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Iran's Efforts to Develop Nuclear Weapons Explicated
Centrifuge Uranium Enrichment Continues Unimpeded
The IAEA's November 8, 2011 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 November 8, 2011, the International Atomic Energy Agency (IAEA) released its much anticipated safeguards update.[3] This update shows that Western efforts to impede Iran's centrifuge enrichment program continue to be ineffective. Iran has maintained a steady production of 3.5% and 19.7% enriched uranium and will soon significantly increase its production of 19.7% enriched uranium. At the same time the IAEA has outlined in unprecedented detail the substantial progress Iran has made in the development of the non-nuclear components needed to produce nuclear weapons.

Iran's continuing uranium enrichment as well as its ongoing efforts to develop non-nuclear weapon components are moving Iran ever closer to nuclear weapons. If Iran were to now make an all-out effort to acquire nuclear weapons, it could probably do so in two to six months. However, given the ineffectiveness of Western counteraction thus far, Iran has no need to make such an all-out effort. Rather Iran will probably continue on its current course, producing an ever growing stockpile of enriched uranium and carrying out additional research to produce non-nuclear weapons components. Though it could be many years before Iran becomes an overt nuclear weapon state, it is already close enough to obtaining a nuclear weapon to be considered a de facto nuclear country.

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 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 November 2, 2011, Iran had installed a total of 54 cascades, 15 of which each contain 174 centrifuges and the remaining 39 cascades each contain 164 centrifuges. This results in a total of 9,006 centrifuges though the IAEA

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[2] My most recent detailed report is: Gregory S. Jones, "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/2011/65, November 8, 2011.

inexplicably characterizes this number as “approximately 8,000”. Of these 54 cascades, only 37 (containing 6,208 centrifuges) were being fed with uranium hexafluoride and therefore were producing 3.5% enriched uranium though the IAEA has indicated that not all of these 6,208 centrifuges may be operational.[4]

Iran began producing 3.5% enriched uranium at the FEP in February 2007 and as of November 1, 2011 Iran had produced a total of 3,327 kilograms (in the form of 4,922 kilograms of uranium hexafluoride). Since 517 kilograms of this enriched uranium has already been processed into 19.7% enriched uranium (see the PFEP below), Iran’s current stockpile of 3.5% enriched uranium is 2,810 kilograms. Iran’s current production rate of 3.5% enriched uranium is about 97 kilograms per month.[5] This production rate has held steady for most of 2011 and represents about a 75% increase 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 4,300 separative work units (SWU) per year.[6]

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
8/14/11-11/1/11	97

The 37 operational cascades at the FEP represent an increase of 2 cascades since the last IAEA report and an increase of 4 cascades since May 2011. However, as can be seen from Table 1, this increase in operational cascades did not lead to an increase in the

[4] “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/2011/65, November 8, 2011, p.3.
[5] 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.
[6] 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.

amount of 3.5% enriched uranium produced. Indeed Iran's uranium production rate at the FEP does not seem to be strongly correlated with the number of operational cascades. This fact was illustrated in reverse in the later part of 2009 when the number of operational cascades declined (from 30 to 24) yet as can be seen from Table 1, Iran's uranium production rate did not decline. Rather the production rate increased sharply in the first part of 2010 even though the number of operational cascades did not increase.

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 single centrifuges or small ten or twenty centrifuge test cascades. However, Iran has installed a cascade of 164 IR-2m centrifuges and though this cascade appears ready to begin to produce enriched uranium, it has yet to do so. Iran has also installed 66 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. As of October 28, 2011, Iran had accumulated a stockpile of 53.9 kilograms of 19.7% enriched uranium (in the form of 79.7 kilograms of uranium hexafluoride). Iran's production rate of 19.7% enriched uranium at the PFEP has been fairly steady and over the past year (from September 18, 2010 to September 13, 2011) it has averaged 2.8 kilograms per month.

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 West had discovered the plant.

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 will probably start operation shortly. 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. As of October 24, 2011, 64 centrifuges of the necessary 348 centrifuges had been installed, indicating that it will probably be at least a few months before this second set of two interconnected cascades begins operation. 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 about 2.8 kilograms of 19.7% enriched uranium per month, this will be a production rate of about 8.4 kilograms per month.

One interesting aspect of Iran's plan to triple its production rate of 19.7% enriched uranium is that to produce this much 19.7% enriched uranium, Iran will need to use about 60 kilograms of 3.5% enriched uranium per month as feed. Since Iran is only currently producing about 100 kilograms of 3.5% enriched uranium per month this means that the majority of Iran's new production of 3.5% enriched uranium will need to go to this purpose and Iran's stockpile of 3.5% enriched uranium will grow much more slowly in the future.

Iranian Options for Producing HEU

Given that Iran currently has an enrichment capacity of 4,300 SWU per year at the FEP and stockpiles of about 2,810 kilograms of 3.5% enriched uranium and 53.9 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 at the FEP. In this process, no major modifications are made to the FEP but rather enriched uranium is successively run though the FEP in batches until the desired enrichment is achieved. In the past I have calculated that Iran could use a two-step process to produce HEU. In the first step, 3.5% enriched uranium would be enriched to 19.7% enriched uranium. Iran has already demonstrated this step on a small scale by producing 19.7% enriched uranium at the PFEP. In the second step, 19.7% enriched uranium would be enriched to 90% enriched uranium. My calculations for this second step rely on work by Glaser which demonstrated that by reducing the flow through the cascade, it was possible to achieve the production of 90% enriched uranium from 19.7% enriched uranium in one step without a significant loss of separative capacity.[7] This process is illustrated for Iran's current situation in Table 2.

Table 2

Time, Product and Feed Requirements for the Production of 20 kg of HEU by Batch Recycling at the FEP (4,300 SWU per year total) (The Second Step is Based on Glaser's Analysis)

Cycle	Product Enrichment and Quantity	Feed Enrichment and Quantity	Time for Cycle (Days)
First	19.7% 104.3 kg	3.5% 1,230 kg	43
Second	90.0% 20 kg	19.7% 153.2 kg*	13
Total			60**

* Includes 53.9 kilograms of 19.7% enriched uranium that Iran has already stockpiled.
**Includes four days to account for equilibrium and cascade fill time.

[7] Alexander Glaser, "Characteristics of the Gas Centrifuge for Uranium Enrichment and Their Relevance for Nuclear Weapon Proliferation", *Science and Global Security*, Vol. 16, 2008. In particular see Table 3 on p.16.

Two steps are required. In the first step, 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 53.9 kilograms of 19.7% enriched uranium, Iran needs only to produce an additional 104.3 kilograms. This step requires 1,230 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, the batch recycling would take about two months.

As was stated above, this calculation depends on Glaser's published calculations of the effectiveness of reduced cascade flow so that uranium can be enriched from 19.7% to 90% in one step. I am not the only analyst who has relied on Glaser's work, as both Levi[8] and the International Institute for Strategic Studies[9] have based their calculations on Glaser's calculations.

However, on October 26, 2011, I received an e-mail from Glaser, indicating that he had "been made aware of certain phenomena that are not taken into account in [Glaser's] breakout model…" Glaser has not been willing to talk to me on the record about this matter nor has he been willing to reveal the identity of the third-party who has made him aware of this issue. This third-party apparently did not provide any specific analysis to Glaser, nor has Glaser done his own analysis of possible problems with his 2008 work. Still it seems that Glaser is no longer willing to stand behind his batch recycling calculations published in 2008 as Glaser also said in his e-mail "We now find that the most credible scenarios involve some kind of cascade reconfiguration." Glaser did not provide any analysis to support this statement.

Nevertheless, in light of Glaser's e-mail, I have examined methods whereby Iran could produce the 20 kilograms of HEU required for a nuclear weapon without relying on Glaser's calculations.

Iran could still produce HEU by batch recycling at the FEP but the process would require three steps. Each pass would produce the feed required for the next cycle, which would include the plant inventory (in this case, 5 kilograms for each cycle). Iran would need to produce sufficient 19.7% enriched uranium from 3.5% enriched feed, then further enrich this 19.7% enriched uranium to 55.4% enriched uranium and finally enrich the 55.4% enriched uranium to 86.3% enriched uranium. I have increased the amount of HEU required from 20 kilograms to 21 kilograms to keep the quantity of U-235 in the product about the same.

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

[8] Michael A. Levi, "Drawing the Line on Iranian Enrichment," *Survival*, Vol. 53, No. 4, August-September 2011, pp.180-181.
[9] *Iran's Nuclear, Chemical and Biological Capabilities, A net assessment*, an IISS strategic dossier, The International Institute for Strategic Studies, London, February 2011, p.73.

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 of the plant cannot be utilized during the latter cycles of the batch production process. The plant is restricted by the flow at the product end of the cascade. Therefore the time required per cycle is then determined by the amount of product required and the amount of product the plant can produce per day and not by a SWU calculation.

The results (Table 3) show that this method of batch recycling would take 6 months in contrast to the two months required in Table 2. In addition Iran would need to start with over 4,200 kilograms of 3.5% enriched uranium, much more than the 1,200 kilograms required by the calculations in Table 2 and well more than the 2,800 kilograms that Iran currently possesses. At current production rates it would take about one and three quarter years before Iran would possess enough 3.5% enriched uranium to start the batch recycling process.

Table 3

Time, Product and Feed Requirements for the Production of HEU by Batch Recycling at the FEP (4,300 SWU per year total)
(Does Not Rely on Glaser's Analysis)

Cycle	Product Enrichment and Quantity	Feed Enrichment and Quantity	Time for Cycle (Days)
First	19.7% 358 kg	3.5% 4,220 kg	146
Second	55.4% 71.4 kg	19.7% 407 kg*	22
Third	86.3% 21 kg	55.4% 66.4	7
Total			181**

* Includes 54 kilograms of 19.7% enriched uranium that Iran has already stockpiled.
**Includes six days to account for equilibrium and cascade fill time.

Iran, however, has additional options for producing the HEU required for a nuclear weapon. As was stated above, in addition to the FEP, Iran is producing 19.7% enriched uranium at the PFEP and in a few months will have tripled its production of 19.7% enriched uranium by starting two sets of two interconnected cascades at the FFEP. Once the cascades at the FFEP start operation, Iran could use its 19.7% production capacity to carry out the final step of the three step batch recycling process. The results are shown in Table 4.

As in the previous case, the times for the second and third steps are determined by the cascade product production rate and not by SWU calculations. The total time required is about five and one half months, which is not that much shorter than the prior case where all three batch recycling steps were carried out at the FEP. This method, however, has the advantage of reducing the required amount of 3.5% enriched uranium feed from 4,200 kilograms to 2,100 kilograms, which is smaller than Iran's current 2,800 kilograms stockpile.

Table 4

Time, Product and Feed Requirements for the Production of HEU by Batch Recycling at the FEP (4,300 SWU per year total)
Final Step at PFEP and FFEP
(Does Not Rely on Glaser's Analysis)

Cycle and Enrichment Plant	Product Enrichment and Quantity	Feed Enrichment and Quantity	Time for Cycle (Days)
First FEP	19.7% 179 kg	3.5% 2,110 kg	73
Second FEP	55.4% 40 kg	19.7% 228 kg*	12
Third PFEP & FFEP**	89.4% 20 kg	55.4% 39 kg	72
Total			163**

* Includes 54 kilograms of 19.7% enriched uranium that Iran has already stockpiled.
** Plant inventory is 1 kilogram.
***Includes six days to account for equilibrium and cascade fill time.

If Glaser's calculations are incorrect, the only way that Iran could currently produce the HEU for a nuclear weapon in just two months would be to use batch recycling at the FEP combined with a clandestine "topping" 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.[10] 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).

[10] "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/2011/65, November 8, 2011, p.10.

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 1,400 IR-1 type centrifuges to be able to produce the 20 kilograms of HEU required for a nuclear weapon in just two months. 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 5. As can be seen, the production of the 19.7% enriched uranium needed (including 2 kilograms for the plant inventory at the clandestine plant) to produce 20 kilograms of HEU at the clandestine enrichment plant now requires only 473 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 5

Time, Product and Feed Requirements for the Production of HEU by Batch Recycling at the FEP (4,300 SWU per year total)
Final Step at 1,400 Centrifuge Clandestine Plant (0.9 SWU per centrifuge-year)
Cycles Carried out Simultaneously
(Does Not Rely on Glaser's Analysis)

Cycle and Enrichment Plant	Product Enrichment and Quantity	Feed Enrichment and Quantity	Time for Cycle (Days)
First FEP	19.7% 40.1 kg	3.5% 473 kg	18
Second Clandestine	90.0% 20 kg	19.7% 106.8 kg*	63**
Total			63***

* Includes 53.9 kilograms of 19.7% enriched uranium that Iran has already stockpiled. Processing the tails of the clandestine plant at the PFEP and FFEP produces an additional 12.8 kilograms of 19.7% enriched uranium.
** Includes two days to account for equilibrium and cascade fill time.
*** Cycle times *not* additive since cycles are simultaneous.

Further, since Iran would have a substantial quantity of 3.5% enriched uranium left over (about 2,338 kilograms), Iran could continue the process and produce additional HEU. An additional 20 kilograms of HEU would require 1,109 kilograms of 3.5% enriched uranium feed, so with its current stockpile Iran could produce a total of about 62 kilograms of HEU, which is enough for about three nuclear weapons. Since the clandestine enrichment plant has been sized to produce about 10 kilograms of HEU per month, Iran could produce enough HEU for a nuclear weapon at successive two month intervals.

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 23 cascades (3,772 centrifuges, 0.9 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.[11] 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 significant drawback to this stand-alone clandestine enrichment plant is that it requires many more centrifuges than would the 1,400 centrifuge clandestine plant discussed above. It is not clear whether Iran could provide this number of centrifuges to a clandestine plant and the larger any clandestine enrichment plant is, the more likely it is that it will be discovered.

Iran then, has a number of methods whereby it could produce the HEU required for a nuclear weapon. If Glaser's previously published calculations are correct, then batch recycling at the FEP alone could produce enough HEU for a weapon in just two months. If Glaser's calculations are incorrect, then the most threatening cases are those involving clandestine enrichment plants. 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, then it could produce a weapon's worth of HEU in two months and enough HEU for three 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.

If Glaser's calculations are incorrect, and one does not want to posit the existence of a clandestine enrichment plant, then the fastest way Iran could produce HEU would be to carry out batch recycling at the FEP and the final enrichment step at the PFEP and FFEP. In this fashion, Iran could produce sufficient HEU for a weapon in about five and one half months which is longer than the two months that would be required if Glaser's calculations are correct. Clearly, it would be helpful to resolve the uncertainties regarding Glaser's calculations. However, even if these uncertainties are not resolved, it is obvious that clandestine Iranian enrichment facilities pose a serious threat.

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[11] *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.

Iran's Work on the Non-Nuclear Components for Nuclear Weapons

The latest IAEA safeguards report has outlined in unprecedented detail the substantial progress Iran has made in the development of the non-nuclear components needed to produce nuclear weapons. Much of Iran's efforts have been reported previously but the IAEA has provided new information as to how close Iran has come to being able to produce sophisticated nuclear weapons. Furthermore, the IAEA has made clear that Iran's efforts are continuing.

The 2007 National Intelligence Estimate (NIE) produced by the U.S. National Intelligence Council indicated that up until the fall of 2003, Iran had a nuclear weapons program.[12] The latest IAEA safeguards report states that during that time Iran was assisted in developing "a multipoint initiation system that can be used to initiate effectively and simultaneously a high explosive charge over its surface" by "a foreign expert" who "worked for much of his career with this technology in the nuclear weapon programme of the country of his origin."[13] According to press reports, this "foreign expert" is a Russian named Vyacheslav Danilenko. The IAEA has been told "by nuclear-weapon States that the specific multipoint initiation concept is used in some known nuclear explosive devices."

What has not been discussed thus far is that this "multipoint initiation system" will allow Iran to manufacture sophisticated nuclear weapons. Most nuclear weapons use the implosion method whereby the nuclear material is surrounded by high explosives which are detonated simultaneously to compress this material to produce the supercritical mass needed for a nuclear explosion. As is discussed by the U.S. Government publication *The Effects of Nuclear Weapons*:

> The second method [implosion] makes use of the fact that when a subcritical quantity of an appropriate isotope of uranium (or plutonium) is strongly compressed, it can become critical or supercritical as indicated above. The compression may be achieved by means of a spherical arrangement of specially fabricated shapes (lenses) of ordinary high explosive. In a hole in the center of this system is placed a subcritical sphere of fissionable material. When the high-explosive lens system is set off, by means of a detonator on the outside of each lens, an inwardly-directed spherical "implosion" wave is produced. *A similar wave can be realized without lenses by detonating a large number of points distributed over a spherical surface*."[14] [Emphasis added]

[12] "Iran: Nuclear Intentions and Capabilities," National Intelligence Estimate, National Intelligence Council, November 2007.
[13] *Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran*, GOV/2011/65, November 8, 2011, Annex, pp.8-9.
[14] Samuel Glasstone and Philip J. Dolan, *The Effects of Nuclear Weapons*, Third Edition, U.S. Government Printing Office, Washington D.C., 1977, p.16.

Therefore by having a multipoint initiation system, Iran can build nuclear weapons without the need to use lenses in the implosion system. Since the lenses add significant weight and volume to the entire weapon, Iran is now in a position to build nuclear weapons that are significantly lighter, and have a smaller diameter. Though some observers still refer to possible Iranian nuclear weapons as "crude," the IAEA report shows that Iran has progressed beyond such designs.

One of the most controversial aspects of the 2007 NIE was its assertion: "we assess with moderate confidence Tehran had not restarted its nuclear program as of mid-2007…" Based on the information provided by the IAEA, it is clear that this statement is incorrect. Iran has continued the development of non-nuclear components for a nuclear weapon though it has been more circumspect since 2003. Iran now tries harder to disguise its efforts to develop nuclear weapons but it has not ceased those efforts.

In particular, in 2003 Iran had already conducted at least one full-scale test of its multipoint initiation system with the hemispheric shape required for a nuclear weapon. Since that time Iran has continued to test this system but it is now using scaled down versions and employing a cylindrical geometry. Such geometry is not directly applicable to a nuclear weapon but according to the IAEA such tests would still allow Iran to improve and optimize the multipoint initiation design. In addition, in 2006 Iran embarked on a four year program to design the neutron initiator that would be required to start a nuclear chain reaction once the supercritical nuclear mass was achieved. In 2008 and 2009 Iran conducted modeling studies of the neutronic behavior of HEU subjected to shock compression in a nuclear weapon. Such analysis would allow the determination of a nuclear weapon's yield. While these activities are already a strong indication of Iran's continuing efforts to produce nuclear weapons, one must keep in mind that there could be additional Iranian activities in this area that are unknown to the IAEA.

The IAEA makes clear that in the past Iran was trying to develop a nuclear warhead that could be fitted on the Shahab 3 missile. The multipoint initiation system referred to above was apparently sized to meet this requirement. However, current discussions on how quickly Iran could obtain nuclear weapons often overemphasize the need for any Iranian nuclear weapon to be missile deliverable. Indeed there are some who claim that missile deliverability is a necessary requirement for any Iranian nuclear weapon,[15]

But there are other viable means for Iran to be able to deliver a nuclear weapon. In the past, nonproliferation analysts would sometimes derisively say that certain nuclear weapon designs were so crude that it would take a truck to deliver the weapon. Unfortunately, vehicle delivery of bombs (up to now all conventional) has become quite common in the region and many such attacks have been carried out on U.S. forces. Vehicle delivery of a nuclear weapon against U.S. forces could have a devastating effect

[15] For example, Olli Heinonen has said "They [Iran] work in all three areas—enrichment, nuclear device design and a missile system to deliver—and in all areas probably progress is slow but you need to have all of them in place in order to have the weapon." See: Fredrik Dahl, "Ex-U.N. inspector sees no Iran atom bomb before 2013," Reuters, October 5, 2011.

and would have the advantage of making it more difficult to attribute the source of the attack.

In 2002-2003, when Iran was clearly attempting to fit its nuclear weapon design into a ballistic missile, Iran's main concern was Iraq. Ballistic missiles would have been an ideal method for delivering nuclear weapons against Iraq. If Iran is now concerned with carrying out nuclear attacks on Israel or U.S. forces in the region, ballistic missile delivery of a nuclear weapon may not be viable given the anti-ballistic missile systems of the U.S. and Israel. Even if Iran acquires the ability to deliver nuclear weapons by ballistic missiles, it is not clear that this will be Iran's preferred nuclear weapon delivery mode.

If Iran were to make an all-out effort, how quickly might it be able to produce the non-nuclear components for a nuclear weapon? I have previously written that the U.S. during World War II was able to develop an implosion nuclear weapon in just eleven months and that this should be considered an upper bound on the time that Iran would require.[16] In light of the IAEA's information about Iran's efforts to develop nuclear weapons and in particular, Iran's acquisition of a multipoint initiation system from a Russia nuclear scientist, it is clear that Iran is well on its way to developing nuclear weapons. On the other hand, though Iran has developed many of the individual non-nuclear components required for a nuclear weapon, there is no evidence that Iran has yet to integrate these individual components and test them. China, for example, conducted a non-nuclear test of a full-scale version of its nuclear device but without any HEU. Iran would have to conduct one or more such tests to have a reasonable assurance that its nuclear design was viable. Therefore I estimate that it would take Iran between two and six months before Iran could have the non-nuclear components for a nuclear weapon ready for use.

It is important to note that this time should NOT be added to the time required to produce the HEU for the weapon. Since the beginning of the nuclear age, it has been well-known that a state can develop the non-nuclear components for its first nuclear weapon in parallel with or prior to the production of the fissile material needed for the weapon. One of the clearest statements of how nuclear weapons are developed can be found in the official British history of its nuclear weapons program. In a memo dated November 1, 1946, William Penney, who was to lead the British effort, outlined how the task could be accomplished. According to the official British history:

> "He said that the manufacture of an atomic bomb of present design fell naturally into two parts: firstly the production of the active material and secondly the ordnance part, that is, the manufacture and assembly of the components causing the explosion of the active material. The second part

[16] Gregory S. Jones, "When Could Iran Have the Bomb? An Analysis of Recent Statements That Iran is 3 to 5 Years Away," April 26, 2010.
http://www.npolicy.org/article.php?aid=94&rt=&key=Jones&sec=article&author=

> of the work could be begun and *completed* without the need to use fissile material at any stage."[17] [Emphasis added]

The U.S. experience in World War II demonstrates that it is possible to complete the "ordnance part" of a nuclear weapon without having the fissile material first. The non-nuclear components of the Hiroshima nuclear weapon were on the cruiser *Indianapolis* and sailing across the Pacific Ocean while some of the HEU components for the weapon were still being manufactured. The fact that the IAEA has provided information showing that Iran is currently developing the non-nuclear components for nuclear weapons even though Iran does not yet have any HEU further reinforces this point.

Conclusions

Iran's centrifuge enrichment program continues its steady production of 3.5% and 19.7% enriched uranium, completely unimpeded by Western counteraction. Iran will soon triple its production of 19.7% enriched uranium, bringing Iran closer to a nuclear weapons capability at a much faster pace.

Just how quickly Iran could produce the HEU for a nuclear weapon should it decide to do so has become more uncertain, as questions have been raised about calculations by Glaser that formed a key part of my earlier analyses. If Glaser's calculations are correct or one is willing to posit that Iran possesses a small clandestine "topping" centrifuge enrichment plant, then Iran could produce enough HEU for a nuclear weapon in just two months. If Glaser's calculations are incorrect and one is unwilling to posit a small clandestine Iranian centrifuge enrichment plant, then it will currently take Iran about five and one half months. Even in this latter case, Iran's increased production of 19.7% enriched uranium means that this time will drop to about three months by the later part of 2013.

On the other hand, the latest IAEA safeguards report has significantly reduced the uncertainty regarding how quickly Iran could produce the non-nuclear components for a nuclear weapon. With the assistance of a Russian nuclear weapon expert, the Iranians have already tested a multipoint initiation system. This development has brought Iran fairly close to the capability for producing small, light-weight, sophisticated nuclear weapons. I estimate that Iran could finish the developed of the non-nuclear components for a nuclear weapon in just two to six months should Iran decide to do so. Since Iran is continuing to work on the development of these components, this time is only decreasing. It is important to note that the development of the non-nuclear components could be carried out in parallel with or prior to the production of the HEU. Also though much of the public discussion has focused on Iranian delivery of nuclear weapons via ballistic missiles, Iran's nuclear weapons could also be delivered by truck or car.

This does not mean that I think that Iran will become an overt nuclear weapon state any time soon. As I have written elsewhere:

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[17] At the time the memo was so highly classified that Penney had to type it himself. See: Margaret Gowing, assisted by Lorna Arnold, *Independence and Deterrence: Britain and Atomic Energy, 1945-1952*, Volume I, Policy Making, St. Martin's Press, New York, 1974, p.180.

> That's 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.[18]

Many analysts have found my conclusion that Iran is already a de facto nuclear power to be unpalatable but there does not appear to be any concrete way to stop Iran from taking the final steps to acquire nuclear weapons whenever it wishes. Most analysts are opposed to U.S. military action against Iran and I agree. As I have written previously:

> After ten years of war in Afghanistan and Iraq, the U.S. is too war-weary and financially exhausted to consider such an action, especially since Iran is much larger and more populous than either Iraq or Afghanistan. The U.S. could try to undertake limited strikes against Iran's centrifuge enrichment program, but isolated strikes would only delay the program and drive it further underground. Only a sustained campaign would likely be able to stop Iran's centrifuge program, but this could easily lead to an unwanted long-term war with Iran. Therefore, the U.S. does not seem to have any realistic military options for eliminating Iran's centrifuge enrichment program. [19]

Similarly an attack by Israel does not seem likely. As I have written previously:

> Israel, which has struck both Iraq (in 1981) and Syria (in 2007) to disable nuclear reactors involved in efforts to produce the fissile material for nuclear weapons, is considered to be the most likely candidate for such action. Ironically, however, Israel's strike on Syria in 2007 illustrates that it is unlikely to strike Iran. As its actions against Syria showed, if Israel perceives a threat, it is likely to strike quickly, without any preliminaries such as appeals to the international community. Iran restarted its centrifuge enrichment program in 2006, yet over five years later, Israel has taken no action. By this inaction Israel appears to have decided that Iran's centrifuge enrichment program is either too far away or too well dispersed or protected to be effectively struck.[20]

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[18] 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
[19] Gregory S. Jones, "An In-Depth Examination of Iran's Centrifuge Enrichment Program and Its Efforts to Acquire Nuclear Weapons," August 9, 2011, p.22 http://www.npolicy.org/article.php?aid=1092&rid=4
[20] *Ibid.*

Another point which applies to both possible U.S. or Israeli military action against Iran is that the time may have passed for such action to be effective. Iran has already dispersed some of its enrichment capacity to the well protected FFEP and has already produced large stockpiles of 3.5% and 19.7% enriched uranium. These enriched uranium stockpiles have small volumes and would be very difficult to find and hit with an aerial assault.

Some analysts believe that sanctions may yet stop Iran but even after the latest IAEA revelations about Iran's weapons development, neither Russia nor China was willing to adopt strong international sanctions against Iran. The resolution passed by the IAEA Board of Governors on November 18, 2011, simply calls for a progress report in March 2012.[21]

Many analysts believe that diplomacy is the only way to try to contain Iran's nuclear program but even an advocate of this position has admitted: "diplomacy has been incredibly difficult to pursue in the current environment."[22] Indeed, in the last attempted negotiations between the West and Iran last January, the parties could not even agree on an agenda. With Iran's recent assault on the British embassy in Tehran, it does not seem that the environment for diplomacy has improved any.

Further most analysts who are in favor of a diplomatic solution think it would be necessary to allow Iran to continue to have centrifuge uranium enrichment.[23] This view fails to recognize that any centrifuge uranium enrichment facility large enough to have any meaningful peaceful uses would also be large enough to allow Iran to quickly produce the HEU for a nuclear weapon. IAEA safeguards are inadequate to provide "timely detection" of the production of HEU at such a facility.

Other analysts take comfort that Iran's leaders apparently have not yet specifically directed a nuclear weapon to be produced, ignoring the fact that the UK, France, India and Nazi Germany all had nuclear weapons programs before there was any specific directive to produce such a weapon. The U.K., France and India all eventually made such a decision and have produced nuclear weapons. This underscores the point that as Iran moves closer to having a nuclear weapons capability, it becomes increasing likely that Iran will make the decision to produce nuclear weapons.

As I have published elsewhere, the bottom line is:

> "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

[21] *Implementation of the NPT safeguards agreement and relevant provisions of United Nations Security Council resolutions in the Islamic Republic of Iran*, GOV/2011/69, November 18, 2011.
[22] Daryl Kimball, transcript, "Briefing-Iran's Nuclear Program: Status and Prospects," An Arms Control Association Press Briefing, September 19, 2011.
[23] For example, see Greg Thielmann, *Ibid*.

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.

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.[24] The costs we face if something goes 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."[25]

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[24] 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 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

[25] 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