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Iran Continues To Move Closer to Nuclear Weapons: Centrifuge Enrichment and the IAEA September 2, 2011 Update

In ten previous reports, this author has outlined how Iran's growing centrifuge enrichment program could provide it with the ability to produce fissile material for nuclear weapons.[2] On September 2, 2011, the International Atomic Energy Agency (IAEA) released a further safeguards update.[3] This update shows that Western efforts to impede Iran's centrifuge enrichment program continue to be ineffective. Iran has maintained its production of 3.5% enriched uranium at a rate of about 100 kilograms per month.[4] Despite repeated press reports of cyber attacks in 2009 having slowed Iran's enrichment efforts, Iran's current production rate of 3.5% enriched uranium has actually increased about 80% over Iran's 2009 production rate (see table 1). Iran has significantly increased its production of 19.7% enriched uranium to 3.2 kilograms per month, which is about 28% higher than its 2010 rate.

As of August 13, 2011, Iran had produced 3,071 kilograms of 3.5% enriched uranium (in the form of 4,543 kilograms of uranium hexafluoride). With this quantity of 3.5% enriched uranium, Iran could produce more than the 20 kilograms of highly enriched uranium (HEU) needed for a nuclear weapon by batch recycling at its centrifuge enrichment facilities at Natanz. With Iran's current number of operating centrifuges and its stockpile of 19.7% enriched uranium, the batch recycling would take about eight weeks once Iran decided to initiate the process.

Iran has already started the process of converting its stockpile of 3.5% enriched uranium into the HEU needed for nuclear weapons, as is evidenced by its production of 19.7% enriched uranium. This is an intermediate step on the road to the production of HEU. As of August 20, 2011, Iran had accumulated a stockpile of about 47.9 kilograms of 19.7% enriched uranium (in the form of 70.8 kilograms of uranium hexafluoride). As of that date, about 385 kilograms of 3.5% enriched uranium had already been processed into 19.7% enriched uranium, making Iran's stockpile of 3.5% enriched uranium about 2,690 kilograms. As Iran's stockpile of 19.7% enriched uranium continues to grow, the time required for it to be able to produce a weapon's worth of HEU will continue to decline.

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[2] My most recent prior report is: "An In-Depth Examination of Iran's Centrifuge Enrichment Program and Its Efforts to Acquire Nuclear Weapons," August 9, 2011, http://www.npolicy.org/article.php?aid=1092&rid=4

[3] *Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran*, GOV/2011/54, September 2, 2011.

[4] To avoid problems with the fact that the length of a month is variable, we have adopted a uniform month length of 30.44 days.

Table 1
Average Iranian Production Rate of 3.5% Enriched Uranium
Late 2008 to Mid-2010

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

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 consists of 164 centrifuges, though Iran has begun to modify some 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 28, 2011, Iran had installed 53 cascades containing approximately 8,000 centrifuges at the FEP. Of these 53 cascades, only 35 (containing 5,860 centrifuges) were being fed with uranium hexafluoride and therefore producing 3.5% enriched uranium though the IAEA has indicated that not all of these 5,860 centrifuges may be operational.[5]

Also at Natanz, Iran has the Pilot Fuel Enrichment Plant (PFEP) which is used to test a number of more advanced centrifuge designs. These are usually configured as single centrifuges or small ten or twenty centrifuge test cascades. However, Iran has installed a cascade of 136 IR-2m centrifuges and has begun feeding this cascade with uranium hexafluoride. Iran has also installed 27 IR-4 centrifuges in a separate cascade but has not yet begun feeding them with uranium hexafluoride. 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.

[5] "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/2011/54, September 2, 2011, p.3.

Finally, Iran is constructing 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 plant had been discovered by the West. According to the IAEA, Iran has installed two interconnected cascades at the FFEP (each containing 174 centrifuges, IR-1 type) in order to produce 19.7% enriched uranium from 3.5% enriched uranium as is currently being done at the PFEP. These two interconnected cascades have yet to begin operation. In addition, Iran has informed the IAEA that it plans to install two more interconnected cascades at the FFEP to produce 19.7% enriched uranium. When these two sets of interconnected cascades begin operation, Iran will triple its production rate of 19.7% enriched uranium. Since it is currently producing 3.2 kilograms of 19.7% enriched uranium per month, this will be a production rate of 9.6 kilograms per month.

From Iran's current monthly production rate of 99 kilograms of 3.5% enriched uranium, one can calculate that the centrifuges at the FEP produce about 4,300 SWU per year.[6] From the production rate of 3.2 kilograms of 19.7% uranium per month at the PFEP, one can calculate that the PFEP is producing about 300 SWU per year.[7] Together this means that Iran's current enrichment capacity is about 4,600 SWU per year.

Given that Iran has an enrichment capacity of 4,600 SWU per year and stockpiles of about 2,690 kilograms of 3.5% enriched uranium and 47.9 kilograms of 19.7% enriched uranium, it can use batch recycling at the FEP and PFEP to produce the HEU needed for a nuclear weapon. This process is illustrated by my calculations shown in Table 2. Two steps are required. In the first step, 3.5% enriched uranium is enriched to 19.7% enriched uranium. Iran needs to produce 158.2 kilograms of 19.7% enriched uranium (including 5 kilograms for the plant inventory in the second step). However, since it has already produced 47.9 kilograms of 19.7% enriched uranium, Iran needs only to produce an additional 110.3 kilograms. This step requires 1,302 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 to the 90% level suitable for a nuclear weapon. Using Iran's currently operating centrifuges at the FEP and PFEP, the batch recycling would take about eight weeks.

Note that there is nothing illegitimate about the first step of this process since Iran's current production of 19.7% enriched uranium at the PFEP has established the principle that Iran is permitted to produce and possess such material. Only at the second step might Iran have to violate IAEA safeguards, but as the second step takes only about two weeks, there would be very little time for Western counteraction before the process was completed. Indeed, since the FEP and PFEP are not continuously monitored by the IAEA, the process could be well along or even completed before it was discovered. And as I have discussed elsewhere, it is not clear that even the production of HEU would be

[6] Assuming 0.4% tails. A SWU is a Separative Work Unit, which 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.

[7] With a feed of 3.5% enriched uranium and a tails of 0.711% uranium.

considered a violation of IAEA safeguards as long as the material was kept under safeguards.[8]

Table 2

Time, Product and Feed Requirements for the Production of 20 kg of HEU by Batch Recycling at the FEP and PFEP (4,600 SWU per year total)

Cycle	Product Enrichment and Quantity	Feed Enrichment and Quantity	Time for Cycle (Days)
First	19.7% 110.3 kg	3.5% 1,302 kg	42
Second	90.0% 20 kg	19.7% 153.2 kg*	12
Total			58**

* Includes 47.9 kilograms of 19.7% enriched uranium that Iran has already stockpiled.
**Includes four days to account for equilibrium and cascade fill time.

Further, as Iran's stockpile of 19.7% enriched uranium continues to grow, the time required for Iran to produce HEU will continue to decline. When Iran has a stockpile of about 160 kilograms of 19.7% enriched uranium, it will be possible to skip the first step entirely and Iran will be able to produce 20 kilograms of HEU in only about 2 weeks. At Iran's current rate of production of 19.7% enriched uranium, the time when Iran will have a stockpile of 160 kilograms of 19.7% enriched uranium is still about three years away. However, Iran appears to be carrying through on it plans to triple its rate of production of 19.7% enriched uranium by installing four cascades (two sets of two interconnected cascades) at the FFEP. If these four cascades at the FFEP start operation reasonably soon, then Iran might have the required 160 kilograms of 19.7% enriched uranium by the latter part of 2012.

If Iran wanted to produce a second 20 kilogram batch of 90% enriched uranium (so that it would have a total of 40 kilograms, enough for two nuclear weapons), then it could repeat the batch recycle process. Since Iran would have already consumed its stockpile of 19.7% enriched uranium producing the first batch of 20 kilograms of HEU, producing the second batch of 20 kilograms of HEU would require using 3.5% enriched uranium as the starting material. My calculations in Table 3 show how this process would be carried out.

As can be seen from Table 3, a total of about 1,900 kilograms of 3.5% enriched uranium is needed to produce the second batch of 20 kilograms of HEU. As was stated above, Iran's current stockpile of 3.5% enriched uranium is 2,690 kilograms. Table 2 shows that producing the first batch of 20 kilograms of HEU would require about 1,300 kilograms of

[8] "An In-Depth Examination of Iran's Centrifuge Enrichment Program and Its Efforts to Acquire Nuclear Weapons," August 9, 2011, p.20 http://www.npolicy.org/article.php?aid=1092&rid=4

3.5% enriched uranium, so that Iran's remaining stockpile of 3.5% enriched uranium would only be about 1,390 kilograms—about 510 kilograms short of the 1,900 kilograms needed to produce the second batch of HEU. Since Iran is producing about 100 kilograms of 3.5% enriched uranium per month, by January 2012 Iran will be in a position to be able to produce two nuclear weapons worth of HEU using batch recycle.

The production of the HEU for two weapons would have to be carried out sequentially with the production of the HEU for the first weapon taking about eight weeks (Table 2) and the production of the HEU for the second weapon taking about two and one half months (Table 3) for a total of about four and one half months. These times should be considered the maximum, since by January 2012, Iran will have produced more 19.7% enriched uranium and likely will have added even more enrichment capacity which will shorten the time required.

Table 3

Time, Product and Feed Requirements for the Production of a Second Batch of 20 kg of HEU by Batch Recycling at the FEP and PFEP (4,600 SWU per year total)

Cycle	Product Enrichment and Quantity	Feed Enrichment and Quantity	Time for Cycle (Days)
First	19.7% 158.2 kg	3.5% 1,872 kg	61
Second	90.0% 20 kg	19.7% 153.2 kg	12
Total			77*

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

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. 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.[9] 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).

[9] "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/2011/54, September 2, 2011, p.9.

A clandestine enrichment plant containing 23 cascades (3,772 centrifuges, 0.9 SWU per machine-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.[10] 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 clandestine 23 cascade enrichment plant could also be used to convert Iran's stockpile of 3.5% enriched uranium into the HEU required for weapons. The 20 kilograms of HEU needed for a weapon could be produced in about four and one half months.[11] Further only about 600 kilograms of 3.5% would be required to produce 20 kilograms of HEU, so the current stockpile of about 2,690 kilograms of 3.5% enriched uranium would be more than enough for four weapon's worth of HEU, though converting all of Iran's stockpile of 3.5% enriched uranium to HEU would take more than one year to complete. Additionally, using its current stockpile in this fashion would require Iran to violate IAEA safeguards since, by definition, the clandestine enrichment facility would not be under IAEA safeguards. The time required could be shortened by assuming that the clandestine enrichment plant contains more that 23 cascades but a very large clandestine enrichment plant appears to be implausible currently, given Iran's resources.

Overall, Iran continues to make rapid progress towards acquiring the ability to produce fissile material for nuclear weapons completely unimpeded by any Western counteraction. Using its current stockpiles of 3.5% enriched uranium and 19.7% enriched uranium, Iran can now produce a weapon's worth (20 kilograms) of HEU any time it wishes. In early 2008, I estimated that it would take Iran two to four years to produce enough HEU for a nuclear weapon. Today, with Iran's current number of operating centrifuges and its stockpiles of enriched uranium, this length of time has diminished to about eight weeks. As Iran produces additional 19.7% enriched uranium and/or brings additional centrifuges on line, this time span will only decrease and by the latter part of 2012 it will be about two weeks. While one can argue about the existence of possible Iranian clandestine enrichment facilities, the ability of Iran to produce HEU by batch recycling at the FEP and PFEP at Natanz is undeniable.

At the same time the IAEA has stated that it is "…increasingly concerned about the possible existence in Iran of past or current undisclosed nuclear related activities involving …the development of a nuclear missile payload…"[12] This statement reiterates concerns expressed in June 2011 by Yukiya Amano, the director general of the IAEA,

[10] *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.
[11] Using tails of 0.4%.
[12] *Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran*, GOV/2011/54, September 2, 2011, p.7.

who said that the agency had received "further information related to possible past or current undisclosed nuclear-related activities that seem to point to the existence of possible military dimensions to Iran's nuclear program."[13] He went on the say "The activities in Iran related to the possible military dimension seem to have been continued until quite recently."

Further, Iran may have received warhead design details from either Pakistan or North Korea. Since Pakistan is thought to already have a viable missile warhead design (believed to have been provided by the Chinese), such aid would be particularly useful to Iran. Supporting this view is an internal IAEA document from 2009 which said:

> "The Agency further assesses that Iran has sufficient information to be able to design and produce a workable implosion nuclear device based upon HEU as the fission fuel. The necessary information was most likely obtained from external sources and probably modified by Iran. The Agency believes that non-nuclear experiments conducted in Iran would give confidence that the implosion system would function correctly.[14]"

Therefore it appears that not only is Iran continuing to shorten the time that will be required for it to produce HEU but also shortening the time needed for it to produce a finished nuclear weapon. These times are already short enough that Iran should be considered a de facto nuclear weapon state. As I have recently published elsewhere:

> "We should accept that Iran already represents a bipartisan nonproliferation policy failure—one that spans the Obama and Bush administrations. Sanctions on Iran and sternly worded U.N. Security Council resolutions have not slowed, let alone stopped Iran's enrichment effort. Nor does there appear to be any realistic military options to stop Iran. (Israel seems to lack the capability, and a war-weary, financially exhausted the United States does not need any more wars.) As a nonproliferation failure, it is not, of course, the first of its kind, resembling as it does the failures that allowed Pakistan and North Korea to ascend to the status of nuclear powers.
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> But the fact that it is not unprecedented does not diminish the risks involved. As the United States' policies towards Pakistan and North Korea illustrate, now that Iran is a de facto nuclear weapon state, there is little that can be done except to hope that these countries can maintain control over their nuclear weapons.[15] The costs we face if something goes

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[13] Fredrik Dahl and Sylvia Westfall, "New data suggests Iran military link-U.N. atom chief," *Reuters*, June 6, 2011.

[14] "Excerpts from Internal IAEA Document on Alleged Iranian Nuclear Weaponization," Institute for Science and International Security, October, 2, 2009, http://www.isisnucleariran.org/assets/pdf/IAEA_info_3October2009.pdf

[15] Michael Krepon has said, "Take Pakistan, the state with nuclear weapons facing the greatest internal security threats. There have now been two commando-style raids with insider help against important military compounds. Army Headquarters in Rawalpindi was attacked in October 2009 and the Mehran

wrong—a nuclear detonation in cities such as Tel Aviv or New York—are horrific, even unimaginable. But one thing that's already clear is that naïve optimism doesn't do us any good."[16]

naval base in Karachi was attacked in May of this year. These patrol-sized assaults took approximately eighteen hours to quell. Commando raids with insider help are a very different ballgame than truck bombs…" http://krepon.armscontrolwonk.com/archive/3211/de-alerting-and-de-legitimization

[16] Greg 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