iran has been converting hexafluoride into oxide at a rate of no more than 13 kilograms per month and I would expect the rate of hexafluoride production from oxide to be about the same. Iran could always increase the conversion rate by building multiple facilities but why should it bother? Iran's enrichment program could provide 19.7% enriched uranium hexafluoride at a much higher rate if needed. Iran was already producing 19.7% enriched uranium at a rate of about 10 kilograms per month before the restrictions of the JPA took effect. If Iran were to have brought all of the FFEP cascades online it could increase this production rate to around 30 kilograms per month. If Iran were to use all of the cascades currently in operation at the FEP to produce 19.7% enriched uranium, then the rate could be around 100 kilograms per month. (See Table 4) If Iran were to bring online at the FEP the many cascades that are already installed but not operating (including those cascades containing the new IR-2m centrifuges) the production rate could be even higher. As a result in the first six months or so after Iran had embarked on the production of HEU for nuclear weapons, its stockpile of 19.7% enriched uranium in oxide form would not be of great concern but in the longer-term this material could be used by Iran to supplement its nuclear weapon stockpile.

Under the terms of the JPA Iran is supposed to convert any 3.5% enriched uranium that is "newly enriched" after January 20, 2014 into an oxide form using a new facility call the Enriched Uranium Production Plant (EUPP). Given that Iran is producing 178 kilograms of 3.5% enriched uranium per month at its three enrichment facilities, Iran is committed to convert about 1,070 kilograms of 3.5% enriched uranium into an oxide form by July 20, 2014. I have estimated that Iran will have a total of 6,570 kilograms of 3.5% enriched uranium on July 20, 2014. Therefore this would leave Iran with about 5,500 kilograms of 3.5% enriched uranium in hexafluoride form on this date assuming that the conversion to oxide actually takes place. Thus far the completion of the EUPP is behind schedule and no conversion to oxide of 3.5% enriched uranium had yet taken place as of mid-April, 2014. Given the delay it is not clear that Iran will be able to meet the schedule to convert the required amount of 3.5% enriched uranium into an oxide form.

The conversion to oxide is not the barrier to further enrichment for 3.5% enriched uranium that it is for 19.7% enriched uranium. The criticality concerns with 3.5% enriched uranium are greatly reduced when compared to that of 19.7% enriched uranium. To convert 3.5% enriched uranium oxide back into hexafluoride, Iran would likely not have to build a special critically safe facility as for the 19.7% enriched uranium but rather could probably adapt its current natural uranium hexafluoride production facilities to the task. It would probably take only a month or two to convert 1,070 kilograms of 3.5% enriched uranium in the form of oxide back into hexafluoride. Since it would take Iran around four months to convert 5,500 kilograms of 3.5% enriched uranium in the form of hexafluoride into HEU, the oxide reconversion could be carried out in sufficient time to support any Iranian effort to produce HEU for nuclear weapons. Even if somehow the 1,070 kilograms of 3.5% enriched uranium were to be unavailable, Iran would still be able to produce about 58 kilograms of HEU from the 5,500 kilograms of 3.5% enriched uranium. This amount of HEU would still be sufficient for about three nuclear weapons.

Nor is a multi-step enrichment process the only pathway for Iran to produce the fissile material required for nuclear weapons, though it is the process that allows Iran to produce HEU most quickly. Iran could produce HEU at a clandestine enrichment plant designed to produce 90% enriched uranium from natural uranium feed.

A clandestine enrichment plant containing 3,400 IR-1 centrifuges (1.0 SWU per centrifuge-year) could produce around 20 kilograms of HEU (the amount required for one nuclear weapon) each year using natural uranium as feed. Since this option does not require any overt actions, the relatively slow rate of HEU production would not necessarily be of any concern to Iran. Such production could be going on right now and the West might well not know. A clandestine enrichment plant would need a source of uranium but Iran is producing uranium at a mine near Bandar Abbas.[32] Since Iran has yet to implement the Additional Protocol to its IAEA safeguards, this uranium mining is unsafeguarded and the whereabouts of the uranium that Iran has produced there is unknown.

Iran then, has at least two methods whereby it could produce the HEU required for a nuclear weapon. By batch recycling at the FEP, PFEP and the FFEP (Table 4), Iran could produce enough HEU for a nuclear weapon in about six weeks. Using its current stockpiles of 3.5% and 19.7% enriched uranium, Iran could produce enough HEU for three nuclear weapons in about four months. Even when Iran's stockpile of 19.7% enriched uranium has been reduced to zero (Table 5), the time required for Iran to produce the HEU for a nuclear weapon would be eight weeks. Alternatively, Iran might build or have already built a stand-alone clandestine plant to enrich natural uranium to HEU. Such a plant would only produce enough HEU for around one weapon a year but since the plant could go undetected for many years, Iran could produce a sizable stockpile before detection.

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[32] *Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran*, GOV/2011/7, February 25, 2011, p.9.

Iranian Production of Plutonium

In addition to its centrifuge enrichment program, Iran is constructing a plutonium production reactor near Arak which would use natural uranium fuel, use heavy water as both the moderator and coolant and have a thermal power output of 40 MW. Iran has claimed this will be a research reactor and the IAEA has used this terminology as well. However, natural uranium fueled reactors make relatively poor research reactors due to the low density of U-235 in the fuel. Only ten natural uranium fueled, heavy water moderated research reactors with a thermal power output of greater than 1 MW have ever been built outside of the P5. Of these ten reactors, five served as plutonium production reactors to support nuclear weapons programs (Israel, India (2), Taiwan and Pakistan). Three more were constructed to help provide a nuclear weapon option (Japan, West Germany and Switzerland). One of the two reactors in Canada provided some plutonium to support the nuclear weapons program in the UK. The other Canadian natural uranium fueled heavy water research reactor (NRU) operated only six years before it was converted to operate on more highly enriched fuel.

Of these ten reactors only three are still in operation using natural uranium fuel (Israel, India and Pakistan). In addition there are two other non-electric power producing natural uranium fueled heavy water reactors (with a third under construction) in Pakistan but there is not even the pretense that these are anything other than plutonium production reactors. Of the five non-electric power producing, natural uranium fueled, heavy water reactors with thermal power outputs of greater than 1MW currently in operation outside of the P5, all five are plutonium production reactors supporting nuclear weapons programs. Clearly Iran's calling the Arak reactor a research reactor is just a cover for the reactor's true mission.

Iran has said that the Arak reactor will use 150 fuel elements containing a total of about 8.5 metric tons of natural uranium in the form of uranium dioxide and will use about 100 metric tons of heavy water. Note that 100 metric tons is a large amount for this type of reactor which typically would require only 70 to 80 metric tons.[33] Once the reactor was in operation it could produce up to 11 kilograms of plutonium per year which would be enough for two or three nuclear weapons.[34]

The reactor is only partially completed. The reactor vessel has been installed and connected to the cooling and moderator piping but major equipment such as the control room equipment, the refueling machine and the reactor cooling pumps have not been installed. Iran has produced 13.8 metric tons of natural uranium in the form of uranium dioxide which is qualified for fuel fabrication. This amount would be sufficient to fuel the reactor for more than one year. Iran has produced only 11 of the required 150 fuel elements. Iran has produced all of the required 100 metric tons of heavy water. Under the terms of the JPA, Iran has stopped major construction at

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[33] The IR-40 will have a power output of 40 MW. The Canadian NPD had a power output of 88 MW yet required only 75 metric tons of heavy water. L.W. Woodhead and W.M. Brown, "Performance and problems of NPD," *Proceedings of the Third International Conference of the Peaceful Uses of Atomic Energy*, August 31-September 9, 1964, Volume 5, Nuclear Reactors—I. Gas-cooled and Water-cooled Reactors, United Nations, New York, 1965. Similarly, Dhruva, India's 100 MW plutonium production reactor is reported to have required only 78 metric tons of heavy water. Gary Milhollin, "Dateline New Delhi: India's Nuclear Cover-up," *Foreign Policy*, Fall 1986.
[34] This calculation assumes that the fuel achieves a burnup of 1,000 MWD/Te. The plutonium would be 5.8% plutonium 240.

the reactor site and the production of fuel elements. Even before the JPA the pace of work on the reactor was slow and it was going to be 2015 at the earliest before the reactor could start operation. Once the reactor starts operation it will still take about another year before Iran would be able to produce and separate enough plutonium for a nuclear weapon.

Iran's heavy water plant has been in operation for many years. Iran has said that its heavy water production plant can produce 16 metric tons per year which would be more than enough to provide the makeup heavy water needed for this reactor once it is in operation. Neither the IAEA nor any other public source has discussed where Iran might have gotten the technology needed for this plant. The plant seems to rely on the widely used water-hydrogen sulfide chemical exchange process, but as the Indians found out in the 1970s, the engineering needed to successfully run such a plant is non-trivial. In particular the long equilibrium time of this process puts a high premium on the ability to operate the plant without interruption for many months at a time. Pakistan may have sold Iran the needed technology but this only raises the question of where did Pakistan acquire the technology.

It has been suggested to convert the Arak reactor to use low-enriched uranium fuel to reduce the amount of plutonium that the reactor could produce. Some have even suggested that such a step would "de-fang" the reactor. However, if the reactor were to use 3.5% enriched uranium fuel, it would still be able to produce 5 to 6 kilograms of plutonium per year.[35] If the reactor were to use 20% enriched uranium fuel, then the amount of plutonium produced in the fuel would only be about 1 kilogram per year. However, in this case Iran could irradiate natural uranium targets and still produce around 6 kilograms of plutonium per year. Reducing the power level in the reactor would be a more effective way to reduce its plutonium production since the rate of this production is directly proportional to the power level. If the reactor were to use low enriched (3.5% or 20% enriched fuel) and have a power level of only 10 MW then it would only be able to produce 1-2 kilograms per year.

Even then there would be concerns that since this reactor was designed as a plutonium production reactor, it could be reconverted to this function. At a minimum it would be necessary to have Iran shutdown and dismantle its heavy water production facility and export its stocks of heavy water. Better still the reactor should never be finished and its components destroyed. It is highly doubtful that Iran needs a second high-power research reactor in addition to its already operating TRR. In the unlikely event that it does, it would make far more sense for Iran to build a copy of the TRR. Not only would this reactor be a much more capable research reactor but it would only be able to produce 1-2 kilograms of plutonium per year.

[35] At a burnup of 3,000 MWD/Te, six kilograms of plutonium per year could be produced with a Pu240 content of 4.2%. At a burnup of 10,000 MWD/Te, five kilograms of plutonium per year could be produced with a Pu-240 content of 11.2%.

Appendix 2

Limiting Iran to Producing and Stockpiling Less Than 5% Enriched Uranium Does Not Prevent Easy Access to HEU

As was discussed in the text, Iranian President Rouhani has proposed that Iran should be able to indigenously provide the fuel to support 20,000 megawatts of nuclear power. This would imply a massive expansion of Iran's centrifuge enrichment program and would require the equivalent of about two million of Iran's current IR-1 centrifuges which would have an enrichment output of about two million SWU per year. Yet even if Iran were to acquire an enrichment capacity of only 100,000 SWU per year, Iran could produce enough HEU for a nuclear weapon in just weeks starting from uranium enriched to less than 5%.

If Iran produced 4.1% enriched uranium[36] with an enrichment capacity of 100,000 SWU per year, it would produce about 15 metric tons of enriched uranium per year. This amount would be somewhat less than that needed to fuel a single large power reactor yet, using batch recycling, these enrichment facilities could produce enough HEU for a nuclear weapon in just two weeks. This process is shown in Table 6.

In the first step, 4.1% enriched uranium is processed into 20.2% enriched uranium. In the second step, this uranium is processed into 60.2% enriched uranium and the third step completes the process by producing the 20 kilograms of 90% enriched uranium needed for a nuclear weapon. Each step produces not only the material needed to be processed in the next step but the material needed for the plant inventory which in this case is 30 kilograms per step.

Instead of just producing enough HEU for one nuclear weapon, Iran could produce enough HEU for five nuclear weapons (100 kilograms) in a single batch recycling campaign. This process would take about five weeks and is shown in Table 7. This process would require starting with 6,090 kilograms of 4.1% enriched uranium but since the plant will be producing about 15,000 kilograms per year, it would not be hard for Iran to stockpile this quantity of enriched uranium.

These calculations confirm that any commercial scale centrifuge enrichment plant is inherently unsafeguardable. The goal of IAEA safeguards is to provide *timely* detection of diversion of nuclear material. Clearly this goal cannot be met for a commercial scale centrifuge enrichment plant.

[36] With tails of 0.2%.

Table 6

Time, Product and Feed Requirements for the Production of 20 kg of HEU by Batch Recycling at a Centrifuge Enrichment Plant Designed to Produce 4.1% Enriched Uranium (100,000 SWU per year total)

Cycle	Product Enrichment and Quantity	Feed Enrichment and Quantity	Time for Cycle (Days)
First	20.2% 304 kg	4.1% 1,990 kg	7.5
Second	60.2% 69.5 kg	20.2% 274 kg	1.7
Third	90.0% 20 kg	60.2% 39.5 kg	0.5
Total			16*

*Includes six days to account for equilibrium and cascade fill time.

Table 7

Time, Product and Feed Requirements for the Production of 100 kg of HEU by Batch Recycling at a Centrifuge Enrichment Plant Designed to Produce 4.1% Enriched Uranium (100,000 SWU per year total)

Cycle	Product Enrichment and Quantity	Feed Enrichment and Quantity	Time for Cycle (Days)
First	20.2% 929 kg	4.1% 6,090 kg	23
Second	60.2% 228 kg	20.2% 899 kg	5.6
Third	90.0% 100 kg	60.2% 198 kg	2.5
Total			37*

*Includes six days to account for equilibrium and cascade fill time.