Gregory S. Jones
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Iran's Increasing Progress towards a Nuclear Weapons Capability: Centrifuge Enrichment and the IAEA February 18, 2010 Update

In three prior reports, this author has outlined how Iran's growing centrifuge enrichment program will be able to provide it with the ability to produce fissile material for nuclear weapons.[1] On February 18, 2010 the IAEA released a further safeguards update.[2] This update shows that Iran has significantly increased its production of enriched uranium and that it remains on a trajectory to attain the capability to produce a weapon's worth (20 kilograms) of highly enriched uranium (HEU) sometime in 2010.

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 (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. These cascades are organized into "Units" of 18 cascades (2,952 centrifuges). Iran has installed centrifuges in three Units (A24, A26 and A28) and work is proceeding on two more Units (A25 and A27). Iran has submitted to the IAEA plans for three more Units (A21, A22 and A23). 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 as single centrifuges or small ten or twenty centrifuge test cascades. There is one full cascade with 164 IR-1 type centrifuges at the PFEP. Finally Iran is constructing an enrichment facility near Qom. Known as the Fordow Fuel Enrichment Plant (FFEP), this plant's construction was started clandestinely in violation of its IAEA safeguards. Its existence was only revealed by Iran in September 2009 after Iran believed that the plant had been discovered by the West. No centrifuges have yet been installed at FFEP.

Iran began producing enriched uranium at the FEP in 2007. The production rate rose steadily and reached a plateau in 2009. From January 31, 2009 to November 22, 2009 the production rate was a steady 57 kilograms of 3.5% enriched uranium per month.[3] However, the latest IAEA update indicates that Iran has significantly increased its rate of production of 3.5% enriched uranium. From November 23, 2009 to January 29, 2010 the

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[1] *IAEA November 16, 2009 Update, Implications for Iran's Ability to Produce Fissile Material for Nuclear Weapons*, November 17, 2009, http://npec.xykon-llc.com/files/20091117-Jones%20Iran%20Enrichment%20Update.pdf; *Iran's Centrifuge Enrichment Program as a Source of Fissile Material for Nuclear Weapons: An Update*, August 17, 2009, appendix added August 31, 2009, http://www.bipartisanpolicy.org/sites/default/files/Iran%20Enrichment%20Update%20%282%29.pdf and *Iran's Centrifuge Enrichment Program as a Source of Fissile Material for Nuclear Weapons*, April 8, 2008. http://www.npec-web.org/Essays/20081017-Jones-IranEnrichment.pdf

[2] *Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions 1737 (2006), 1747 (2007), 1803 (2008) and 1835 (2008) in the Islamic Republic of Iran*, GOV/2010/10, February 18, 2010.

[3] 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.

production rate was 78 kilograms of 3.5% enriched uranium per month—a 37% increase. As of January 29, 2010 Iran had produced a total of 1,396 kilograms of 3.5% enriched uranium (in the form of 2,065 kilograms of uranium hexafluoride).

The latest IAEA update reveals an interesting development with regard to the number of centrifuges that have been installed at the FEP. As of November 2, 2009 Iran had already installed all of the cascades in Units A24 and A26 as well as 17 of the 18 cascades in A28. The installation of the final cascade in A28 was underway. So as of November 2, 2009 Iran had 8,692 centrifuges (53 cascades) installed and one would expect this number to increase by 164 to 8,856 (54 cascades) when the final cascade in A28 was completed. Instead as of January 31, 2010, 11 cascades in Unit A26 have been disconnected and one cascade in Unit A28 has been removed and a second is in the process of being removed—leaving 16 installed cascades in Unit A28. The IAEA reports that Iran has only 8,610 (52.5 cascades) installed and this number includes the 11 disconnected cascades in Unit A26. Only 41 cascades (6,724 centrifuges) appear to be fully installed.

The reason for the disconnection and removal of these centrifuges is unclear. It is possible that technical problems required this removal so that defective centrifuges can be repaired or replaced. Or it is possible that Iran is dispersing the centrifuges to other known or unknown sites. According to the current IAEA update, the discovery of a small number of depleted uranium particles on equipment at the FFEP near Qom has led Iran to say that some of the equipment at the FFEP had come from the FEP. This development supports the view that the centrifuges being removed from the FEP are being sent to other locations. Note that IAEA safeguards apply only to nuclear material and not equipment such as centrifuges so once a centrifuge leaves the FEP the IAEA has no way to know where it goes.

The trend in the number of centrifuges actually enriching uranium at the FEP has been declining. On May 31, 2009, 30 cascades (4,920 centrifuges) were in operation, on August 12, 2009 this number had declined to 28 cascades (4,592 centrifuges), on November 2, 2009 the number had declined to 24 cascades (3,936 centrifuges) and as of the latest IAEA update (January 31, 2010) only 23 cascades (3,772 centrifuges) were in operation. Again the reasons for this decline are unclear. Some have attributed it to technical problems with Iran's enrichment effort but this explanation is hard to reconcile with the actual increase in Iran's uranium production. Indeed one of the most interesting developments over the last eight months is that Iran has managed to maintain and then significantly increase the amount of 3.5% enriched uranium that it is producing while the number of operating centrifuges seem to have declined. This raises the issue of the enrichment capacity of Iran's centrifuges.

The ability to carry out enrichment is measured in terms of "Separative Work Units" (SWU). Based on what is known about the technical characteristics of Iran's IR-1 centrifuges (as well as the European technology on which they are based), several years ago it was assumed that each of Iran's centrifuges could produce around 2.5 SWU per machine-year. This value was somewhat similar to the 1.9 SWU per machine-year that

the Iranians themselves had suggested (based on a 2005 briefing).[4] However, as this author pointed out in prior analysis, the Iranian output of enriched uranium seemed nowhere close to these values but rather about 0.5 SWU per machine-year (based on performance from late 2008 to the first half of 2009).[5] The reason for this poor performance was unclear. At the time this author suggested that this low value could be inherent to the Iranian centrifuges or it could be some teething problem and the performance could increase as the Iranians managed to work out the problems.

That Iran has been able to increase the amount of enriched uranium produced while using fewer centrifuges indicates that the latter is the case. Indeed the current operating centrifuges seem to be producing 0.87 SWU per machine-year—about a 75% increase. This is a very significant development since such an increase is equivalent to having 75% more centrifuges. Though Iran is operating fewer centrifuges at the FEP, the total SWU output has increased from about 2,400 SWU per year (4,920 centrifuges at 0.5 SWU per machine-year) to about 3,300 SWU per year (3,772 centrifuges at 0.87 SWU per machine-year)—a 37% increase. Furthermore there is no reason to think that an output of 0.87 SWU per machine-year is the ultimate limit for Iran's IR-1 centrifuges.

Another important development is that Iran has begun to produce 19.8% enriched uranium at the PFEP from 3.5% enriched uranium that had previously been produced at the FEP. On February 8, 2010 Iran informed the IAEA that on February 9, 2010 it intended to start this process. On February 9, 2010 the IAEA asked Iran not to proceed until necessary additional safeguards were put into place at the PFEP but when IAEA inspectors arrived there on February 10, they found that Iran had already started the process. By February 11 Iran had started producing 19.8% enriched uranium--a result that is consistent with the short equilibrium time of the centrifuge enrichment process. Initially Iran had only transferred about 10 kilograms of 3.5% enriched uranium to the PFEP but on February 14 Iran transferred about 1,320 kilograms of 3.5% enriched uranium from the FEP to the PFEP. This is almost all of the 3.5% enriched uranium that Iran has produced.

Only one cascade at the PFEP is capable of producing 19.8% enriched uranium from 3.5% enriched uranium. This is the 164 centrifuge cascade which consists of IR-1 type centrifuges. Assuming that each centrifuge can produce 0.87 SWU per machine-year this cascade can produce about 2.5 kilograms of 19.8% enriched uranium per month, requiring about 30 kilograms of 3.5% enriched uranium feed per month. Ostensively Iran's reason for undertaking this action is to produce fuel for the Tehran Research Reactor. My prior analysis found that this reactor uses about 7 kilograms of 19.75% enriched uranium per year so that it will only take Iran about 3 months to produce this amount of enriched uranium.[6] However, Iran's transfer of over 1,300 kilograms of 3.5%

[4] http://www.world-nuclear.org/sym/2005/pdf/Saeidippt.pdf
[5] *Iran's Centrifuge Enrichment Program as a Source of Fissile Material for Nuclear Weapons: An Update*, August 17, 2009, appendix added August 31, 2009, http://www.bipartisanpolicy.org/sites/default/files/Iran%20Enrichment%20Update%20%282%29.pdf
[6] *Fueling the Tehran Research Reactor: Technical Considerations on the Risks and Benefits*, October 12, 2009, http://npec.xykon-llc.com/files/20091012-Jones%20trr.pdf

enriched uranium to the PFEP would seem to imply that Iran intends a much longer campaign. At its current rate of consumption it will take about 3 years 8 months to process all of the 3.5% enriched uranium currently at the PFEP.

Iran is developing multiple pathways to attain the capability to produce HEU for nuclear weapons. In the author's past analysis one of the principal pathways was to break out from safeguards and undertake a two step process of batch recycling at the FEP starting with Iran's stockpile of 3.5% enriched uranium.[7] We consider any situation where Iran can produce a weapon's worth of HEU in less than two months as one where IAEA safeguards can not be adequately applied. Table 1 illustrates the process assuming Iran is limited to just the 3,772 centrifuges (23 cascades) that it currently is operating. Table 2 illustrates the same process assuming Iran uses all 8,528 centrifuges that it has installed in full cascades (52 cascades).

The two tables show that to carry out this process, Iran will need to start with a stockpile of about 1,900 kilograms of 3.5% enriched uranium. Its current stockpile (as of January 31, 2010) is about 1,400 kilograms. At its current rate of production it will take Iran only about six months (around the end of July 2010) for it to have 1,900 kilograms of 3.5% enriched uranium. If only 23 cascades are used after the breakout from safeguards, then the 107 days required might be long enough so that the West could undertake counteraction before the process was completed. Table 2 shows that if 52 cascades are used instead, then the time required after breakout from safeguards is only 51 days which is less than our standard of two months. Exactly when Iran could have 52 cascades operational is unclear but there is no reason to think it could not occur sometime in 2010 given that Iran already has the centrifuges installed.

Table 1

Time, Product and Feed Requirements for the Production of 20 kg of HEU by Batch Recycling in a 23 Cascade Enrichment Plant (3,772 Centrifuges, 0.87 SWU per Machine-Year)

Cycle	Product Enrichment and Quantity	Feed Enrichment and Quantity	Time for Cycle (Days)
First	19.75% 159 kg	3.5% 1,880 kg	85
Second	91.1% 20 kg	19.75% 155 kg	18
Total			107*

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

[7] *Iran's Centrifuge Enrichment Program as a Source of Fissile Material for Nuclear Weapons: An Update*, August 17, 2009, appendix added August 31, 2009, http://www.bipartisanpolicy.org/sites/default/files/Iran%20Enrichment%20Update%20%282%29.pdf

Table 2

Time, Product and Feed Requirements for the Production of 20 kg of HEU by Batch Recycling in a 52 Cascade Enrichment Plant (8,528 Centrifuges, 0.87 SWU per Machine-Year)

Cycle	Product Enrichment and Quantity	Feed Enrichment and Quantity	Time for Cycle (Days)
First	19.75% 164 kg	3.5% 1,940 kg	39
Second	91.1% 20 kg	19.75% 155 kg	8
Total			51*

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

Furthermore Iran's production of 19.8% enriched uranium at the PFEP has shown that the first step of this two step process does not require breaking IAEA safeguards. Breakout from safeguards would only be required for the cycle where the HEU is actually produced. As can be seen from Table 3 (a truncated version of Table 1) even using only 23 cascades (3,772 centrifuges) this process can be carried out in only 20 days—far less than the two months required for effective safeguards. This method of HEU production would still require Iran to first produce about 1,900 kilograms of 3.5% enriched uranium but as was discussed above, Iran will achieve this goal around the end of July this year. Iran will then have to convert this 3.5% enriched uranium to 19.8% enriched uranium (about 160 kilograms will be required to produce 20 kilograms of HEU). Using only one cascade as it is currently doing, it will take Iran about five years to produce this much 19.8% enriched uranium. However, there is nothing preventing Iran from using more cascades. If it were to use five cascades then only about a year will be needed to produce the required amount of 19.8% enriched uranium. If it uses ten cascades, then only about six months would be required. Clearly, this is well within Iran's capability.

Table 3

Time, Product and Feed Requirements for the Production of 20 kg of HEU Starting with 19.75% Enriched Uranium in a 23 Cascade Enrichment Plant (3,772 Centrifuges, 0.87 SWU per Machine-Year)

Cycle	Product Enrichment and Quantity	Feed Enrichment and Quantity	Time for Cycle (Days)
First	91.1% 20 kg	19.75% 155 kg	18
Total			20*

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

While these two pathways to the production of HEU are quite worrisome, they are not the only ones available. 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. The IAEA has admitted as much in its latest safeguards update.[8] While this has been a theoretical possibility since 2007, the discovery in September 2009 that Iran was actually building such a clandestine enrichment plant (the FFEP near Qom) has increased the salience of this concern. That Iran is now removing centrifuges from the FEP and taking them to an unknown location only further increases the concern. A clandestine enrichment plant containing 23 cascades (3,772 centrifuges, 0.87 SWU per machine-year) could produce around 20 kilograms of HEU (the amount required for one nuclear weapon) each year. 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.

Nor is the production of HEU Iran's only path to a nuclear weapon capability. Iran is currently building a plutonium production reactor (the IR-40) at Arak. This reactor will use heavy water as a moderator. In its latest safeguards report, the IAEA has indicated that Iran has a large number of drums that Iran says contain heavy water. Iran has refused to allow the IAEA to sample the contents of these drums but if they do contain heavy water the amount is likely over 40 metric tons which is enough to start the reactor. How long before the reactor is ready to operate it unclear but once the reactor begins operation, it will probably take around a year before Iran can extract its first plutonium. The reactor will be able to produce enough plutonium to produce about two nuclear weapons per year.

Iran is clearly pursuing a multifaceted effort to attain the capability to produce the HEU and/or plutonium required to produce nuclear weapons. It has significantly increased its production of enriched uranium and will likely achieve the capability to produce a weapon's worth of HEU in 2010. Furthermore the IAEA in its latest update has raised concerns that Iran may have an ongoing effort to produce a nuclear warhead for a missile which could make use of this HEU.[9] Iran's determination to move ahead with this effort has not been matched by a similar determination by the West to stop it. But unless some very determined action is soon taken by the West to bring Iran into compliance with UN Security Council resolutions 1737, 1747, 1803 and 1835, which call on Iran to suspend without delay "all enrichment-related and reprocessing activities", Iran will have a latent nuclear weapons capability and the West will need to start planning for Iran's new status as a defacto nuclear weapons state.

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[8] "While the Agency continues to verify the non-diversion of declared nuclear material in Iran, Iran has not provided the necessary cooperation to permit the Agency to confirm that all nuclear material in Iran is in peaceful activities." *Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions 1737 (2006), 1747 (2007), 1803 (2008) and 1835 (2008) in the Islamic Republic of Iran*, GOV/2010/10, February 18, 2010, p.9.

[9] "Altogether, this raises concerns about the possible existence in Iran of past or current undisclosed activities related to the development of a nuclear payload for a missile." *Ibid*, p.9.