National Security Project

Iran's Nuclear Program

Status and Breakout Timing

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BIPARTISAN POLICY CENTER

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AUTHORED BY

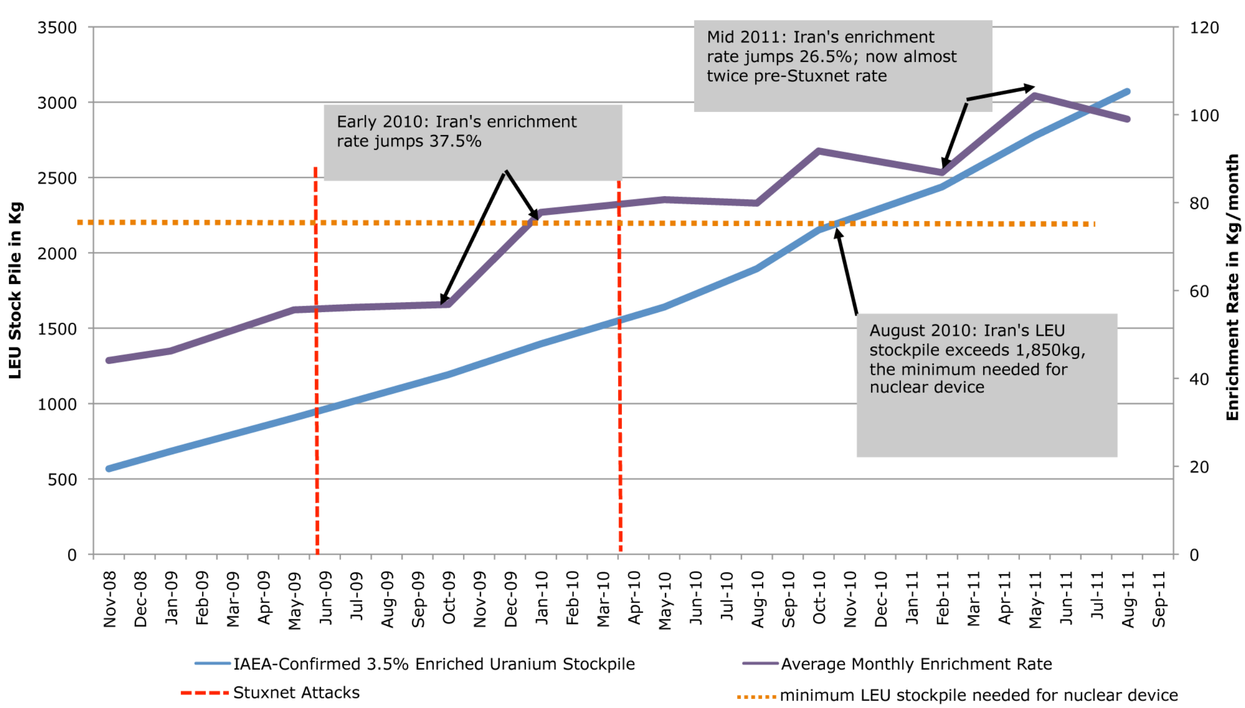
Blaise Misztal, Associate Director,
Bipartisan Policy Center's National Security Project

Overview

For much of the second half of 2010 and well into 2011, any discussion of the Islamic Republic of Iran's nuclear program was dominated by a series of events that suggested deliberate attempts at sabotage on the part of foreign powers. Chief in captivating the world's attention was a computer worm, dubbed "Stuxnet," which infected several Iranian industrial sites and appears to have been designed specifically to target the computers controlling Iran's centrifuges.[i] Bomb attacks that targeted Iranian nuclear scientists—killing one and injuring another—only added to the perception that Iran's nuclear program was encountering significant setbacks.[ii] These stories, however, obscured the fact that Iran's nuclear program, rather than being slowed, has been accelerating.

Indeed, although Iran's main enrichment facility at Natanz did experience problems with some of its centrifuges during 2010, the rate of uranium enrichment at that site has been growing steadily. By May 2011, that rate had reached almost double what it was in 2009 and exceeded the average 2010 enrichment rate by more than 25 percent. (See figure 1.)

Figure 1. Iran's LEU Stockpile and Enrichment Rate



Moreover, several developments in early 2011 have been alarming, portending Tehran's advancement toward nuclear weapons capability. These changes include (a) Tehran's continued production of 19.8% enriched uranium; (b) Iran's testing and installation of advanced centrifuge models, which could enrich uranium as much as six times faster than the model currently in use; (c) installation of centrifuges at the previously undisclosed underground Fordow[iii] facility near Qom, with the stated purpose of tripling the 19.8% enriched uranium output; and (d) mounting evidence that Tehran never ceased its nuclear weapons program.

Such activities—both covert and overt—underscore the hostile intentions of Iran's nuclear program and facilitate a potential Iranian "breakout" from its obligation "not to manufacture or otherwise acquire nuclear weapons" under the Nuclear Nonproliferation Treaty (NPT) and the safeguards mandated by the NPT and imposed by the International Atomic Energy Agency (IAEA). Such a breakout would severely constrain options to prevent the threat of a nuclear Iran. Indeed, once Iran acquires fissile material, U.S. policymakers, military leaders and strategic planners should assume that Tehran has a nuclear weapons capability, even if it does not test the device.

Every day that Iran's centrifuges spin shortens the time Tehran requires to produce a nuclear weapon. Already it has accumulated more than 3,000 kilograms (kg) of low-enriched uranium (LEU)—more one and a half times the 1,850 kg needed to yield, with further enrichment, enough fissile material for a nuclear device. Although it remains unclear if Iran has mastered the technology needed to construct a working nuclear weapon, Iran now could, if it so chooses, produce 20 kg of highly enriched uranium (HEU)—one nuclear device's worth—in as little as two months. Thus, the Islamic Republic of Iran could be a *de facto* nuclear power before 2011 is over.

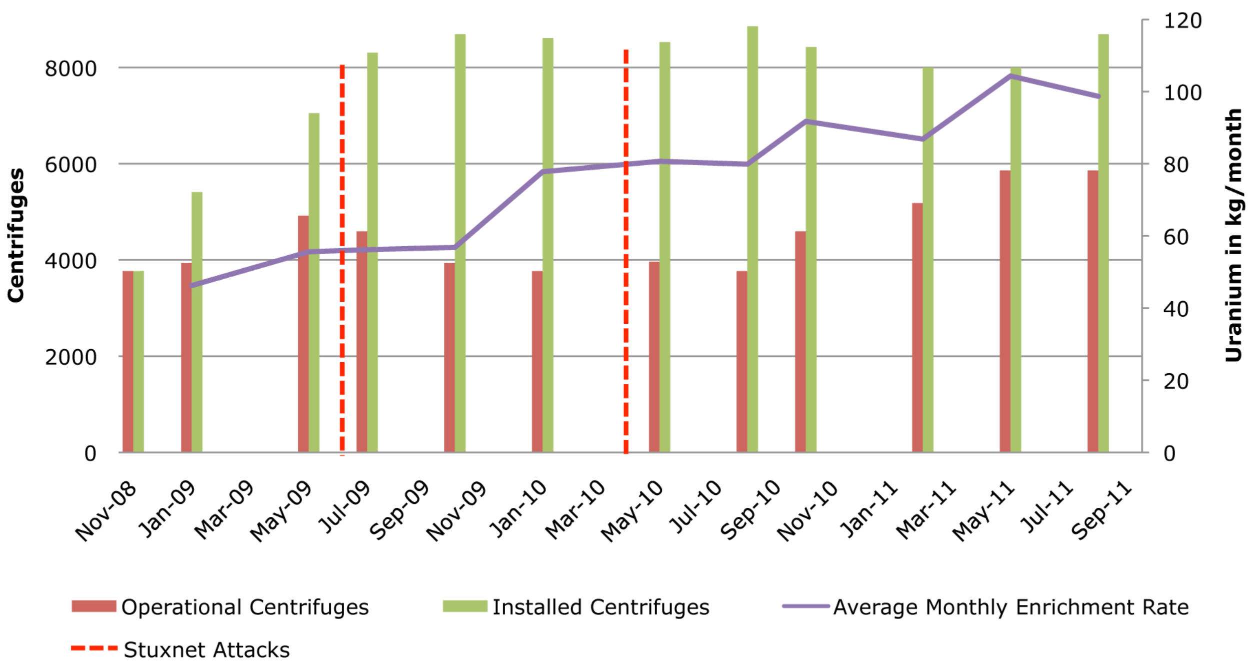
Enrichment Activities

Advances in Enrichment Rate, Amid Stuxnet

Despite the attention devoted to the Stuxnet cyberattack on Iranian nuclear facilities—and the subsequent assumption of damage inflicted—the reality is that Iran's nuclear program has made great advances since mid-2009, when Stuxnet is believed to have first infected Iranian computers. Iran is now producing 3–5% enriched uranium at Natanz faster than ever before, and it is doing so without a significant increase in the number of centrifuges installed there.

Using IAEA data, we have calculated that between February and May 2011, Iran was able to produce an average of almost 105 kg of LEU per month. [iv] In the period between May and August 2011, that rate fell slightly to 99 kg per month.[v] Still, this represents a nearly twofold increase over Iran's average production rate in 2009—which amounted to 56 kg of LEU per month—and is almost 25% more than 2010 average production rate of 86 kg per month. (See figure 2.)

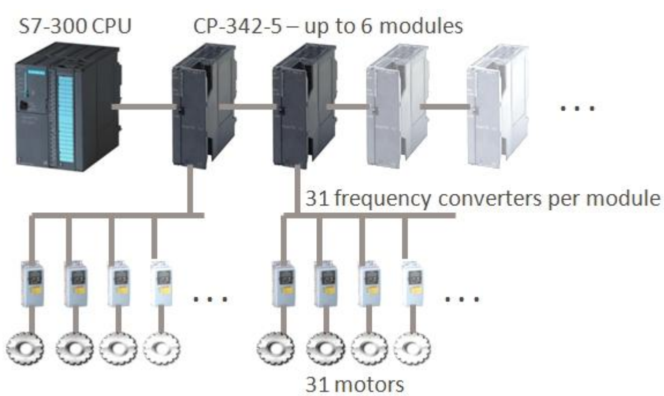
Figure 2. Enrichment Rate vs. Operational Centrifuges at Natanz FEP



Astoundingly, much of this increase in Iran's enrichment rate occurred at the same time as the number of operational centrifuges at the Natanz Fuel Enrichment Plant (FEP) dropped dramatically, and the increase roughly corresponds to the first known appearance of the Stuxnet computer worm in June 2009. In May 2009, Iran was operating 4,920 centrifuges and producing just 56 kg of LEU per month.[vi] By January 2010, the number of operating centrifuges fell to only 3,772 while enrichment rates rose to 78 kg per month.[vii] It was not until all centrifuges at the FEP were taken offline for at least a week in November 2010 that the amount of centrifuges enriching uranium began to rise again.[viii]

It is possible that this sustained decrease in operational centrifuges was the result of damage sustained because of the Stuxnet computer worm. First detected in June 2010 by a Belarusian computer security firm, Stuxnet is a self-propagating piece of malicious software that appears to have been designed to find, spread to and infect Supervisory Control and Data Acquisition (SCADA) systems that met very specific criteria: (a) they had to be a particular model manufactured by Siemens, which had been reported by the IAEA to be used in Iran's nuclear program; and (b) the Siemens SCADA systems, in turn, had to be attached to a particular model of frequency convertors—devices used to control the speed at which centrifuges spin. (See figure 3.)

Figure 3: Design of Systems Targeted by Stuxnet Worm



(Source: "W32.Stuxnet Dossier," Symantec)

Once it gained access to those systems, Stuxnet issued a series of commands to the frequency convertors:

1. Raise rotational speed nearly 40% above normal operating frequency for a period of 15 minutes.
2. Return rotational speed to normal operating frequency.
3. Wait 27 days.
4. Lower rotational speed to almost a complete standstill for 50 minutes.

5. Raise rotational speed to normal operating frequency.
6. Wait 27 days and repeat sequence.[ix]

By creating such fluctuations in the speed at which centrifuges spin, Stuxnet seems to have been designed to disrupt their normal operation or even to cause them to break down and fail. It is thus entirely possible that the Stuxnet cyberattack resulted in the significant drop in centrifuges enriching uranium at FEP between May 2009 and November 2010, as well as the entire cessation of all enrichment for a week in November 2010.

Alternative explanations exist, however. The IR-1 gas centrifuges currently used at FEPs are based on an antiquated design known to have a high rate of mechanical failure; some sources suggest as many as 10 percent of those centrifuges fail in the first year of operation.[x] The unreliability of the IR-1 centrifuges can be further compounded by imprecise manufacturing and assembly. Indeed, some have suggested that the centrifuges that failed *en masse* at FEP could have been the first batch domestically manufactured in Iran, rather than centrifuges provided by the Pakistani A.Q. Khan network.[xi]

Regardless of the cause of these failures, however, they did not slow the growth of Iran's LEU stockpile. To the contrary, it accelerated precisely during the period in which the technical problems were taking place. More important, by May 2011, Iran had overcome whatever difficulties it might have faced in 2009 and 2010. On May 14, 2011, the IAEA found nearly 8,000 centrifuges installed at FEP, of which 5,860 centrifuges were under vacuum and spinning, although inspectors noted that possibly not all of them were being fed uranium.[xii] In August 2011, the same number of centrifuges was found to be operating, but the number of installed centrifuges had increased to 8,692.[xiii]

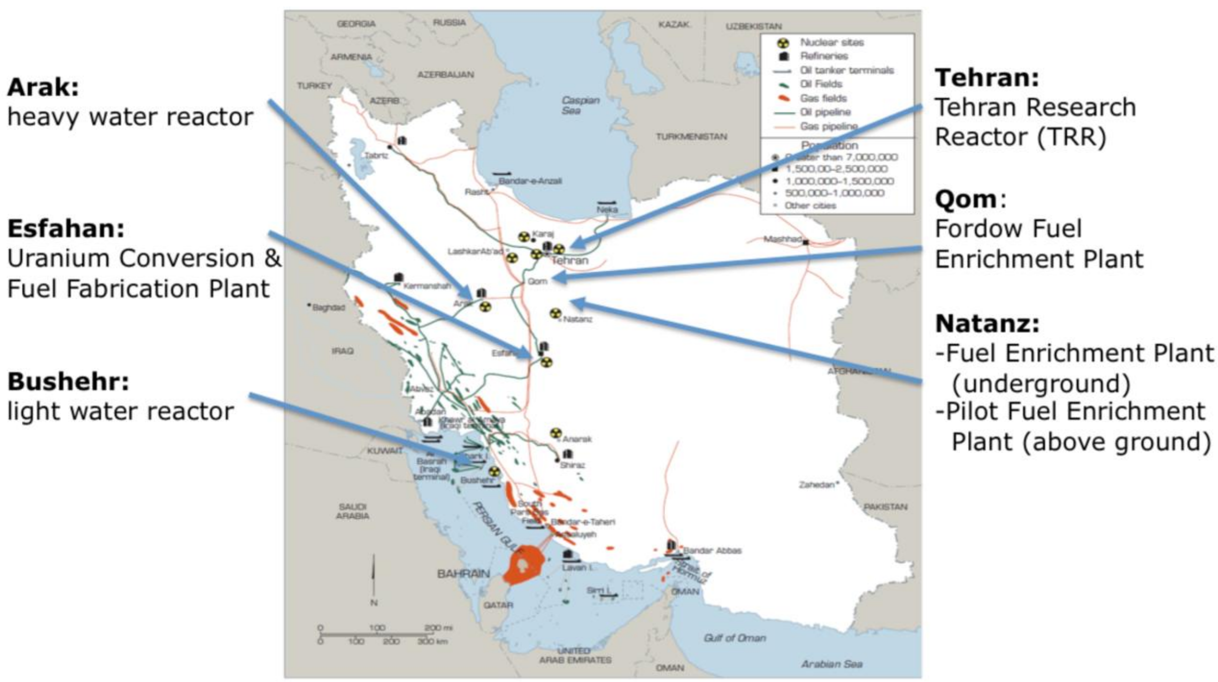
Production of 19.8% Enriched Uranium

On February 8, 2010, Iran informed the IAEA that it would begin producing 19.8% enriched uranium with the stated goal of producing fuel to power the Tehran Research Reactor (TRR), which the government uses to produce medical isotopes. In the year and a half since then, Iran has not only produced more than five years worth of fuel for the TRR but also announced its intention to triple its production 0f 19.8% enriched uranium and to move that production into a secured, underground location—the previously covert facility near Qom.[xiv]

Those actions, which have been met by almost no international protest, have effectively legitimized Iran's production of 19.8% enriched uranium and are allowing Iran to move one step closer to acquiring fissile material while seemingly remaining compliant with the NPT and IAEA safeguards. Because enriching uranium to low levels is much more time-consuming than going from a low level to a higher one, Iran can reduce the time it will need to produce HEU by as much as two-thirds if it enriches its stockpile of 3.5% enriched uranium to 19.8%. (See section that follows about breakout timing for more details.) Although it still lacks a sufficient stockpile to produce the 20 kg of HEU needed for a nuclear device using solely 19.8% feedstock, if Iran does devote the Qom facility to the production of 19.8% enriched uranium and is able to speed its production rate, this development could prove even more dangerous than the acceleration of enrichment at Natanz.

Enrichment Facilities

Figure 4. Main Iranian Nuclear Facilities



Fuel Enrichment Plant—Natanz. The Fuel Enrichment Plant (FEP) is a below-ground enrichment facility located at Natanz. Since 2002, it has been the hub of Iran's enrichment program. It consists of two underground halls designed to hold a total of 50,000 centrifuges.

According to the IAEA's September 2, 2011, report,[xv] between May 14, 2011, and August 13, 2011, Iran produced an additional 438 kg of 3.5% enriched uranium hexafluoride (UF6) at the Natanz FEP, bringing Iran's total LEU stockpile to just more than 4,540 kg of UF6, which is equivalent to about 3,071 kg of low-enriched uranium.[xvi]

During its August 28, 2011, inspection, the IAEA found nearly 8,692 centrifuges installed at FEP, of which 5,860 centrifuges were under vacuum and spinning.[xvii] Some sources have estimated that the number of centrifuges actually enriching uranium has remained steady at 5,184 since February 2011.[xviii] Nevertheless, this marks a sharp rise from a low of 3,772 in August 2010.

Both the increased the uranium production at FEP and the upswing in operational centrifuges has a drastic impact on the timing of a potential nuclear breakout, as discussed later.

Pilot Fuel Enrichment Plant—Natanz. Iran notified the IAEA of its intent to begin producing 19.8% enriched uranium at the above-ground Natanz Pilot Fuel Enrichment Plant (PFEP) on February 8, 2010. Despite the IAEA's insistence that Iran not undertake enrichment at the PFEP until the installation of additional safeguards, inspectors who examined the facility on February 9, 2010, found the centrifuges already spinning. This activity likely violated Article 45 of its IAEA Safeguards Agreement and prompted the IAEA to remark that "additional measures need to be put in place to … verify the nondiversion of the nuclear material at PFEP."[xix]

A research facility, the PFEP is designed to hold only six cascades of 164 centrifuges each. Currently, only two cascades—totaling 328 centrifuges—are installed and being used to enrich 3.5% enriched uranium to levels of 19.8%. To date, Iran has produced 47.9 kg of 19.8% enriched uranium at the PFEP, with a production rate that in the past reporting period reached about 3.2 kg of 19.8% enriched uranium per month, using a feedstock of 30 kg of 3.5% enriched uranium per month.[xx]

The annual fuel consumption of the Tehran Research Reactor, for which the PFEP is purportedly producing fuel, is only about 7 kg of 19.8% enriched uranium.[xxi] If Iran were interested in ensuring an ample supply of fuel for the reactor, it would need to run the PFEP centrifuges for only three months out of the year and to introduce no more than 100 kg of the LEU into the centrifuges. As it stands, Iran has already stockpiled almost seven years worth of fuel for the TRR. Yet, not only does Iran intend to produce more 19.8% enriched uranium, but it wants to speed up production as well.

In January 2011, Iran submitted plans to the IAEA indicating that it planned to install two new, advanced cascades at PFEP: one each of IR-4 and IR-2m centrifuge models.[xxii] Iranian scientists declared that they had fully tested and were ready to deploy these new models, which outside experts suggested could raise production rates as much as six times higher than the current IR-1 model.[xxiii] On July 19, 2011, Iran's Foreign Ministry announced that the "the installation of new centrifuges with better quality and speed is ongoing."[xxiv] And in its inspection on August 28, 2011, the IAEA indeed found that Iran had installed 136 IR-2m and 27 IR-4 centrifuges at the PFEP. Of those, 54 of the IR-2m model were already enriching uranium.[xxv]

Fordow Fuel Enrichment Plant—Qom. Speaking to the G20 summit in Pittsburgh on

September 25, 2009, Presidents Barack Obama and Nicolas Sarkozy and Prime Minister Gordon Brown revealed publicly the existence of a secret Iranian nuclear facility near Qom. The announcement sparked allegations that the plant could be part of a weapons program and was constructed in contravention of the NPT.[xxvi]

IAEA inspections of the site suggest the facility—technically known as the Fordow Fuel Enrichment Plant—is designed to hold 2,624 centrifuges. When its existence was first revealed, Iran told the IAEA that the Fordow plant was intended for the production of LEU at up to 5% enrichment. However, on June 8, 2011, Fereidoun Abbasi, then Iranian vice president, announced not only that "soon, we will install 164-machine centrifuge cascades of the new generation [at Qom]" but also that Iran planned to "transfer the 20 percent–uranium enrichment … to the Fordow plant" from Natanz and would "triple its (production) capacity."[xxvii]

Abbasi, now head of the Atomic Energy Organization of Iran (AEOI), proved as good as his word, declaring on August 22, 2011, that "the site is being made ready and a series of centrifuges have already been transferred."[xxviii] Indeed, the IAEA reports that 174 centrifuges intended to enrich uranium to 19.8% were installed by August 20, 2011.[xxix] "These reports," according to Victoria Nuland, spokesperson for the State Department, "are troubling." She went on to state that

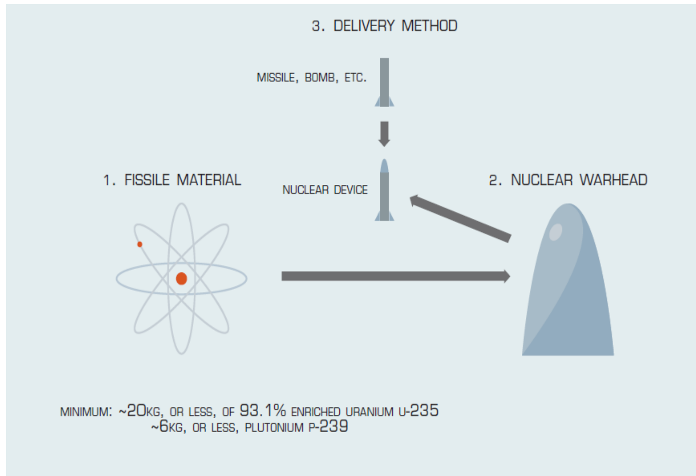
> The Iranian nuclear program offers no plausible reason for its existing enrichment of uranium up to nearly 20 percent, nor ramping up this production, nor moving centrifuges underground. And its failure to comply with its obligations to suspend its enrichment activities up to 3.5 percent at nearly 20 percent have given all of us in the international community reason to doubt its intentions.[xxx]

Nuclear Weapons Capability

A nuclear weapon, broadly speaking, consists of three main components:

1. fissile material, either highly enriched uranium (HEU) or plutonium;
2. a device, usually referred to as the "weapon," designed to force the fissile material into a supercritical mass, thereby unleashing a nuclear chain reaction, most commonly done using spherically arranged high explosives; and
3. a delivery mechanism.

Figure 5. Three Components of a Nuclear Device



Because Iran already possesses (a) ballistic missiles capable of carrying nuclear payloads and (b) an extensive network of terrorist organizations that could deliver a nuclear weapon by other means, we will here consider only the first two of these components.

According to our analysis, which is examined in greater depth later, given Iran's current number of operational centrifuges, the efficiency of its centrifuges and the size of its LEU stockpile, Iran could produce enough HEU for a nuclear weapon in as little as 62 days. It is important to understand, however, what this estimate does not signify. Although we note IAEA revelations about Iran's ongoing weapons program, we *do not* estimate (a) whether Iran currently possesses the technology to construct a working nuclear weapon, (b) how long it might take to attain that technology or (c) how long the construction of such a weapon might take. Moreover, we *do not* suggest that Iran will produce a weapon's worth of HEU two months from now, merely that it possesses the capability to do so.

However, acquiring HEU is the foremost technical hurdle for any country seeking to become a nuclear power. Once Iran surmounts it, U.S. policymakers, military leaders and strategic planners should assume Tehran has a nuclear weapons capability, even if it does not test the device. Indeed, we believe that Iran is most likely to amass the components of a nuclear device without assembling them or conducting a test explosion, thus remaining "a screwdriver's turn" away from a weapon while promoting ambiguity about its true intentions and status. In this way, Tehran can gain the benefits of a *de facto* nuclear deterrent without incurring legal and political repercussions.

Weapons Design

In late 2007, the U.S. intelligence community released a National Intelligence Estimate (NIE) that asserted "with high confidence that in fall 2003, Tehran halted its nuclear weapons program."[xxxi] Now, the IAEA reports possessing extensive information relating to a possible military dimension to the Islamic Republic of Iran's nuclear program in the period after 2004.[xxxii]

In prior reports, the IAEA has repeatedly voiced worries about possible military dimensions of Iran's nuclear program. In its latest report, however, it took the extraordinary step of highlighting that it is

> … increasingly concerned about the possible existence in Iran of past or current undisclosed nuclear related activities involving military related organizations, including activities related to the development of a nuclear payload for a missile, about which the Agency continues to receive new information.[xxxiii]

The report goes on to specify:

> The information available to the Agency in connection with these outstanding issues is extensive and comprehensive and has been acquired both from many Member States and through its own efforts. It is also broadly consistent and credible in terms of technical detail, the time frame in which the activities were conducted and the people and organisations involved.[xxxiv]

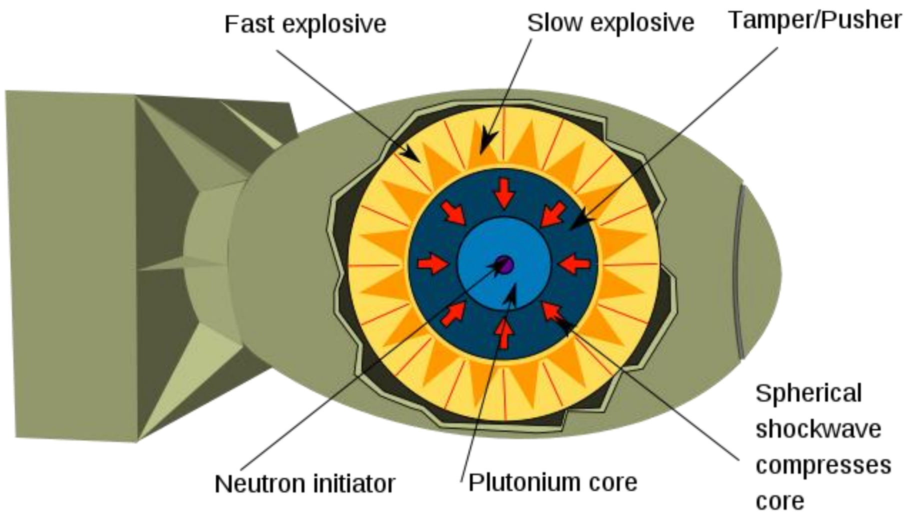
In its May 2011 report, the IAEA specified some of the military-related activities it believes Iran to have been involved in, thereby

> … indicating seven particular areas of concern,
> - neutron generator and associated diagnostics,
> - uranium conversion and metallurgy,
> - high explosives manufacture and testing,
> - exploding bridgewire (EBW) detonator studies,
> - multipoint explosive initiation and hemispherical detonation studies,
> - high voltage firing equipment, [and]

- missile re-entry vehicle redesign activities.[xxxv]

Indeed, these activities seem to line up closely with the technology involved in assembling an implosion type nuclear device. (See figure 6.)

Figure 6. Basic Elements of an Implosion Type Nuclear Device



(Source: Wikipedia)

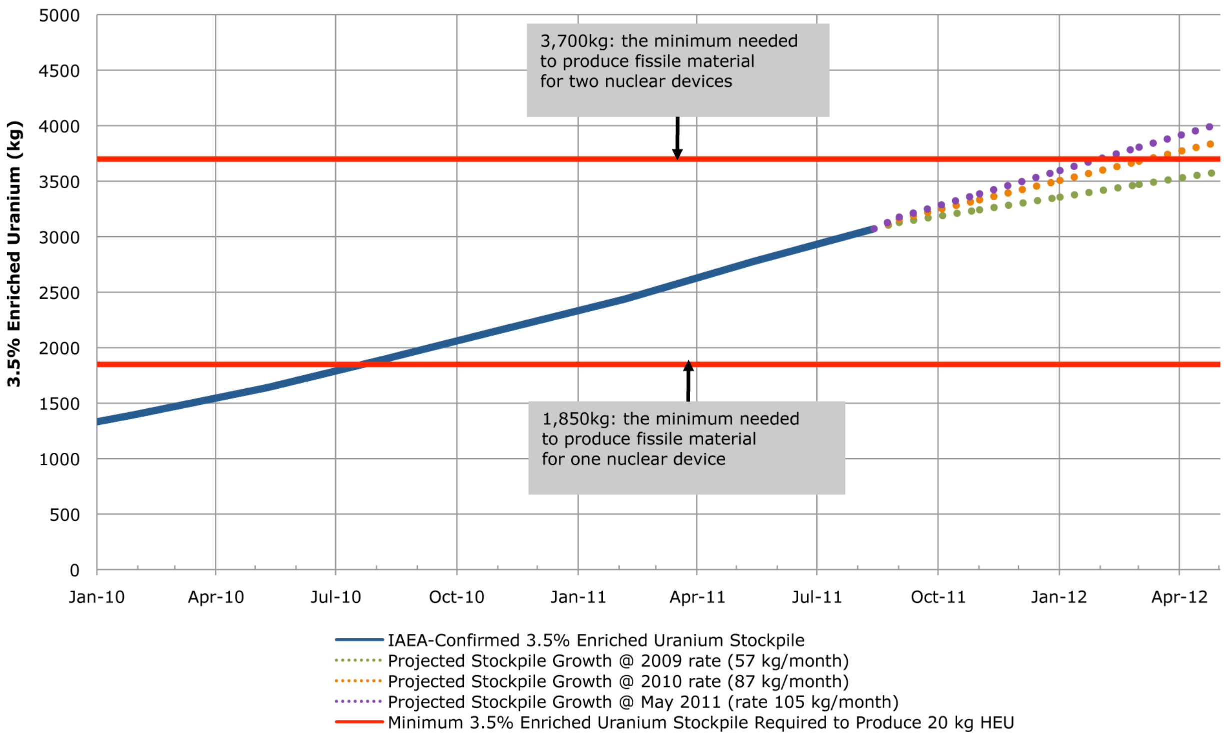
Moreover, the report notes, *contra* the 2007 NIE, that these activities "seem to have continued beyond 2004."[xxxvi] As the director of National Intelligence, Admiral James Clapper, told Congress, "Iran is keeping open the option to develop nuclear weapons in part by developing various nuclear capabilities that better position it to produce such weapons, should it chose to do so."[xxxvii]

Breakout Timing

Although continued IAEA revelations about Iran's nuclear military program show that Iran has made more progress in developing a weapons design than previously admitted by the U.S. intelligence community, acquiring a weapons-worth of HEU remains Iran's primary hurdle. Once Iran successfully acquires sufficient fissile material—experts agree that a crude, small-yield nuclear device requires about 20 kg of HEU[xxxviii]—policymakers must assume Tehran has a nuclear weapons capability.

Iran could obtain 20 kg of HEU in three ways. First, it could enrich its own LEU stockpiles in Natanz. It has already stockpiled enough 3.5% enriched uranium to produce the necessary amount of HEU and could have two bombs-worth of LEU by January 2012. (See figure 7.) Second, it could produce HEU at a covert facility. Third, it could acquire the necessary material from abroad, from countries such as North Korea, Pakistan, or even rogue elements in Russia.

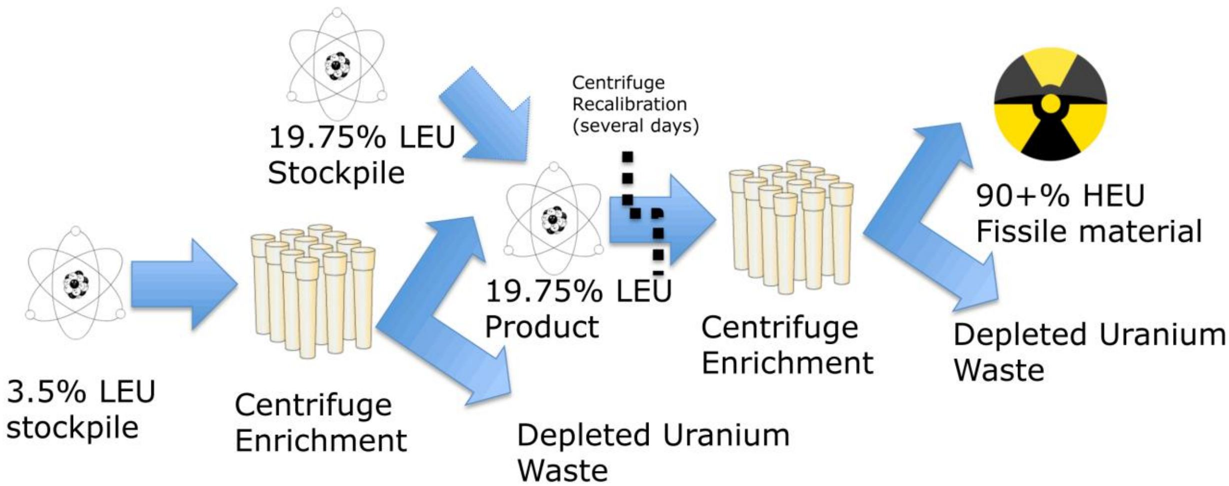
Figure 7. Growth of Iranian 3.5% Enriched Uranium Stockpile



Because the second and third options are necessarily covert, thereby rendering meaningful open source analysis unfeasible, we will focus in this report on evaluating the timeline of a potential "breakout" at Natanz. The term "breakout" signifies any action by Iran that would contravene—effectively break out of—the Safeguards Agreement it has signed with the IAEA. Producing highly enriched uranium or diverting nuclear materials to an unknown facility would constitute a breakout; thus the term is used here to refer to an Iranian attempt to produce enough HEU for a nuclear device. Because IAEA inspections of Iranian nuclear facilities occur only every two to three months, were Iran able to produce 20 kg of HEU in 60 days or less, the breakout would be undetectable by the international community until it was too late.

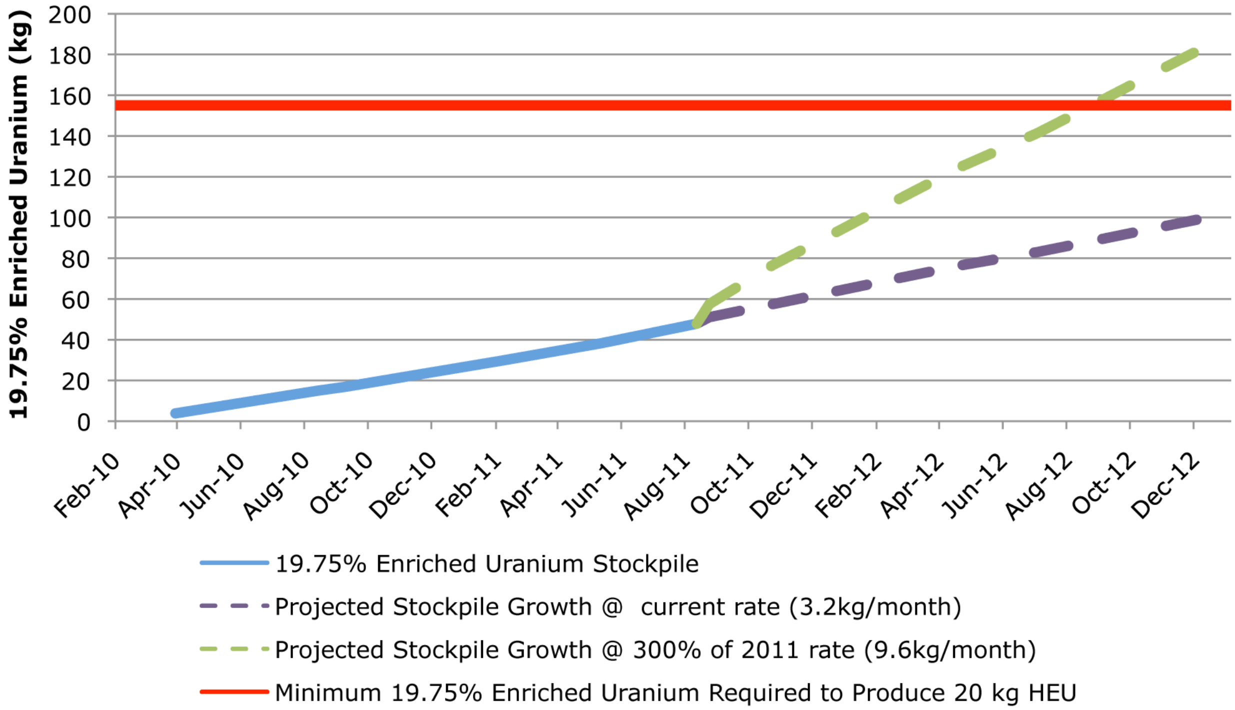
Although there has been some disagreement between experts about the procedure by which Iran might seek to produce HEU at the Natanz FEP, we believe it most likely that Tehran would resort to a two-step process known as "batch recycling."[xxxix] This process requires running uranium through the centrifuge cascades twice: once to enrich from 3.5% to 20% and a second time to go from 20% to 90%. Using this process requires a larger initial feedstock of 3.5% enriched uranium than does other methods; however, it is faster and less readily detectable because it requires no reconfiguration of the centrifuges.[xl] A further advantage of this process is that it would allow Iran to leverage its stockpiles of both 3.5% and 19.8% enriched uranium. (See figure 8.)

Figure 8. Batch Recycling Process



Indeed, the continued production of 19.8% enriched uranium at the PFEP and now Iran's declared intention to increase those efforts at the larger Fordow facility should be particularly troubling. (See figure 9.) Tehran appears determined to push the boundaries of nuclear activities tolerated by the IAEA, the United States and the international community, despite four rounds of United Nations Security Council sanctions demanding a cessation to all enrichment activity. These latest developments are most troubling because Iran is effectively conducting one of the two steps in the batch recycling process needed to produce HEU while remaining within safeguards, thus significantly reducing the time it needs to break out and to legitimize its nuclear program. It is imaginable at this point that Tehran might even seek to produce HEU under the eyes of the IAEA and with some civilian pretext.[xli]

Figure 9. Projected Growth of 19.75% Stockpile at PFEP



Ultimately, the amount of time Iran will require to break out depends on three variables: (a) the enrichment level of the feedstock, (b) the efficiency and (c) the number of its centrifuges. As we describe next, four different breakout scenarios can be based on various permutations of these three variables. We will consider the first of these to be the most important because that scenario shows that by Iran's using its already existing capabilities—its current stockpile of 3.5% and 19.8% enriched uranium and the current specifications of the Natanz FEP facility—the Islamic Republic of Iran could produce enough highly enriched uranium for a nuclear device in as little as 62 days. The second, under which Iran uses only 19.8% enriched uranium feedstock, suggests that in the not too distant future Iran's breakout horizon might fall to less than two weeks. (See figures 10A and 10B.)

Figure 10A. Time to Produce 20 kg HEU at Natanz

(assuming 5,184 centrifuges and .87 SWU/machine year)

CYCLE	FEEDSTOCK ENRICHMENT	FEEDSTOCK QUANTITY	PRODUCT ENRICHMENT	PRODUCT QUANTITY	TIME
First	3.5%	1,415 kg	19.7%	119.9 kg	46 days
Second	19.8%	153.2 kg (119.9 kg from 1st cycle + 38.3 kg from stockpile)	90%	20 kg	12 days
Total					62 days

1. If Iran used (a) 3.5% enriched uranium feedstock for the first round of the batch recycling process and then added in its existing 19.8% enriched uranium stockpile, with (b) the efficiency of its centrifuges currently remaining at 0.87 Separative Work Units (SWU) per machine year and (c) using all 5,184 centrifuges currently enriching uranium at the FEP, Iran could produce 20 kg of HEU in 62 days.

2. If Iran used (a) only 19.8% enriched uranium feedstock, which it does not currently possess but could have by the end of 2012, at the (b) the current efficiency and if it used (c) 5,184 centrifuges, it could produce 20 kg HEU in 12 days.

3. If Iran used (a) only 3.5% enriched uranium feedstock, at (b) the current efficiency, it could breakout in between 43 and 105 days, depending on the number of centrifuges used.

4. If Iran used (a) 3.5% enriched uranium feedstock and its (b) centrifuges' efficiency remained at the previous level of 0.5 SWU per machine year, it could break out in between 73 and 181 days, depending on the number of centrifuges used.

Figure 10B. Time to Produce 20 kg HEU at Natanz
(with variable stockpile enrichment levels, centrifuge efficiency and number)

CENTRIFUGES USED:	STOCKPILE ENRICHMENT LEVEL:	CENTRIFUGE EFFICIENCY (IN SWU/MACHINE YEARS):	REQUIRED STOCKPILE:	TIME TO PRODUCE:
3,772	3.5%	0.5	1,960 kg	181 days
	3.5%	0.87	1,860 kg	105 days
	19.75%	0.87	157 kg	19 days
8,528	3.5%	0.5	1,920 kg	84 days
	3.5%	0.87	1,920 kg	50 days
	19.75%	0.87	162 kg	10 days
10,004	3.5%	0.5	1,930 kg	73 days
	3.5%	0.87	1,930 kg	43 days
	19.75%	0.87	163 kg	8 days

Differences Between BPC Estimates and Others

The analysis provided above—that given Iran's current number of operational centrifuges, centrifuge efficiency and LEU stockpile, it could produce enough HEU for a nuclear weapon in 62 days—at first glance might appear in striking contrast to other statements, especially by members of the Obama administration, about Iran's nuclear timeline. However, our analysis is more conservative than some, especially when it comes to assessing how many nuclear devices could be produced from Iran's current LEU stockpile. Moreover, differences between our estimates and those that suggest an Iranian nuclear device is still years away are foremost differences of scope and threshold.

This analysis is limited to the time Iran requires to produce a nuclear weapons-worth of fissile material. Other analyses, however, seek to calculate the time required for Iran to construct the entirety of a nuclear device. Yet, acquiring HEU is the foremost technical hurdle for any country seeking to become a nuclear power. Once Iran surmounts it, we argue that, due to the high costs of miscalculation where nuclear weapons are at stake, U.S. policymakers, military leaders and strategic planners will have to assume Tehran has a nuclear weapons capability, even if it does not test a device or the status of its weaponization program remains ambiguous.

Shorter Estimates

Our assessment of 62 days to produce 20kg HEU is still slow compared to the estimate of the Wisconsin Project on Nuclear Arms Control. According to their calculations, the "number of months…needed to fuel a bomb" stands at one and a half.[xlii] It should be noted, however, that this calculation was seemingly performed assuming that Iran was using 8,000 centrifuges at the Natanz FEP, many more than they have ever had operating there.

Moreover, the Wisconsin Project assesses that Iran's LEU stockpile—3,071kg as of August 2011—is sufficient for four nuclear devices, with further enrichment.[xliii] They are, however, far from alone in this assessment. The Institute for Science and International Security notes, in regards to the LEU figures reported in the latest IAEA report, "This amount of low enriched uranium if further enriched to weapon grade is almost enough to make four nuclear weapons."[xliv] Our analysis, however, is much more conservative on this score, suggesting that Iran has not yet acquired enough LEU for more than one nuclear device. Much of the difference in these conclusions can be tied to varying assumptions about the enrichment process Iran would use to produce HEU, discussed in greater detail in the following section.

Longer Estimates

Public statements by members of the Obama administration, as well as various foreign officials, most commonly refer to a two to five year timeline for Iranian development of a nuclear weapon. As these statements are not accompanied by any more detailed analysis that explains how those figures were arrived at, they are hard to evaluate. However, these more conservative estimates are in line with a study of the International Institute for Strategic Studies (IISS), which found that

> Notwithstanding the technical troubles at Natanz and centrifuge-production limitations, Iran has already produced a sizable amount of low-enriched uranium (LEU). If further enriched, the current stockpile would be enough for one or two nuclear weapons. … The minimum timeline, then, for the first weapon, is over two years under the Pakistan method and one year for the batch method.[xlv]

The difference between this estimate and our own is due to four main factors: 1) IISS assumes Iran will use a slower enrichment process because it is more efficient, our analysis is based on a faster method; 2) IISS assumes Iran will only use 3,936 centrifuges, while they have 5,184 currently operational at Natanz; 3) IISS estimates that Iran will need 37.5kg of HEU for a nuclear weapon, compared to our estimate of 20kg; and 4) the IISS assessment is of the time to go from LEU stockpile to a manufactured, spherical uranium metal core for a nuclear device, our calculations only include enriching LEU into HEU. When updated with our assumptions (faster enrichment, more centrifuges, less HEU), the IISS calculation is actually closely in line with our own: 2.5 months to produce HEU at Natanz.[xlvi] (See figure 11.)

Figure 11. Differences between BPC and IISS estimates of Iranian Nuclear Breakout

	ESTIMATE OF WHAT?	ENRICHMENT PROCESS	AMOUNT OF HEU	NUMBER OF CENTRIFUGES	TIME
BPC	HEU production	Batch recycling	20kg	5,184	62 days
IISS	HEU production	"Pakistan" method	37.5kg	3,936	1 year, 7 months
	HEU production	Batch recycling	37.5kg	3,936	Six months
	Metal core production				Six months

ENRICHMENT PROCESS: REPIPING VS. BATCH RECYCLING

The IISS analysis looks at two possible methods by which Iran might seek to turn its LEU into HEU at Natanz: a) the "Pakistan method;" and b) the "batch method." The first involves enriching 3.5% LEU to levels of 90%+ enrichment by way of a four step process, the details of which A.Q. Khan sold Iran along with the design of its current centrifuges. The advantage of this process is that it uses a smaller amount of LEU feedstock, compared to the "batch method," to produce HEU. However it is an onerous process, requiring four large-scale reconfiguration of the centrifuges at Natanz—known as "repiping"—which is both time-consuming and would alert the IAEA to Iran's intentions.

As argued previously, it appears much more likely that Iran would opt to use the "batch" or batch recycling method in any attempted breakout. While this method—which consists of enriching from 3.5% to 20%, slightly recalibrating the centrifuges and enriching from 20 to 90%--does require a larger LEU feedstock, it is quicker, can make use of Iran's existing 19.8% LEU stockpile to hasten the process even further and requires less centrifuge reconfiguration. Indeed, by IISS's own analysis, using batch recycling significantly reduces the amount of time needed to create HEU: six months for batch, compared to a year and seven months for repiping.

AMOUNT OF HEU NEEDED: 37.5KG VS. 20KG

In calculating how long Iran requires to enrich enough HEU for a nuclear device, the IISS analysis starts with the IAEA assessment that 25kg constitutes a "significant quantity" of HEU for military purposes. They then factor in "wastage" that might occur in the process of constructing a nuclear weapon, which might amount to up to 50%. They thus arrive at 37.5kg HEU (25kg x 1.5) as the minimum needed for a nuclear weapon.

However, the IAEA explicitly states that its assessment of "significant quantities takes into account unavoidable losses,"[xlvii] i.e. "wastage" is included in the 25kg figure. Moreover, the U.S. nuclear program's history demonstrates that "wastages" in the manufacturing process can be recovered fairly quickly. For this reason, in our calculations we assume that effectively Iran could make do with less than 25kg and estimate that the minimum amount of HEU needed for a nuclear device at 20kg. Using this figure, IISS's estimate comes more closely in line with ours, falling to about 3.2 months to produce 20kg by the batch recycling method.[xlviii]

AMOUNT OF CENTRIFUGES USED: 3,936 VS. 5,184

IISS conducts its calculations for producing enough HEU for a nuclear device assuming Iran will use only 3,936 centrifuges. That was the amount of centrifuges in operation at the Natanz FEP in May 2010, the number has gone up since then. During its latest inspection August 2011, the IAEA found 5,860 centrifuges spinning at FEP, those some experts assume only 5,184 are being fed with uranium. Using these figures provides a more realistic assessment of Iran's true capabilities today. By raising the number of centrifuges from 3,936 to 5,184, IISS's estimate comes even closer to our own, falling to about two and half months compared to our 62 days.[xlix]

SCOPE: CREATING A METAL CORE VS. PRODUCING HEU

The IISS estimate of "one year for the batch method" includes time not only to turn LEU into HEU, which they put at six months, but also to then turn that HEU into a solid metal (uranium is enriched as a gas) and manufacture the metal in a spherical core for use in a nuclear weapon, which they calculate will take another six months.

Our analysis, however, is limited to only the first process of obtaining HEU. As producing HEU is the most technically demanding aspect of any nuclear weapons program and because we limit our analysis to open source material about Iran's nuclear capabilities, we do not estimate how long it would take Iran to weaponize that HEU. However, the history of nuclear development suggests that the IISS estimate of six months for weaponization is also overstated. In 1964, the Chinese built their first uranium core in 1.5 to 2.5 months.[l] And now, the IAEA estimates "the time required to convert different forms of nuclear material to the metallic components of a nuclear explosive device" as 1 to 3 weeks, significantly less than IISS's figure of six months.[li]

Thus, as we have seen, taking into account differences between our assumptions about this process, the IISS calculations are actually in line with our own, coming in at about two and a half months to produce 20kg of HEU using 5,184 centrifuges at Natanz.

Endnotes

[i] Nicolas Falliere, Liam O. Murchu and Eric Chien, "W32.Stuxnet Dossier," *Symantec*, Version 1.4, February 2011; William J. Broad, John Markoff and David E. Sanger, "Israeli Test on Worm Called Crucial in Iran Nuclear Delay," *New York Times*, January 15, 2011.
[ii] William Yong and Robert F. Worth, "Bombings Hit Atomic Experts in Iran Streets**,"** *New York Times,* November 29, 2010.

[iii] Alternatively spelled "Fordo."
[iv] "Implementation of the NPT Safeguards Agreement and Relevant Provisions of Security Council Resolutions in the Islamic Republic of Iran," Board of Governors Report, *International Atomic Energy Agency*, May 24, 2011 (GOV/2011/29), 3; Gregory S. Jones, "Out of the Spotlight Iran's Rate of Enriched Uranium Production Continues to Increase: Centrifuge Enrichment and the IAEA May 24, 2011, Update," Nonproliferation Policy Education Center, June 2, 2011.

[v] "Implementation of the NPT Safeguards Agreement and Relevant Provisions of Security Council Resolutions in the Islamic Republic of Iran," Board of Governors Report, *International Atomic Energy Agency*, September 2, 2011 (GOV/2011/54), 3.

[vi] "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," Board of Governors Report, *International Atomic Energy Agency*, June 5, 2009 (GOV/2009/35), 2n.

[vii] "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," Board of Governors Report, *International Atomic Energy Agency*, February 18, 2010 (GOV/2010/10), 1n.

[viii] "Implementation of the NPT Safeguards Agreement and Relevant Provisions of Security Council Resolutions in the Islamic Republic of Iran," Board of Governors Report, *International Atomic Energy Agency*, November 23, 2010 (GOV/2010/62), 3n.

[ix] W32.Stuxnet Dossier, 42–44; David Albright, Paul Brannan and Christina Walrond, "Did Stuxnet Take Out 1,000 Centrifuges at the Natanz Enrichment Plant?," Institute for Science and International Security, December 22, 2010, 3–5.

[x] Albright et al., 2010, 2–3.

[xi] Albright et al., 2010, 3.

[xii] GOV/2011/29, 2.

[xiii] GOV/2011/54, 3.

[xiv] Akbar Dareini, "Iran to Triple Nuke Output, Use Better Centrifuges," *Associated Press*, June 8, 2011.

[xv] GOV/2011/54, 3.

[xvi] For enrichment, uranium must be in gas form as uranium hexafluoride (UF_6). However, for this paper, we will refer to solid form uranium. One kilogram of UF_6 yields roughly 0.67 kg of uranium metal.

[xvii] GOV/2011/54, 3.

[xviii] Jones, 2011, 2.

[xix] GOV/2010/10, 3.

[xx] GOV/2011/54, 3–4.

[xxi] Gregory S. Jones, "Fueling the Tehran Research Reactor: Technical Considerations on the Risks and Benefits," Nonproliferation Policy Education Center, October 12, 2009.

[xxii] "Implementation of the NPT Safeguards Agreement and Relevant Provisions of Security Council Resolutions in the Islamic Republic of Iran," Board of Governors Report, *International Atomic Energy Agency*, May 24, 2011 (GOV/2011/7), 4.

[xxiii] Joby Warrich, "Iran Touts Major Advances in Nuclear Program," *Washington Post*, April 11, 2011.

[xxiv] Farhad Pouladi, "Iran Installs 'Speedier' Nuclear Centrifuges," *Agence France-Presse*, July 18, 2011.

[xxv] GOV/2011/54, 4.

[xxvi] "IAEA: Iran Broke Law by Not Revealing Nuclear Facility," *CNN*, September 30, 2009

[xxvii] Ali Akbar Dareini, "Iran to Triple Nuke Output, Use Better Centrifuges," *Associated Press*, June 8, 2011; GOV/2011/54, 4.

[xxviii] Ladane Nasseri, "Iran Starts Transfer of Centrifuges to Fordo Nuclear Site**,"** *Bloomberg*, August 22, 2011; "Iran Transferring Centrifuges to Fordo," *PressTV*, August 22, 2011.

[xxix] GOV/2011/54, 4

[xxx] Victoria Nuland, "Daily Press Briefing," *U.S. Department of State*, August 22, 2011.

[xxxi] "Iran: Nuclear Intentions and Capabilities," National Intelligence Council*,* November 2007, 5.

[xxxii] GOV/2010/10, 8–9.

[xxxiii] GOV/2011/54, 7.

[xxxiv] Ibid.

[xxxv] GOV/2011/29. 7.

[xxxvi] Ibid.

[xxxvii] "U.S. Intelligence: Iran leaders Reopened Nuke Debate," *Reuters*, February 17, 2011.

[xxxviii] The calculations in this section are based on Jones, 2011.

[xxxix] See *Iran's Nuclear, Chemical and Biological Capabilities, A Net Assessment,* The International Institute for Strategic Studies, London 2011; and Gregory S. Jones, "Critique of IISS Estimates of the Time Required for Iran to Produce the HEU Metal Core Required for a Nuclear Weapon," Nonproliferation Policy Education Center, April 6, 2011.

[xl] R. Scott Kemp and Alexander Glaser, "Statement on Iran's Ability to Make a Nuclear Weapon and the Significance of the 19 February 2009 IAEA Report on Iran's Uranium Enrichment Program," March 2, 2009, 2.

[xli] Gregory S. Jones, "An In-Depth Examination of Iran's Centrifuge Enrichment Program and Its Efforts to Acquire Nuclear Weapons," August 9, 2011, 20.

[xlii] "Iran's Nuclear Timetable," Wisconsin Project on Nuclear Arms Control, May 25, 2011.

[xliii] Ibid.

[xliv] David Albright, Paul Brannan, Andrea Stricker, and Christina Walrond, "IAEA Iran Safeguards Report: Deployment of Advanced Centrifuges Commences at Natanz Pilot Plant but Not Yet at Fordow Plant; LEU Monthly Production at Natanz Fuel Enrichment Plant Decreases Slightly; 19.75 Percent LEU Production Increases Significantly; IAEA "Increasingly Concerned" about Possible Existence of Past or Current Nuclear Weaponization Work," *Institute for Science and International Security*, September 2, 2011, 1.

[xlv] *Iran's Nuclear, Chemical and Biological Capabilities, A Net Assessment*, 3.

[xlvi] Much of this analysis is based on Jones, "Critique of IISS Estimates of the Time Required for Iran to Produce the HEU Metal Core Required for a Nuclear Weapon."

[xlvii] *IAEA Safeguards Glossary*, 2001 Edition, International Atomic Energy Agency, Vienna, 2002, 19.

[xlviii] The time required to produce HEU is roughly proportional to the amount of HEU being produced, allowing us to calculate: 6 months x (20kg/37.5 kg) = 3.2 months

[xlix] The time required to produce HEU is roughly inversely proportional to the number of centrifuges used, allowing us to calculate: 3.2 months x (3,936/5,184) = 2.5 months

[l] Based on John Wilson Lewis and Xue Litai, *China Builds the Bomb*, Stanford University Press, 1988.

[li] *IAEA Safeguards Glossary*, 18 – 19.