Gregory S. Jones[1]
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"Not a Game-Changer" But Is the West Playing a Game With Iran That It Has Already Lost?
Centrifuge Enrichment and the IAEA August 30, 2012 Safeguards Update

In various papers since 2008, this author has outlined how Iran's growing centrifuge enrichment program could provide it with the ability to produce Highly Enriched Uranium (HEU) for nuclear weapons.[2] On August 30, 2012 the International Atomic Energy Agency (IAEA) published its latest safeguards update. The official reaction to this document was a sigh of relief. Iran's production of 3.5% enriched uranium increased only slightly. Though Iran has installed a large number of centrifuges (over 2,100) at its well-protected Fordow site, only about a third of them (about 700) are in operation and therefore Iran's rate of production of 20% enriched uranium did not increase much. Furthermore Iran has started converting some of its 20% enriched uranium stockpile into research reactor fuel so that Iran's net stockpile of 20% enriched uranium also grew very little. This has led officials to claim that the IAEA report was "not a game-changer."

But focusing on the relative change since the last IAEA quarterly report does not address the overall question of how close Iran is to being able to produce a nuclear weapon. As my latest analysis shows (Appendix 1, Table 2), Iran could use its enrichment facilities and enriched uranium stockpiles to produce enough HEU for a nuclear weapon in a little less than two and one half months (10 weeks). Given Iran's demonstrated ability to deploy a large number of centrifuges at the Fordow site, Iran could have also built a separate small clandestine enrichment plant to produce HEU in combination with Iran's declared enrichment facilities. If this is the case, then Iran could produce enough HEU for a nuclear weapon in just one and one half months (six and one half weeks) and enough HEU for four nuclear weapons in six months (Appendix 1, Table 4).

Focusing only on Iran's improvements in its enrichment effort since last quarter ignores Iran's substantial progress over a longer time scale. Iran's production of 3.5% enriched uranium has increased 60% since last year and tripled since 2009. Iran's production of 20% enriched uranium has tripled since last year. Though Iran's has been using some of its 20% enriched uranium stockpile to fuel the Tehran Research Reactor (TRR), this reactor only uses seven kilograms of 20% enriched uranium per year while Iran is producing about 10 kilograms of 20% enriched uranium *per month*. Obviously Iran's stockpile of 20% enriched uranium is going to be expanding. Iran's ability to install over 2,100 centrifuges at Fordow since last year not only demonstrates that Iran has a significant capacity to build centrifuges but is also disproves claims

[1] The author has multiple affiliations. This paper was produced for the Nonproliferation Policy Education Center. Though the author is also a part-time adjunct staff member at the RAND Corporation, this paper is not related to any RAND project and RAND bears no responsibility for any of the analysis and views expressed in it.
[2] My most recent report is: Gregory S. Jones, "Iran's Rapid Enrichment Progress Moves It Ever Closer to a Nuclear Weapons Capability: Centrifuge Enrichment and the IAEA's May 25, 2012 Safeguards Update," June 6, 2012, http://www.npolicy.org/article.php?aid=1185&tid=30

that were being made last fall that sanctions had capped Iran's ability to build additional centrifuges.

In order to produce a nuclear weapon Iran would also have to manufacture the non-nuclear components for such a weapon. Iran has already made substantial progress in this area, in part aided by a Russian nuclear weapon expert. I have estimated that Iran could produce these required non-nuclear components in just two to six months should it decide to quickly do so.[3]

Though Iran had obviously made substantial progress in developing the non-nuclear components for a nuclear weapon before 2004, the question remained whether Iran was continuing work in this area today. Recent statements by the intelligence community make it clear that the answer is yes. The clearest statement to this effect was made in July by John Sawers the chief of British intelligence MI6: "The Iranians are determinedly going down a path to master *all* aspects of nuclear weapons; all the technologies they need."[4] [Emphasis added] More recently an unnamed U.S. official made a similar statement that Iran is: "…pursuing the research and science on all three components of the program" [i.e. nuclear enrichment, weaponization and a delivery system].[5] Clearly Iran is developing nuclear weapons despite official claims that Iran has yet to formally decide to do so.

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

> 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.[6]

Most analysts (including those in the U.S. Government) have yet to accept the view that Iran is a de facto nuclear weapon state though increasingly this lack of acceptance appears to be just a stubborn reluctance to face the obvious. The official position is that "…there is time and space to continue a diplomatic path, backed by growing international pressure on the Iranian

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[3] 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, pp.10-13, http://npolicy.org/article.php?aid=1124&rid=4

[4] 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

[5] Ken Kilanian, *Los Angeles Times*, August 23, 2012, http://articles.latimes.com/2012/aug/23/world/la-fg-iran-nuclear-20120824

[6] 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

government."[7] However the P5+1 engaged in three rounds of talks with Iran in April, May and June.[8] These talks are widely considered to have been failures. There have been no more talks nor are any scheduled. This development raises the question of how negotiations can resolve the issues with Iran when none are taking place.

Many have suggested that the basic focus of the negotiating effort should be to get Iran to stop enriching uranium to 20% and to export its stockpile of this material but that Iran should otherwise be allowed to keep its enrichment program and be allowed to continue to enrich uranium to levels less than 5%. However, as my analysis shows, even if Iran were to agree to take these steps, it would only increase the time Iran would require to produce the HEU for a nuclear weapon from 10 weeks to 13 weeks (Appendix 1, Table 3).

Furthermore, such a position would legitimize Iran's centrifuge enrichment program and permit Iran to expand it. This expanded program would provide Iran rapid access to the HEU needed for a nuclear weapon. A substantially expanded enrichment program which was limited to producing less than 5% enriched uranium could still produce the HEU required for a nuclear weapon in just a few weeks (Appendix 2). The only reasonable negotiated outcome that will make it difficult for Iran to quickly produce nuclear weapons is for Iran to give up its entire enrichment program and all of its enriched uranium stockpiles. However, most U.S. analysts oppose the condition that Iran give up its entire enrichment program, saying that Iran would never agree to this condition. But this is just another way of saying that negotiations will not be able to prevent Iran from moving ever closer to the possession of nuclear weapons.

Iran's inflexible position on uranium enrichment gives the lie to the notion that sanctions are having a crippling effect on Iran. The latest round of sanctions is designed to significantly affect Iran's overall economy by making it more and more difficult for Iran to export its oil. However, these sanctions are not authorized by the United Nations but rather imposed unilaterally by the U.S. and the EU. Despite the IAEA's revelations last November of Iran's efforts to develop the non-nuclear components for a nuclear weapon, both Russia and China have refused to support any additional UN sanctions against Iran. Indeed both countries have continued trading with Iran and China continues to purchase oil from Iran.

Nor are China and Russia the only countries that have not adopted these sanctions. India, with its important economy, has actually increased its purchases of Iranian oil. India has gone so far as to change its tax code so as to facilitate a method of payment that involves using rupees rather than dollars. On August 27 Indian External Affairs Minister S.M. Krishna said that India hopes to boost mutual cooperation with Iran especially in the economic sector.[9] With such an attitude by non-Western countries, it is hardly surprising that U.S. and EU sanctions have not had the necessary bite to compel Iran to give up its uranium enrichment program.

If negotiations and sanctions cannot stop Iran from acquiring nuclear weapons, military action is the only remaining option. For over a year now there has been much discussion of the possibility

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[7] Statement by a "White House National Security Council spokesman." "Key U.S. Findings on Iran Nuclear Program Unchanged, Insiders Say," *National Journal*, August 10, 2012.
[8] The P5+1 are the United States, United Kingdom, France, Russia, China and Germany.
[9] "India, Iran firm up ties ahead of NAM Summit," *Times of India*, August 28, 2012.

of an Israeli military strike to "take out" Iran's enrichment facilities. By last month the threat of such a strike leading to a large scale war with Iran was high enough that Israel was distributing gas masks to its citizens and preparing bomb shelters.

There is certainly precedent for such a strike considering that Israel carried out attacks on nuclear reactors in Iraq in 1981 and in Syria in 2007. However, a significant difference between these prior Israeli strikes and a possible one today is that for these prior attacks there was no public discussion that such attacks might be carried out so that the 1981 and 2007 attacks achieved operational and strategic surprise. Given the current level of public discussion, any Israeli attack on Iran's nuclear facilities in 2012 could hardly be surprising. This fact leads to the conclusion that the repeated public discussion of such a military strike by the Israelis is intended more to try to intimidate Iran and get the West to take stronger measures to rein in Iran than it is to actually prepare for the possibility of a strike.

Indeed any Israeli attack on Iran would face serious operational difficulties given Iran's size and its distance from Israel. Furthermore, attacking centrifuge enrichment facilities is quite different from attacking single nuclear reactors. At its main enrichment facility at Natanz, Iran has somewhere between 46 and 54 cascades operating in parallel.[10] An air strike on Natanz that scored multiple bomb hits would shut down the entire facility. But the majority of the cascades would be undamaged and not able to operate only due to damage to piping and the loss of utilities. It would only take a few months of repairs before these undamaged cascades were back in operation. Even for the cascades that suffered bomb hits, the majority of the centrifuges would still be undamaged. Iran could pull out the undamaged centrifuges and use them to build new cascades. At the underground enrichment facility at Fordow, an Israeli attack would be unable to destroy any centrifuges and the best the Israelis could do would be to collapse the entrance tunnels and cut off utilities. Iran could quickly repair the damage from such attacks and be back to near full production in two to six months.

A further problem is Iran's current stockpiles of about 3,570 kilograms of 3.5% enriched uranium and 79 kilograms of 19.7% enriched uranium. These stockpiles represent years of centrifuge plant operation but would be very difficult to destroy by air attack. The combined volume of these two stockpiles is less than one cubic yard—making them very easy to hide or protect.

Certainly the Israelis must be aware of the limitations of a military strike against Iran's nuclear facilities. No doubt this is one reason why Israel has not struck Iran already. Though the Israelis may find strike threats useful in order to put pressure on Iran and to try to gain assistance from the West, one must be concerned that by repeatedly emphasizing this option, Israel's government may have painted itself into a corner. Israel may feel compelled for internal political reasons to eventually carry out such an attack even though Israel's government is aware that such an attack will be ineffective.

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[10] Iran has declared to the IAEA that it has 54 cascades in operation but its enriched uranium production is only equivalent to about 46 cascades operating at full capacity.

President Obama and Defense Secretary Leon Panetta have pledged to take any action necessary to prevent Iran from obtaining nuclear weapons.[11] Fulfilling such a pledge militarily would require at a minimum a prolonged bombing campaign against Iran's nuclear sites. There are two problems with such a bombing campaign. First, Iran could respond by dispersing its centrifuges. Indeed, centrifuge enrichment with its many parallel cascades would be ideal for such dispersal. The U.S. would be able to find and bomb some of these dispersed enrichment sites but many would continue in operation undetected. Second, such a prolonged bombing campaign would run a serious risk of turning into a large-scale war with Iran. Though no doubt the U.S. would eventually win such a war, I think that given the financially-exhausted and war-weary condition of the U.S., such a war would be ill-advised. In any case, the current situation in which the U.S. faces the choice between accepting Iran as a nuclear weapon state or needing to go to war to prevent it must be considered a policy failure.

The Implications of a Nuclear-Armed Iran for the Future of IAEA Safeguards and the Non-Proliferation Treaty

Many analysts assume that if Iran were to produce HEU by batch recycling (Appendix 1, Table 2) then this would involve a violation of IAEA safeguards. But as long as Iran informed the IAEA of its intention to produce the HEU there would be no violation. In the past Iran has gotten into trouble by carrying out uranium enrichment in secret but during the summer Iran has shown that it is getting better at playing the game. Iran announced that it is planning to build nuclear-powered submarines. Such submarines often use HEU as fuel and these plans would provide a ready excuse to produce such material while staying within IAEA safeguards.

Iran is still a little new at providing such excuses and though nuclear-powered submarines are almost always for military purposes, Iran's Rear Admiral Abbas Zamini said that nuclear-powered submarines are among the "civilian" uses of nuclear energy to which all countries are entitled.[12] A few weeks later Iran changed its story and suggested that it intended to build nuclear-powered oil tankers. The head of the Atomic Energy Organization of Iran, Fereydoon Abbasi clarified that Iran currently has no plans to produce higher levels of enriched uranium but should it decide to do so it would first inform the IAEA.[13] Nor does Iran need to go ahead with nuclear naval propulsion to have an excuse to produce HEU. Currently a number of non-nuclear weapon states use HEU research reactor fuel and HEU irradiation targets for the production of medical isotopes.

The fact that the IAEA does not restrict the production of HEU in non-weapons states is a problem that goes far beyond Iran. For example, South Africa's President Jacob Zuma announced that he considered it South Africa's right to be able to produce HEU saying, "Our international legally binding obligations on nuclear disarmament and nuclear non-proliferation allow for the enrichment of uranium for peaceful purposes only, irrespective of the enrichment

[11] "Full Transcript: Defense Secretary Leon Panetta," ABC News, May 27, 2112, http://abcnews.go.com/Politics/full-transcript-defense-secretary-leon-panetta/story?id=16437246&page=7
[12] "Iranian officer: Tehran developing nuclear sub," *The Jerusalem Post*, June 6, 2012.
[13] "Iran's nuclear chief says Iran can make higher grade nuclear fuel for ships, but no plans now," *The Washington Post*, July 22, 2012.

level."[14] Ironically this announcement was made at the March 2012, nuclear security summit in Seoul, South Korea.

Nor is HEU the only issue. The IAEA permits non-nuclear weapon states to produce pure compounds of plutonium by reprocessing spent fuel. For example, Japan already has a plutonium stockpile of nearly 45 metric tons. About 35 metric tons is stored overseas but about 10 metric tons (enough to produce thousands of nuclear weapons) is stored in Japan.[15] Though in the aftermath of the Fukushima nuclear accident Japan's future use of nuclear power is in question, Japan's nuclear industry has announced plans to further increase its domestic stockpile of plutonium.[16] Japan says that it is stockpiling the plutonium for use in a breeder reactor but it is now more than 40 years since such reactors were first supposed to come into operation and such reactors are still decades away.

Nor is the problem just HEU and plutonium, it is facilities that can quickly produce such materials as well, i.e. centrifuge enrichment plants and reprocessing plants. (See Appendix 2) Germany, the Netherlands, Brazil and Japan all possess such facilities.

The U.S. Government has recognized this problem and in its nuclear cooperation agreement with the United Arab Emirates, it requires the UAE not to possess facilities that can engage in uranium enrichment or the reprocessing of spent fuel which could produce plutonium, HEU or U-233 (another material that can be used to produce nuclear weapons). The U.S. will likely place similar requirements on Taiwan whose nuclear cooperation agreement is soon to be renewed.

However, whether such conditions should be made a requirement for all new U.S. nuclear cooperation agreements has become a contentious issue. It is considered unlikely that Jordan, Saudi Arabia, Vietnam or South Korea will agree to these conditions and there are those who advocate removing this requirement to gain new nuclear cooperation agreements with these countries. However, the question remains, if such a requirement makes good non-proliferation sense for the UAE and Taiwan, then why not for these countries as well?

The purpose of IAEA 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."[17] [Emphasis in original] To meet the requirement to provide timely detection even the standards for the UAE are not enough. Non-nuclear weapon countries must 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

[14] "SA playing both sides of the nuclear coin," *IOL*, March 30, 2012.
[15] *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.
[16] Eric Talmadge, "Japan to make more plutonium despite big stockpile," Associated Press, June 1, 2012.
[17] "The Structure and Content of Agreements Between The Agency and States Required in Connection With The Treaty on the Non-Proliferation of Nuclear Weapons," International Atomic Energy Agency, INFCIRC/153 (Corrected), June 1972, p.9.

unirradiated reactor fuel (such as HEU fuel for research reactors or mixed oxide fuel for power reactors).

Nor is this issue new. These problems were known in the 1970s. As I wrote with my colleagues Albert and Roberta Wohlstetter and Henry Rowen in 1979:

> "…bilateral and international inspection systems do indeed need improvement, but if such improved inspection is to be more than a facade for a possible steady advance toward nuclear explosive materials by states that do not presently have them, the facilities, processes and stocks inspected must be far enough away from yielding bomb material to make timely warning feasible. Unless sensitive technologies are restricted, "effective safeguards" in the sense defined by the IAEA and the NPT are literally infeasible."[18]

It is up to the U.S. and the IAEA to decide what the purpose of IAEA safeguards and the Non-Proliferation Treaty (NPT) is. If in fact the main concern is non-proliferation then all non-weapon states must accept restrictions on their nuclear activities that allow IAEA safeguards to provide the necessary *timely* warning. If it is decided that non-weapon states have the "right" to large centrifuge enrichment plants, reprocessing plants and stocks of HEU and separated plutonium, then in fact the NPT is really a Proliferation Treaty and Iran will not be the last NPT member to use the guise of peaceful nuclear activities to acquire nuclear weapons.

[18] Albert Wohlstetter, Gregory Jones, Roberta Wohlstetter, Henry S. Rowen, "Summary", *Towards a New Consensus on Nuclear Technology*, Volume I, PH-78-04-832-33, Pan Heuristics, Prepared for U.S. Arms Control and Disarmament Agency, July 6, 1979, p.2. http://www.npolicy.org/files/19790706-TowardsANewConsensus-Vol01.pdf

Appendix 1

Detailed Analysis of the IAEA August 30, 2012 Safeguards Report and Methods Whereby Iran Could Produce HEU 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 installed 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 August 21, 2012, Iran had installed a total of 55 cascades and had partially installed one additional cascade. Of the 55 cascades, 31 each contain 174 centrifuges and the remaining 24 cascades each contain 164 centrifuges. This results in a total of 9,330 centrifuges. Of these 55 cascades, 54 (containing 9,156 centrifuges) were declared by Iran as being fed with uranium hexafluoride and therefore were producing 3.5% enriched uranium though the IAEA has indicated that not all of these 9,156 centrifuges may be operational.[19]

Iran began producing 3.5% enriched uranium at the FEP in February 2007 and as of August 6, 2012 Iran had produced a total of 4,648 kilograms (in the form of 6,876 kilograms of uranium hexafluoride). Since 1,059 kilograms of this enriched uranium has already been processed into 19.7% enriched uranium (see the PFEP and FFEP below) and a further 21 kilograms was converted into uranium dioxide for use as fuel in the TRR, Iran's current stockpile of 3.5% enriched uranium is 3,568 kilograms. Iran's current production rate of 3.5% enriched uranium is about 161 kilograms per month.[20] This production rate represents about a 60% increase from 2011 when the production rate was about a steady 100 kilograms per month and represents about a tripling of the rate since 2009 (see Table 1). From the production rate of 3.5% enriched uranium, it is easy to calculate that the FEP has a separative capacity of about 7,000 separative work units (SWU) per year.[21] If all 9,156 centrifuges at the FEP are in fact operational, then these centrifuges are each producing 0.77 SWU per centrifuge-year. However, since the IAEA has stated that perhaps not all of the 9,156 centrifuges may be working then this number should be considered a minimum value and could be higher.

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. No enriched uranium has been produced by these test cascades.

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[19] "Not all of the centrifuges in the cascades that were being fed with UF_6 may have been working." *Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran*, GOV/2012/37, August 30, 2012, p.4.

[20] 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.

[21] Assuming 0.4% tails. A Separative Work Unit is a measure of the amount of enrichment a facility can perform. The SWU needed to produce a given amount of enriched uranium product can be calculated if the U-235 concentration in the product, feed and tails are known.

In addition, there are two full cascades each with 164 IR-1 type centrifuges at the PFEP. These two cascades are interconnected and are being 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. As of August 21, 2012, Iran had produced 83.9 kilograms of 19.7% enriched uranium (in the form of 124.1 kilograms of uranium hexafluoride) at this facility. Iran's production rate of 19.7% enriched uranium at the PFEP has been fairly steady over the past year and is currently about 3.04 kilograms per month. The centrifuges at this facility are each producing about 0.90 SWU per centrifuge-year.

Table 1
Average Iranian Production Rate of 3.5% Enriched Uranium
November 2008 to August 2012

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

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 its 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 would hold 174 IR-1 type centrifuges). As of August 18, 2012 Iran had installed twelve cascades and had installed 52 IR-1 type centrifuges in a partially completed 13th cascade. This makes a total of 2,140 centrifuges installed at the FFEP which is about double the 1,064 centrifuges that had been installed there just last May.

Only four of the cascades are producing enriched uranium. They are configured as two sets of two interconnected cascades so as to produce 19.7% enriched uranium from 3.5% enriched uranium as is being 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 August 12, 2012, Iran had produced 44.1 kilograms of 19.7% enriched uranium (in the form of 65.3 kg of uranium hexafluoride) at this facility. This facility is currently producing 19.7% enriched uranium at the rate of 6.72 kilograms per month. These centrifuges are each producing about 0.95 SWU per centrifuge-year.

With the start of these two sets of interconnected cascades at the FFEP, Iran has made good on its announcement in June 2011 that it would triple its production rate of 19.7% enriched uranium. Currently Iran is producing a total of about 9.8 kilograms of 19.7% enriched uranium per month. As of mid-August, Iran had produced a total of about 128 kilograms of 19.7% enriched uranium. Since Iran has converted about 48 kilograms of this uranium into a uranium oxide compound for use as fuel in the TRR, and further blended down about 1 kilogram to lower enrichments, Iran's current stockpile of 19.7% enriched uranium is about 79 kilograms.[22]

Regarding the eight other cascades at the FFEP that have yet begun operation, the IAEA has asked Iran whether these new cascades are to be interconnected to produce yet more 19.7% enriched uranium or only 3.5% enriched uranium. However, Iran says that the installation of these new cascades is not yet complete and that it will only inform the IAEA prior to the start of their operation. This development opens the possibility that Iran could further increase its rate of 19.7% enriched uranium. Using the eight cascades already installed, Iran could put a four more sets of two interconnected cascades into operation at almost any time and increase its production of 19.7% enriched uranium to as much as 23.2 kilograms a month.[23] Given Iran's current rate of production rate of 3.5% enriched uranium at the FEP, Iran could run these four additional sets of two interconnected cascades (in addition to the two cascades already in operation at the FFEP and the one cascade in operation at the PFEP) to produce 19.7% enriched uranium without the need to drawdown its stockpile of 3.5% enriched uranium.

Iranian Options for Producing HEU

Given that Iran currently has a total enrichment capacity of about 8,000 SWU per year at the FEP, FFEP, and PFEP and stockpiles of about 3,570 kilograms of 3.5% enriched uranium and 79 kilograms of 19.7% enriched uranium, 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 three-step process to produce HEU. This process is illustrated in Table 2.

[22] The IAEA safeguards report gives contradictory information as to the amount of 19.7% enriched uranium that Iran has converted to uranium oxide form. At one place the safeguard report says that about 48 kilograms (71.25 kilograms of uranium hexafluoride) and another it says about 65 kilograms (96.3 kilograms of uranium hexafluoride). I assume that the smaller number is correct since even this amount would be more than enough to replace the TRR's entire core. See: *Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran*, GOV/2012/37, August 30, 2012, p.8 and p.13.

[23] Assuming the performance of these additional cascades matches that of the four already in operation at the FFEP.

Table 2

Time, Product and Feed Requirements for the Production of HEU by Batch Recycling at the FEP (7,000 SWU per year total)
Final Step at PFEP and FFEP
(6 sets of two interconnected cascades at the FFEP)

Cycle and Enrichment Plant	Product Enrichment and Quantity	Feed Enrichment and Quantity	Time for Cycle (Days)
First FEP	19.7% 131 kg	3.5% 1,550 kg	33
Second FEP	55.4% 39.8 kg	19.7% 227 kg*	8
Third PFEP & FFEP**	89.4% 20 kg	55.4% 39.0 kg	26
Total			73***

* Includes 79 kilograms of 19.7% enriched uranium that Iran has already stockpiled and 19 kilograms of 19.7% enriched uranium from the tails of the PFEP and FFEP. Plant inventory at the FEP is 2 kilograms.
** The combined plant inventory at the PFEP and FFEP is 0.8 kilogram.
***Includes six days to account for equilibrium and cascade fill time.

In the first step, Iran needs to produce 229 kilograms of 19.7% enriched uranium (including 2 kilograms for the plant inventory in the second step). However, since it has already produced 79 kilograms of 19.7% enriched uranium, and the tails from the third step are 19.7% enriched uranium, Iran needs only to produce an additional 131 kilograms. This step requires 1,550 kilograms of 3.5% enriched uranium as feed but Iran's current stockpile well exceeds this figure. In the second step, the 19.7% enriched uranium is further enriched at the FEP to 55.4% enriched uranium. This step requires the production of 39.8 kilograms of 55.4% enriched uranium (including the 0.8 kilograms for the plant inventory at the PFEP and FFEP). In the third step, the 55.4% enriched uranium is enriched to the 20 kilograms of 89.4% enriched uranium needed for a nuclear weapon. For this last step I assume that all twelve cascades that are installed at the FFEP are operated and function as six interconnected cascades. The total time required is 73 days which is about 10 weeks or a little less than two and one half months.

The results for the first step can be found using separative work calculations but for the other two steps a SWU calculation would not produce accurate results. Since the plant at Natanz is designed to produce 3.5% product from natural uranium, its cascade is more tapered than is optimal for the upper stages of an enrichment plant designed to produce highly enriched uranium. As a result, some of the SWU output cannot be utilized during the latter two cycles of the batch production process. The cascades are restricted by the flow at the product end of the cascade. Therefore the time required for these cycles is determined by the amount of product required and the amount of product the plant can produce per day and not by a SWU calculation.

Though much attention has been focused on Iran's growing 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 growing enrichment capacity and not its growing 19.7% enriched uranium stockpile. As is shown in Table 3, even if Iran did not have a stockpile of 19.7% enriched uranium, it could still produce a weapon's worth of HEU in just 3 months (thirteen weeks) which is only a little longer than the two and one half months (ten weeks) that would be required given Iran's current stockpile of 19.7% enriched uranium (Table 2). As is shown in Appendix 2, continued growth of Iran's centrifuge enrichment capacity, even if it does not stockpile 19.7% enriched uranium, means that the time required for Iran to produce the HEU required for a nuclear weapon will become quite short. This is not to say that Iran's growing stockpile of 19.7% enriched uranium is unimportant, but rather focusing only on the 19.7% enriched uranium and not Iran's growing enrichment capacity as well will not provide a solution to the problem of Iran's ability to quickly produce the HEU required for a nuclear weapon.

Table 3

Time, Product and Feed Requirements for the Production of HEU by Batch Recycling at the FEP (7,000 SWU per year total)
Using 3.5% Enriched Uranium as the Starting Material
Final Step at PFEP and FFEP
(6 sets of two interconnected cascades at the FFEP)

Cycle and Enrichment Plant	Product Enrichment and Quantity	Feed Enrichment and Quantity	Time for Cycle (Days)
First FEP	19.7% 210 kg	3.5% 2,480 kg	53
Second FEP	55.4% 39.8 kg	19.7% 227 kg*	8
Third PFEP & FFEP**	89.4% 20 kg	55.4% 39.0 kg	26
Total			93***

* Includes 19 kilograms of 19.7% enriched uranium from the tails of the PFEP and FFEP. The plant inventory at the FEP is 2 kilograms.
** Plant inventory is 0.8 kilogram.
***Includes six days to account for equilibrium and cascade fill time

Currently the fastest way for Iran to produce the HEU for a nuclear weapon is by using batch recycling at the FEP combined with a clandestine "topping" enrichment plant. This method would allow Iran to produce a weapon's worth of HEU in just one and one half months (six and one half weeks). Since Iran continues to refuse to implement the Additional Protocol to its safeguards agreement, the IAEA would find it very difficult to locate a clandestine enrichment plant—a fact that the IAEA has continued to confirm.[24] While this has been a theoretical possibility since 2007, its salience increased with the discovery in September 2009 that Iran was actually building such a clandestine enrichment plant (the FFEP near Qom).

In this case, the clandestine enrichment plant could be designed as an ideal cascade to enrich 19.7% enriched uranium to the 90% enriched uranium needed for a nuclear weapon. By starting from 19.7% enriched uranium, this clandestine enrichment plant need only contain about 2,000 IR-1 type centrifuges to be able to produce the 20 kilograms of HEU required for a nuclear weapon in just one and one half months.[25] Furthermore since Iran already has a stockpile of 19.7% enriched uranium, the production of the 19.7% enriched uranium at the FEP and the 90% enriched uranium at the clandestine enrichment plant could be carried out *simultaneously*.

The results of this process are shown in Table 4. As can be seen, the production of the 19.7% enriched uranium needed (including 0.6 kilograms for the plant inventory at the clandestine plant) to produce 20 kilograms of HEU at the clandestine enrichment plant requires 182 kilograms of 3.5% enriched feed. Since the cycle time at the FEP is shorter than that at the clandestine enrichment plant and the cycles are carried out simultaneously, the time required at the FEP has no impact on the overall time required to produce the HEU.

Table 4

Time, Product and Feed Requirements for the Production of HEU by Batch Recycling at the FEP (7,000 SWU per year total)
Final Step at 2,000 Centrifuge Clandestine Plant (0.90 SWU per centrifuge-year)
Cycles Carried out Simultaneously

Cycle and Enrichment Plant	Product Enrichment and Quantity	Feed Enrichment and Quantity	Time for Cycle (Days)
First FEP	19.7% 15.4 kg	3.5% 182 kg	6**
Second Clandestine	90.0% 20 kg	19.7% 93.8 kg*	45**
Total			45***

* Includes 79 kilograms of 19.7% enriched uranium that Iran has already stockpiled. There is additional processing of the tails of the clandestine plant at the PFEP and FFEP.
** Includes two days to account for equilibrium and cascade fill time.
*** Cycle times *not* additive since cycles are simultaneous.

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24 "While the Agency continues to verify the non-diversion of declared nuclear material at the nuclear facilities and LOFs declared by Iran under its Safeguards Agreement, as Iran is not providing the necessary cooperation, including by not implementing its Additional Protocol, the Agency is unable to provide credible assurance about the absence of undeclared nuclear material and activities in Iran, and therefore to conclude that all nuclear material in Iran is in peaceful activities." *Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran*, GOV/2012/37, August 30, 2012, p.11.

25 In past analysis I have assumed that the clandestine plant would hold only 1,400 centrifuges. However, Iran's ability to install over 2,100 centrifuges at the FFEP in less than one year shows that Iran possesses a greater capacity to manufacture new centrifuges than was previously thought.

Further, since Iran would have a substantial quantity of 3.5% enriched uranium left over (about 3,400 kilograms), Iran could continue the process and produce additional HEU. An additional 20 kilograms of HEU would require about 1,110 kilograms of 3.5% enriched uranium feed, so with its current stockpile Iran could produce a total of over 80 kilograms of HEU, which is enough for about four nuclear weapons. Therefore Iran would produce enough HEU for a weapon every one and one half months, and could have a four weapon arsenal in just six months.

Nor is batch recycling of enriched uranium 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 3,800 centrifuges (0.90 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 breakout from safeguards, 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.[26] Since Iran has refused 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. A drawback to this stand-alone clandestine enrichment plant is that it requires more centrifuges than would the 2,000 centrifuge clandestine plant discussed above. However Iran's rapid installation of centrifuges at the FFEP means that this possibility cannot be ruled out.

Iran then, has a number of methods whereby it could produce the HEU required for a nuclear weapon. By batch recycling at the FEP, PFEP and the FFEP (Table 2), Iran could produce enough HEU for a nuclear weapon in a little less than two and one half months (ten weeks). Even if Iran were to give up its current stockpile of 19.7% enriched uranium (Table 3), the time required for Iran to produce the HEU for a nuclear weapon would be just three months (thirteen weeks). If Iran were to produce 19.7% enriched uranium at the FEP and simultaneously enrich 19.7% enriched uranium to HEU at a clandestine enrichment plant (Table 4), then it could produce a weapon's worth of HEU in one and one half months (six and one half weeks) and enough HEU for four weapons in six months. Alternatively, Iran might build a stand-alone clandestine plant to enrich natural uranium to HEU. Such a plant would only produce enough HEU for 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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[26] *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.

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, many who propose a diplomatic solution with Iran have suggested that Iran should be allowed to continue to enrich uranium as long as this activity is subject to "proper" controls. In particular, they propose that Iran should not enrich uranium to more than 5% and that Iran's current stockpile of near 20% enriched uranium should be removed from Iran. Further, they propose that the size of Iran's enrichment effort be determined by the needs of Iran's peaceful nuclear program.

But as was shown in Appendix 1 (Table 3), even if Iran were to give up its current stockpile of 19.7% enriched uranium, Iran could still produce the HEU required for a nuclear weapon in just three months (thirteen weeks). The problem is Iran's growing enrichment capacity. Furthermore, Iran's current enrichment effort is quite small compared to that needed for most peaceful nuclear activities such as providing fuel for a single nuclear power reactor. A diplomatic solution could provide Iran with the justification for greatly expanding its current enrichment facilities as well as removing sanctions. Under these circumstances, Iran might receive assistance to expand its enrichment facilities (from say China or Pakistan) as part of normal nuclear commerce. These greatly expanded facilities would provide Iran easy access to the HEU needed for nuclear weapons.

For example, even if Iran produced only 4.1% enriched uranium[27] and expanded its enrichment capacity by about a factor of 12 (100,000 SWU/yr), it would only produce about 15 metric tons of enriched uranium per year. This amount would still be 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 5.

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 6. 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.

Though Iran's expansion of its 19.7% enriched uranium stockpile contributes to the shrinking time required for Iran to produce the HEU needed for a nuclear weapon, unless restrictions are placed on the size of Iran's overall enrichment effort, Iran's growing centrifuge enrichment capacity will allow Iran to quickly produce the HEU required for a nuclear weapon.

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[27] With tails of 0.2%.

Table 5

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 6

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.