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Iran's Rapid Expansion of its Enrichment Facilities Continues as the Entire Nonproliferation System Threatens to Unravel
Centrifuge Enrichment and the IAEA May 22, 2013 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) and thereby the ability to manufacture nuclear weapons.[2] On May 22, 2013, the International Atomic Energy Agency (IAEA) published its latest safeguards update which shows that Iran has continued the rapid expansion of its enrichment program.

At the end of the summer of 2011, Iran had installed approximately 8,000 centrifuges at its main enrichment facility at Natanz and some pundits were claiming that sanctions had cut off Iran's supply of materials needed to build new centrifuges, thereby capping Iran's enrichment capacity. Since that time Iran has increased the number of centrifuges at Natanz to 14,244, installing 3,830 centrifuges in just the last six months. In addition, since the summer of 2011 Iran has installed 2,710 centrifuges at its underground facility at Fordow. In less than two years, Iran has installed about 9,000 new centrifuges at these two facilities which are enough to more than double its number of centrifuges.

Some of the new centrifuges at Natanz are more advanced. Iran has installed 689 of these more advanced centrifuges up to now and has announced plans to install 3,000 such centrifuges. Iran also has announced plans to start enriching uranium using 326 advanced centrifuges that are operating at its pilot enrichment facility at Natanz.

Despite converting increasing amounts of its stockpile of 3.5% enriched uranium to 20% enriched uranium, Iran's production rate of 3.5% enriched uranium is sufficiently high so that in the last two years Iran's stockpile of 3.5% enriched uranium has increased from about 2,500 kilograms to about 4,300 kilograms.

Despite converting some of its stockpile of 20% enriched uranium into research reactor fuel, in the last two years Iran's stockpile of 20% enriched uranium has grown from 38 kilograms to 123 kilograms, increasing 10 kilograms in the last quarter. (This stockpile is in the form of 182 kilograms of uranium hexafluoride).

With this enrichment capacity and these enriched uranium stockpiles, Iran has two different ways to quickly produce the HEU required for nuclear weapons should it decide to do so. I have

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[2] My most recent report is: Gregory S. Jones, "Iran's Rapid Expansion of its Enrichment Facilities Continues as the U.S. Concedes That Iran Is Getting 'Closer and Closer' to Having Nuclear Weapons: Centrifuge Enrichment and the IAEA February 21, 2013 Safeguards Update," March 19, 2013, http://nuclearpolicy101.org/wp-content/uploads/2013/03/Iran-Enrichment-Update-03-2013.pdf

analyzed this issue in detail in Appendix 1 and summarize the results here in Table 1. My analysis assumes that 20 kilograms of HEU are required per weapon.

Iran can produce the HEU for nuclear weapons by using batch recycling. In this process the enriched uranium is run through Iran's enrichment facilities multiple times until it reaches the required enrichment level. This process has the advantage of requiring only slight modifications to Iran's enrichment facilities and is entirely permitted by the IAEA as long as Iran notifies it in advance. It does have the disadvantage of using Iran's enriched uranium stockpiles inefficiently and in the past Iran would have been able to produce only one nuclear weapon's worth of HEU by this method. However now Iran's stockpiles of enriched uranium have grown large enough that Iran can produce two nuclear weapon's worth of HEU using batch recycling. Using Iran's currently operating enrichment capabilities, Iran could produce the HEU for a nuclear weapon in just two months and enough HEU for a second nuclear weapon two months after that. Roughly 5,000 of the centrifuges that Iran has installed are not yet enriching uranium. It is not hard to imagine that these additional centrifuges could come on-line in the next three to six months (i.e. in the "near-term"). If they do, then by using batch recycling Iran could produce enough HEU for a nuclear weapon in just one and one-half months and enough HEU for two nuclear weapons in two and two-thirds months.

Table 1

Time Required For Iran to Produce Various Amounts of HEU For Nuclear Weapons Should Iran Decide to Do So Quickly
Capabilities are Either "Current" or Ones That Could Come On-line in the Next 3 to 6 Months ("Near-Term")

Number of Nuclear Weapons (HEU)	Batch Recycling in Known Enrichment Plants Current	Batch Recycling in Known Enrichment Plants Near-Term	Clandestine Enrichment Plant Current	Clandestine Enrichment Plant Near-Term
One (20 kg)	2 months	1 ½ months	1 month	3 weeks
Two (40 kg)	4 months	2 2/3 months	2 months	1 ½ months
Five (100 kg)	N/A*	N/A*	5 months	3 ½ months

*Iran's current enriched uranium stockpiles are only large enough to allow it to produce two nuclear weapon's worth (40 kg) of HEU by batch recycling.

Iran can also produce the HEU for nuclear weapons by building a clandestine enrichment facility specifically designed to enrich uranium from 20% to 90%. A small such facility using centrifuges of the type that Iran currently uses could produce enough HEU for a nuclear weapon in just one month. A major advantage of such a facility would be that it would use Iran's stockpile of enriched uranium much more efficiently than would batch recycling and Iran could produce enough HEU for five nuclear weapons (i.e. a small arsenal) with one nuclear weapon's worth of HEU being produced every month. In the "near-term" Iran may be able to build a clandestine enrichment facility partially using some of the advanced centrifuges of the type that it has begun to install at Natanz. If so, Iran could produce a nuclear weapon's worth of HEU in just three weeks and enough HEU for five nuclear weapons in just three and one-half months. A disadvantage of using a clandestine enrichment facility is that this process would require violating IAEA safeguards, though the time needed for Iran to produce HEU by this method is becoming so short as to make it doubtful that any effective counteraction could be taken before Iran obtained a nuclear weapon.

However, this does not mean that I think Iran will become an overt nuclear weapons state in the near future. As I stated in September 2011:

> That is not to say that I expect Iran to divert nuclear material from IAEA safeguards anytime soon. After all, why should it? It can continue to move ever closer to the HEU required for a nuclear weapon with the blessing of the IAEA. Iran would only need to divert nuclear material from safeguards when it would want to test or use a nuclear weapon. Recall that the U.S. was unable to certify that Pakistan did not have nuclear weapons in 1990, but it was only in 1998 that it actually tested a bomb. Similarly, though it could be many years before Iran becomes an overt nuclear power, it needs to be treated as a de facto nuclear power simply by virtue of being so close to having a weapon.[3]

Israeli Prime Minister Benjamin Netanyahu's September 2012 speech at the UN has focused much attention on Iran's stockpile of 20% enriched uranium. Netanyahu said that Israel's "red line" was preventing Iran from obtaining sufficient 20% enriched uranium that could be further enriched to produce enough HEU for a nuclear weapon. Iran's enrichment process produces the 20% enriched uranium in the form of uranium hexafluoride which is the form that would be needed to further enrich the uranium to HEU. Iran has converted some of its 20% enriched uranium hexafluoride to uranium oxide. Some of this oxide has been manufactured into fuel elements for Iran's Tehran Research Reactor (TRR) and a few of these elements have been placed into the reactor and irradiated.

Since Iran began producing 20% enriched uranium in April 2010, it has produced 219 kilograms (see Appendix 1, Table 2). As of mid-May 2013, 123 kilograms (56%) of this material was still in the form of hexafluoride. In the last quarter, Iran produced about 30 kilograms of 20% enriched uranium. About 20 kilograms (67%) of this material was fed into the oxide conversion process and 10 kilograms was added to Iran's hexafluoride stockpile which represents a 9% increase since February 2013.

Netanyahu did not specify how much 20% enriched uranium Iran would have to produce to cross his red line. The media has taken this amount to be about 165 kilograms (240-250 kilograms of hexafluoride) and since Iran's stockpile is only 123 kilograms, it has been widely reported that Iran has not yet crossed this red line. But these statements are not correct. Netanyahu's red line is actually quite thick and can be as little as 94 kilograms or as much as 210 kilograms,

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[3] Gregory S. Jones, "No More Hypotheticals: Iran Already Is a Nuclear State, *The New Republic*, September 9, 2011, http://www.tnr.com/article/environment-and-energy/94715/jones-nuclear-iran-ahmadinejad

depending on how the enrichment to HEU is carried out. Therefore by having 123 kilograms of 20% enriched uranium in hexafluoride form, Iran has already passed into but is not yet entirely across Netanyahu's red line.

A matter that has sparked considerable interest is how difficult would it be to reconvert some of the 20% enriched uranium oxide to hexafluoride since this extra material could put Iran over the supposed 165 kilogram mark. Iran has put 95 kilograms of 20% enriched uranium into the oxide conversion process. Sixty three kilograms of uranium have completed the process and have been converted into finished oxide. It is unknown whether the other 32 kilograms are in intermediate chemical compounds or are contained in waste materials. Of the 63 kilograms converted to oxide, about 23 kilograms have been manufactured into fuel elements for the TRR of which about 3 kilograms have actually been placed into the reactor and irradiated.

The three kilograms of 20% enriched uranium that has been irradiated in the TRR are now highly radioactive and would be difficult to recover for the purpose of producing HEU but in principle it would not be difficult to recover some part of the other 92 kilograms that have been put into the oxide conversion process. The chemistry needed to convert this 20% enriched uranium back into hexafluoride is simple and has already been practiced by Iran to produce all of the uranium hexafluoride that it has used in its centrifuge enrichment plants. The only problem is that since this uranium is 20% enriched instead of being natural uranium, Iran would have to build a new critically safe facility to produce this 20% enriched uranium hexafluoride. While Iran certainly has the means to build such a facility, I am not sure it would go to the bother, especially since the reconversion process could be slow due to the needed to limit batch size as a result of criticality concerns. As I point out in Appendix 1, if Iran were to start all of the centrifuges that it has installed at Fordow, it could produce over 30 kilograms of 20% enriched uranium per month. If Iran wanted to quickly produce a large quantity of 20% enriched uranium in hexafluoride form, I think increasing production at Fordow would be an easier way to get it rather than to go to the trouble to convert the 20% enriched uranium oxide. However, converting the 20% enriched uranium oxide to hexafluoride remains an emergency option for Iran.

Despite all of the media attention put on Iran's 20% enriched uranium stockpile that is in the form of hexafluoride, it is important to note that the time required for Iran to produce the HEU for nuclear weapons depends not only on the size of its 20% enriched uranium stockpile but also strongly on Iran's overall enrichment capacity. Since this capacity has been growing rapidly, the time that would be required for Iran to produce the HEU for nuclear weapons has been continuing to decline. Indeed, even if Iran were to agree to relinquish its stockpile of 20% enriched uranium, it could currently use batch recycling to produce a weapon's worth of HEU in three months. (See discussion in Appendix 1 and Appendix 2.) As Iran's enrichment capacity continues to grow, this time will decrease.

Despite this intense focus on Iran's 20% enriched uranium stockpile, Israel is very unlikely to attack Iran on its own and Netanyahu's statement of a red line was really just a way for him to back down from the strident position he took in the summer of 2012. As Israel demonstrated with its strike on the plutonium production reactor in Syria in 2007 and more recently with its 2013 strikes into Syria, when Israel plans to actually strike a target, there is no prior public discussion. Israel simply carries out the strike. Israel's public threats to take military action against Iran have had two purposes: to attempt to intimidate Iran; and, more importantly, to attempt to prod the U.S. into taking military action against Iran. For example, in January 2011 Israeli Prime Minister Netanyahu said: "You have to ratchet up the pressure…I don't think that this pressure will be sufficient to have this regime change course without a credible military option that is put before them by the international community *led by the United States.*"[4] [Emphasis added.] In the run up to the U.S. 2012 presidential election Netanyahu ratcheted up his pressure on the Obama administration to take military action but as it became clear that the Obama administration was not going to act, Netanyahu was forced to back down.

At one time it appeared that Netanyahu had raised his rhetoric to such a high level that he would be forced to carry out a military strike against Iran just to save political face. However, by setting his red line in September 2012, he managed to back down without many realizing that he had done so. No one seemed to think it odd that Netanyahu did not set any specific quantity for Iran's 20% enriched uranium stockpile as part of his red line but only said that he would not have to take any action until at least spring of 2013. The media's formulation of Natanyahu's red line (165 kilograms of 20% enriched uranium) has the further advantage in that it now appears that Iran may not attain this level until the fall of 2013 or the winter of 2014. It is not surprising that Natanyahu has done nothing to contradict these media assessments.

Further, by focusing just on Iran's stockpile of 20% enriched uranium, Netanyahu can ignore other aspects of Iran's nuclear enrichment program that are just as important for the production of HEU for nuclear weapons, namely Iran's expanding enrichment capacity and its growing stockpile of 3.5% enriched uranium. In a speech on March 6, 2013, Netanyahu said that a "credible military threat" was needed to stop a nuclear-armed Iran but he gave no indication that Israel would be the country providing this threat.[5]

The U.S. Director of National Intelligence, James Clapper, testified before Congress in March 2013 and noted that "Iran has made progress during the past year that better positions it to produce weapons-grade uranium (WGU)…" But he added reassuringly, "Despite this progress, we assess Iran could not divert safeguarded material and produce a weapon-worth of WGU before this activity is discovered."[6] Unfortunately this last statement is incorrect and demonstrates a fundamental lack of understanding of the problem.

As I stated above, Iran could produce a weapon's worth of HEU in two months by using batch recycling. This would seem to be enough time for the IAEA and/or the U.S. to detect the diversion of safeguarded uranium except for the fact that no diversion would be needed. IAEA safeguards as currently implemented permit non-weapon states to possess HEU or plutonium or to manufacture such material. Japan for example, already has 9 metric tons of separated plutonium and plans to soon open a reprocessing plant that will allow it to separate roughly eight metric tons of plutonium every year. All Iran would need to do is inform the IAEA one day in

[4] "Netanyahu: Only 'credible' military threat led by U.S. can stop nuclear Iran," *Haaretz*, January 11, 2011.
[5] Matt Spetainick and Paul Eckert, "Biden, Netanyahu set tone on Iran for Obama visit to Israel," *Reuters*, March 4, 2013.
[6] James Clapper, "Statement for the Record, Worldwide Threat Assessment of the US Intelligence Community," Senate Select Committee on Intelligence, March 12, 2013, p.7.

advance that it intended to produce HEU.[7] Once Iran had produced sufficient HEU in hexafluoride form the HEU could be converted into metal and manufactured into a sphere for a weapon's core in only about one week.[8] The IAEA might even allow the production of the HEU metal to be carried out under safeguards if Iran were to claim that it wanted to manufacture some research reactor fuel. The only time an unambiguous diversion of nuclear material would have to take place is when the HEU metal sphere was placed into an actual weapon, but this process would take at most only a few hours. Even if the diversion of nuclear material took place a week before the manufacture of a nuclear weapon, it is very unlikely that the diversion could be detected in time before a nuclear detonation occurred. That IAEA safeguards permit the production of HEU or plutonium is a fundamental flaw in the entire nonproliferation system. This subject will be discussed in more detail below.

In the past there have been some (including some in the U.S. government) who contended that it would take years for Iran to produce the non-nuclear components of a nuclear weapon. This would run counter to historical experience, even if Iran were to start from scratch. However, given the significant aid that Iran has received from a Russian nuclear weapon designer, Iran is not starting from scratch. In December 2011 I estimated that Iran could produce an implosion-type nuclear weapon (the design of most nuclear weapons) in just two to six months and that this development could take place in parallel with or prior to the production of the HEU.[9] Since 2011, Iran's continuing efforts have shortened this time. In July 2012 John Sawers the chief of British intelligence MI6 said: "The Iranians are determinedly going down a path to master *all* aspects of nuclear weapons; all the technologies they need."[10] [Emphasis added] Recently Secretary of State Kerry agreed that Iran was getting "closer and closer" to a nuclear weapon.[11] Reports that senior Iranian officials attended North Korea's February 2013 nuclear test indicate that Iran may be receiving nuclear weapon design assistance from more than just the Russians.[12]

Further if it were really so time consuming to produce the traditional implosion-type nuclear weapon, Iran could always just produce a gun-type nuclear weapon instead. This was the weapon type that the U.S. used to destroy Hiroshima. This type of nuclear weapon is very simple to design and produce, so much so that it does not require prior nuclear testing. Such a weapon would require the 20 kilograms of HEU that I assumed was needed for an implosion-type weapon and would produce a yield of 2 to 4 kilotons.[13]

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[7] In February 2010, Iran gave the IAEA only one day advanced notice before it began to produce 20% enriched uranium at its pilot enrichment facility at Natanz.

[8] Gregory S. Jones, "Critique of IISS Estimates of the Time Required for Iran to Produce the HEU Metal Core Required for a Nuclear Weapon, Addendum: Time Required to Produce the Non-Nuclear Components Needed For a Nuclear Weapon," March 3, 2011, Revised April 6, 2011, pp.4-6. http://www.npolicy.org/article_file/Critique_of_IISS_Estimates_with_Addendum.pdf

[9] Gregory S. Jones, "Iran's Efforts to Develop Nuclear Weapons Explicated, Centrifuge Uranium Enrichment Continues Unimpeded, the IAEA's November 8, 2011 Safeguards Update," December 6, 2011, http://npolicy.org/article_file/Iran_Efforts_to_Develop_Nuclear_Weapons_Explicated.pdf

[10] Christopher Hope, *The Telegraph*, July 12, 2012, http://www.telegraph.co.uk/news/uknews/terrorism-in-the-uk/9396360/MI6-chief-Sir-John-Sawers-We-foiled-Iranian-nuclear-weapons-bid.html

[11] "John Kerry Concedes Iran is Moving Closer to Possessing Nuclear Weapon," Secretary of State Interviewed by Martha Raddatz in Qatar, ABC News, March 5, 2013.

[12] "Iranian nuclear chief observed Korean nuke test," *Jerusalem Post*, February 17, 2013.

[13] J. Carson Mark, "Some Remarks on Iraq's Possible Nuclear Weapon Capability in Light of Some of the Known Facts Concerning Nuclear Weapons," *Nuclear Control Institute*, May 16, 1991, p.23. This nuclear weapon could be

The bottom line is that should it choose to do so, Iran could produce enough HEU for a nuclear weapon in a month or two and, by using either implosion- or gun-type nuclear weapon designs, Iran could likely produce a complete nuclear weapon rather quickly (within days or weeks) after producing the required HEU.[14] Olli Heinonen, former head of the IAEA's safeguards division, has recently come to the same conclusion, saying that Iran can now produce a nuclear weapon in "a month or two."[15]

In March 2013, DNI Clapper stated that U.S. intelligence assesses that Iran's preferred nuclear delivery mode will likely be by ballistic missile.[16] Apparently U.S. intelligence believes that it would take Iran some time to develop a nuclear weapon small enough to fit onto its ballistic missiles and to conduct the flight tests needed to assure that the warhead was functional. This assessment may be the basis for President Obama's statement that "it would take over a year or so for Iran to actually develop a nuclear weapon."[17] However, there are several problems with this assessment. The nuclear weapon design that the Russian nuclear weapon expert provided to Iran was specifically designed to fit upon Iran's ballistic missiles. North Korea may also have already developed such a lightweight nuclear warhead and may be providing aid to Iran. In addition, a small gun-type nuclear weapon, which would be easy to develop and would require no prior nuclear testing, could easily fit upon a ballistic missile. Thus it is not clear that Iran would require anywhere close to a year to develop a nuclear-armed ballistic missile.

The more serious problem with this intelligence assessment is that Iran does not have to deliver its nuclear weapons by ballistic missile. Indeed, given the missile defenses of the U.S. and Israel, it is not clear that Iran's preferred delivery method would be ballistic missiles or why U.S. intelligence believes that it is. As I have discussed previously, Iran could deliver its nuclear weapons by vehicles, i.e. trucks or ships.[18] Such delivery could be particularly effective against U.S. military forces in the region.

Iran's rapid progress in its enrichment program during the past two years demonstrates that sanctions are not going to stop Iran's enrichment efforts. Repeated rounds of negotiations with Iran have gone nowhere, leading some in the U.S. to call for additional concessions to Iran. Already, the measures proposed by the P5+1 countries, even if Iran agreed to them, would not do much to eliminate the danger. For example, it has been proposed that Iran give up its stockpile of 20% enriched uranium. But as I have calculated in Appendix 1, in the near-term Iran could

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easily fitted onto an Iranian ballistic missile. Further, it is important to note that the lethal area of a nuclear weapon does not scale linearly with yield, especially at low yields. Though two to four kilotons is only one-eighth to one-quarter (13% to 25%) of the yield of the Hiroshima bomb, the lethal area of such a weapon would still be about 3 km^2 (over one square mile). This is about three-eighths (38%) the lethal area of the Hiroshima bomb and such a weapon would kill tens of thousands if exploded over a city.

[14] The development of the non-nuclear components for the nuclear weapon could take place in parallel with or prior to the production of the HEU.

[15] David Feith, "How Iran Went Nuclear," *The Wall Street Journal*, March 2, 2013, p.A13.

[16] James Clapper, "Statement for the Record, Worldwide Threat Assessment of the US Intelligence Community," Senate Select Committee on Intelligence, March 12, 2013, p.7.

[17] Michael D. Shear and David E. Sanger, "Iran Nuclear Weapon to Take Year or More, Obama Says," *The New York Times*, March 14, 2013. Note that it is unclear whether Obama meant "over a year," or "a year or so."

[18] In his September 2012 speech to the UN, Israeli Prime Minister Netanyahu also suggested that Iran might deliver a nuclear weapon by "container ship."

produce a weapon's worth of HEU in just six weeks with its stockpile of 20% enriched uranium and in eight and one-half weeks without its stockpile of 20% enriched uranium. This is a difference of only two and one-half weeks (compare tables 6 & 7). As Iran further expands its enrichment capacity, this difference will only further diminish.

To prevent Iran from having the ability to quickly produce the HEU required for nuclear weapons, it would be necessary to shut down and eliminate Iran's entire enrichment program. Those who favor continued negotiations with Iran have called this proposal "unrealistic," which is just another way of saying that no satisfactory negotiated outcome is possible.

President Obama and Vice-President Biden have both said that they are not bluffing and that Iran will not be allowed to acquire nuclear weapons. But given that IAEA safeguards will allow Iran to get within a week or less of having a nuclear weapon, will there really be enough time for the U.S. to militarily strike Iran before it acquires a nuclear weapon? In some discussions of this option it is assumed that the U.S. would strike almost instantly upon seeing any Iranian movement to build a nuclear weapon but recent events regarding possible chemical weapon use in Syria demonstrate that such swift action is unlikely. President Obama has stated that any use of chemical weapons by the Assad regime would lead to a U.S. military intervention but when there were reports in May 2013 that such use had actually occurred, the U.S. reaction was not swift action but a call for more investigation into the issue. What to do about the civil war in Syria is far beyond the scope of this paper but this event demonstrates that U.S. military action to stop Iran's nuclear program would probably take weeks or even months to be decided on and carried out and by then Iran could already have one or more nuclear weapons.

In addition, as I have written previously, Iran's centrifuge enrichment program is resistant to destruction by air attack. To be effective, a long-term bombing campaign would be required. Iran's installation of increasing numbers of centrifuges only reinforces this point. A prolonged bombing campaign would run a serious risk of turning into a large-scale war with Iran. Though no doubt the U.S. would eventually win such a war, I think that given the financially-exhausted and war-weary condition of the U.S., such a war would be ill-advised. In any case, the current situation in which the U.S. faces the choice between accepting Iran as a nuclear weapon state or having to go to war to prevent it must be considered a policy failure.

In sum, sanctions appear to be having no effect on Iran's production of enriched uranium and negotiations are going nowhere. I and many analysts believe that a full-scale war with Iran would be ill-advised. Consequently, as I stated over a year and one-half ago, nothing can be done to stop Iran from getting nuclear weapons. At the time some accused me of being "irresponsible" for saying this but as Iran's progress has become so unmistakable, other analysts have started saying the same thing. For example, Olli Heinonen, former head of the IAEA's safeguards division recently said that the time it would take Iran to produce a nuclear weapon could now be shorter than the time required for the West to respond.[19]

As bad as the Iranian situation is, an even worse problem is that the entire nonproliferation system is threatening to unravel. This is the result of decades of neglect and short-term "fixes" that have spanned both Republican and Democratic administrations with regard to the acquisition

[19] David Feith, "How Iran Went Nuclear," *The Wall Street Journal*, March 2, 2013, p.A13.

of nuclear weapons by Pakistan and North Korea, as well as Iran's steady progress toward such weapons.

One result of the most recent North Korean nuclear test was to increase pressures in both Japan and South Korea to acquire their own nuclear weapons.[20] Japan already has a plutonium stockpile of 44 metric tons produced as a result of its civil nuclear power program. About 35 metric tons are stored overseas but about 9 metric tons (enough to produce thousands of nuclear weapons) are stored in Japan.[21] Though in the aftermath of the Fukushima nuclear accident Japan's future use of nuclear power is in question, Japan's nuclear industry has announced plans to greatly increase its domestic stockpile of plutonium by starting the operation of the Rokkasho reprocessing plant in 2014. Japan says that it is stockpiling the plutonium for use in a breeder reactor but it is now more than 40 years since such reactors were first supposed to come into operation and the commercial operation of such reactors is still decades away. Strangely, U.S. officials have encouraged Japan to continue with its plans to accumulate even more plutonium. In the meantime a number of Japanese political figures have openly argued that Japan should continue its plutonium program as a nuclear weapon hedge and Japan's parliament has amended its atomic energy act to explicitly include "national security" as one of the prime missions of Japan's civilian nuclear energy program.

For South Korea the pressure is considerably higher, as it is the direct target of North Korea's threats, nuclear and otherwise. North Korea recently abrogated the armistice with South Korea putting these countries back into a technical state of war. Influential political figures in South Korea have suggested that now might be the time for South Korea to develop its own nuclear weapons or that at least the U.S. should return tactical nuclear weapons to South Korea.[22] In contrast to Japan, the U.S. has not permitted South Korea to extract the plutonium from the spent fuel of its civil nuclear power reactors, because South Korea had a nuclear weapons program in the 1970s. The current U.S.-South Korea nuclear cooperation agreement is up for renewal and South Korea is pushing hard for the right to extract this plutonium. It seems unlikely that South Korea's effort is related to any belief that this plutonium has a role to play in its civil nuclear program. The U.S. and South Korea have not been able to resolve this issue and the current U.S.-South Korea nuclear cooperation agreement had to be extended for two more years to allow additional time to find a solution.

These developments in East Asia provide a preview of how events in the Middle East may play out in response to the Iranian nuclear threat. Saudi Arabia's foreign minister, Prince Saud al-Faisal has recently warned against the danger of Iran's nuclear program.[23] Countries like Egypt and Saudi Arabia currently lack the necessary nuclear technology to be able to emulate Iran anytime soon. However, with Saudi Arabia now expressing a strong interest in developing a broad nuclear power program (it has said it wants 16 nuclear reactors by 2030), Saudi Arabia may be starting down the road to attempt to match Iran's nuclear capability.

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[20] Henry Sokolski, "After North Korea's Nuclear Test," *The National Review Online*, February 12, 2013.
[21] *Global Fissile Material Report 2011: Nuclear Weapon and Fissile Material Stockpiles and Production*, Sixth Annual report of the International Panel on Fissile Materials, January 2012, p.23.
[22] Martin Fackler and Choe Sang-Han, "South Korea Flirts With Nuclear Ideas as North Blusters," *The New York Times*, March 10, 2013.
[23] "Saudi Arabia warns against Iran's nuclear program," *The Times of India*, May 25, 2013.

Further undermining nonproliferation efforts world-wide is that both Pakistan and North Korea have sold the technology needed for other countries to produce their own HEU or plutonium for nuclear weapons. Pakistan has sold centrifuge technology to Iran, North Korea and Libya. North Korea sold a plutonium production reactor to Syria and ballistic missile technology to Iran and Pakistan. One can only wonder which countries Iran will favor with its nuclear technology.

The U.S. needs to stop treating the nuclear programs in countries such as Iran as regional problems and start considering how to strengthen the nonproliferation system as a whole. Key to this effort will be to stop countries from using nominally peaceful nuclear activities to acquire the HEU or plutonium needed for nuclear weapons. A negotiated agreement with Iran that legitimizes it centrifuge enrichment program would be a step in the wrong direction. It will also be important for the U.S. to continue to prohibit South Korea from producing separated plutonium and to help Japan find a way to dispose of its huge plutonium stockpile.

Additionally, the IAEA must stop being complicit in this problem. The IAEA must stop pretending that it can effectively safeguard such dangerous material and activities. Nuclear safeguards are supposed to be more than an accounting system. Rather the purpose of IAEA safeguards "…is the timely detection of diversion of significant quantities of *nuclear material* from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection."[24] [Emphasis in original]

For safeguards to be effective non-nuclear weapon countries must be prohibited from possessing any materials or facilities that can quickly provide fissile material for nuclear weapons. This includes prohibiting not only enrichment and reprocessing facilities but also separated HEU, plutonium or U-233 and HEU, plutonium or U-233 that is contained in unirradiated reactor fuel (such as HEU fuel for research reactors or mixed oxide fuel for power reactors).[25] Such restrictions would require shutting down enrichment facilities not only in Iran but also in Germany, the Netherlands, Brazil and Japan as well as reprocessing facilities in Japan. Such restrictions would also require the removal of Japan's massive plutonium stockpile.

We are reaching a crisis point in the survival of the current non-proliferation system. Unless major changes are made to the way the IAEA conducts business, we will see countries such as South Korea, Japan, and Saudi Arabia follow Iran's strategy using its "peaceful" nuclear program as a cover for the acquisition of nuclear weapons, all with the blessings of the IAEA. The U.S. needs to take the lead. The U.S. should insist that the IAEA safeguards perform the function for which they were intended and push for an international agreement that prohibits non-nuclear weapon countries from having nuclear materials or facilities that can easily provide the nuclear material for nuclear weapons.

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[24] "The Structure and Content of Agreements Between The Agency and States Required in Connection With The Treaty on the Non-Proliferation of Nuclear Weapons," International Atomic Energy Agency, INFCIRC/153 (Corrected), June 1972, p.9.

[25] U-233 like plutonium and HEU can be used to manufacture nuclear weapons. It is produced by the irradiation of thorium. Mixed oxide power reactor fuel is a mixture of uranium and plutonium oxides.

Appendix 1

Detailed Analysis of the IAEA May 22, 2013 Safeguards Report and Methods Whereby Iran Could Produce HEU and/or Plutonium for Nuclear Weapons

Iranian Centrifuge Enrichment of Uranium

Iran has three known centrifuge enrichment facilities. Iran's main facility is the Fuel Enrichment Plant (FEP) at Natanz. The basic unit of Iran's centrifuge enrichment effort is a cascade which originally consisted of 164 centrifuges but Iran has now modified the majority of the cascades by increasing the number of centrifuges to 174. (All centrifuges operated 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 May 15, 2013, Iran had installed a total of 79 cascades of IR-1 type centrifuges and had partially installed one additional cascade. This results in a total of 13,555 IR-1 centrifuges which is an increase of 886 since the IAEA's February 2013 safeguards update. Of these 79 cascades, 53 (containing 8,892 centrifuges) were declared by Iran as being fed with uranium hexafluoride and therefore were producing 3.5% enriched uranium. In addition Iran has begun to install some of the more advanced IR-2m centrifuges at the FEP. Iran has installed four cascades of IR-2m type centrifuges and has partially installed a fifth for a total of 689 IR-2m centrifuges. This is an increase of 509 IR-2m type centrifuges since February 2013. Thus far no IR-2m cascade has begun to enrich uranium. In March 2013, Iran stated that it would install 3,000 of these more advanced centrifuges.[26]

Iran began producing 3.5% enriched uranium at the FEP in February 2007 and as of May 4, 2013 Iran had produced a total of 6,057 kilograms (in the form of 8,960 kilograms of uranium hexafluoride). Since 1,724 kilograms of this enriched uranium has already been processed into 19.7% enriched uranium (see the PFEP and FFEP below) and a further 36 kilograms was used in the conversion process to produce uranium dioxide for use as fuel in the TRR, Iran's current stockpile of 3.5% enriched uranium is 4,297 kilograms. Iran's current production rate of 3.5% enriched uranium is about 158 kilograms per month.[27] This production rate has held roughly steady since early 2012 and represents about a 60% increase from 2011 when the production rate was about a steady 100 kilograms per month and is about triple the rate since 2009 (see Table 2). From the production rate of 3.5% enriched uranium, it is easy to calculate that the FEP has a separative capacity of about 6,880 separative work units (SWU) per year.[28] Assuming that 8,892 IR-1 centrifuges at the FEP are in fact operational, these centrifuges are each producing 0.77 SWU per centrifuge-year. However, since in the past the IAEA has stated in the past that perhaps not all of the 8,892 centrifuges may be working this number should be considered a minimum value and could be higher.

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[26] Yeganeh Torbati, "Iran says building 3,000 advanced centrifuges," *Reuters*, March 3, 2013.
[27] To avoid problems with the fact that the length of a month is variable, I have adopted a uniform month length of 30.44 days.
[28] 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.

Iran also has the Pilot Fuel Enrichment Plant (PFEP) at Natanz, which is used to test a number of more advanced centrifuge designs. These are usually configured as either single centrifuges or test cascades containing various numbers of centrifuges. Two of these test cascades are complete cascades. One contains 164 IR-4 centrifuges and one contains 162 IR-2m centrifuges. Up to now no enriched uranium has been produced by these test cascades. Iran had said that it planned to start producing enriched uranium with these two complete test cascades but more recently indicated that these plans had been delayed. Since each of these cascades will be equivalent to multiple IR-1 cascades, the enriched uranium output will be significant.

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 May 10, 2013, Iran had produced 110.1 kilograms of 19.7% enriched uranium (in the form of 162.8 kilograms of uranium hexafluoride) at this facility. Iran's production rate of 19.7% enriched uranium at the PFEP has been fairly steady over the past two years and is currently about 3.05 kilograms per month. The centrifuges at this facility are each producing about 0.91 SWU per centrifuge-year.

Table 2
Average Iranian Production Rate of 3.5% Enriched Uranium
November 2008 to May 2013

IAEA Reporting Interval	Average 3.5% Enriched Uranium Production Rate (Kilograms Uranium per Month)
11/17/08-1/31/09	52
2/1/09-5/31/09	53
6/1/09-7/31/09	57
8/1/09-10/31/09	57
11/22/09-1/29/10	78
1/30/10-5/1/10	81
5/2/10-8/6/10	80
8/7/10-10/17/10	95
10/18/10-2/5/11	88
2/6/11-5/14/11	105
5/15/11-8/13/11	99
8/14/11-11/1/11	97
11/2/11-2/4/12	115
2/5/12-5/11/12	158
5/12/12-8/6/12	161
8/7/12-11/11/12	156
11/12/12-2/3/13	162
2/4/13-5/4/13	158

Finally, Iran has constructed an enrichment facility near Qom. Known as the Fordow Fuel Enrichment Plant (FFEP), Iran clandestinely started to construct this plant in violation of its IAEA safeguards. Iran only revealed the existence of this plant in September 2009, after Iran believed that the West had discovered the plant.

The FFEP is designed to hold a total of 16 cascades (each cascade holds 174 IR-1 type centrifuges for a total of 2,784 centrifuges). Fifteen of the sixteen cascades have been vacuum tested and could operate at any time. The sixteenth cascade had been fully installed in November 2012 but for some reason, some of the centrifuges in this cascade have since been removed.

Only four of the fifteen cascades are producing enriched uranium. They are configured as two sets of two interconnected cascades so as to produce 19.7% enriched uranium from 3.5% enriched uranium as is being done at the PFEP. The first of these two sets began production on December 14, 2011 and the second set began operation on January 25, 2012. As of May 10, 2013, Iran had produced 109.3 kilograms of 19.7% enriched uranium (in the form of 161.6 kg of uranium hexafluoride) at this facility. This facility is currently producing 19.7% enriched uranium at the rate of 7.33 kilograms per month. These centrifuges are each producing about 1.03 SWU per centrifuge-year.

With the start of these two sets of interconnected cascades at the FFEP, Iran has made good on its announcement in June 2011 that it would triple its production rate of 19.7% enriched uranium. Currently Iran is producing a total of about 10.4 kilograms of 19.7% enriched uranium per month (see Table 3). As of May 2013, Iran had produced a total of about 219 kilograms of 19.7% enriched uranium. Since Iran has converted about 95 kilograms of this uranium (43 percent) into a uranium oxide compound for use as fuel in the TRR, and further blended down about 1 kilogram to lower enrichments, Iran's current stockpile of 19.7% enriched uranium that is being kept as uranium hexafluoride is about 123 kilograms of uranium.

Regarding the twelve other cascades at the FFEP that have yet begun operation, the IAEA has asked Iran whether these new cascades are to be interconnected to produce yet more 19.7% enriched uranium or only 3.5% enriched uranium. However, Iran says that the installation of these new cascades is not yet complete and that it will only inform the IAEA prior to the start of their operation. This development opens the possibility that Iran could further increase its rate of 19.7% enriched uranium. Using these cascades Iran could put a six more sets of two interconnected cascades into operation and increase its production of 19.7% enriched uranium to as much as 32 kilograms a month.[29] Given Iran's current rate of production rate of 3.5% enriched uranium at the FEP, the current size of Iran's its stockpile of 3.5% enriched uranium and the capacity expansion occurring at the FEP, Iran could maintain this high rate of 19.7% enriched uranium production indefinitely.

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

Table 3

Iranian Production of 19.7% Enriched Uranium
April 2010 to May 2013

IAEA Reporting Interval	Average Monthly* Production at PFEP (kg U)	Average Monthly* Production at FFEP (kg U)	Total Average Monthly* Production (kg U)	Cumulative Production (kg U)	Cumulative Total 20% U Converted From UF_6 (kg U)	Total Net Production 20% U in Form of UF_6 (kg U)
2/9/10-4/7/10	2.0	0	2.0	3.9	0	3.9
4/8/10-8/20/10	2.5	0	2.5	14.9	0	14.9
8/21/10-11/19/10	2.5	0	2.5	22.3	0	22.3
11/20/10-2/11/11	2.6	0	2.6	29.5	0	29.5
2/12/11-5/21/11	2.7	0	2.7	38.3	0	38.3
5/22/11-8/20/11	3.2	0	3.2	47.9	0	47.9
8/21/11-10/28/11	2.7	0	2.7	53.9	0	53.9
End 10/11-Mid 2/12**	3.1	6.5***	9.6	73.8	7	66.8
Mid 2/12-Mid 5/12	3.1	5.2	8.3	98.4	30.2	68.2
Mid 5/12-Mid 8/12	3.0	6.7	9.7	128.0	49.3	78.7
Mid 8/12-Mid 11/12	3.3	6.9	10.2	157.4	57.0	100.4
Mid 11/12-Mid 2/13	2.8	7.7	10.5	189.1	76.1	113.0
Mid 2/13-Mid 5/13	3.1	7.3	10.4	219.3	96.3	123.0

*In order to avoid the problem of the variable length of a month I use a uniform 30.44 day month
**IAEA inspections are carried out at the PFEP and the FFEP on slightly different dates
***The first set of interconnected cascades began operation on 12/14/11. The second set began operation on 1/25/12.

Iranian Options for Producing HEU

Given that Iran currently has in operation a total enrichment capacity of about 8,000 SWU per year at the FEP, FFEP, and PFEP and stockpiles of 4,297 kilograms of 3.5% enriched uranium and 123 kilograms of 19.7% enriched uranium, Iran has a number of options for producing the 20 kilograms of HEU required for a nuclear weapon.

The most straightforward method Iran could use to produce HEU would be batch recycling. In this process, no major modifications are made to Iran's enrichment facilities but rather enriched uranium is successively run though the various enrichment facilities in batches until the desired enrichment is achieved. Iran could use a three-step process to produce HEU. This process is illustrated in Table 4.

Table 4

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

Cycle and Enrichment Plant	Product Enrichment and Quantity	Feed Enrichment and Quantity	Time for Cycle (Days)
First FEP	19.7% 87 kg	3.5% 1,025 kg	22
Second FEP	55.4% 39.8 kg	19.7% 227 kg*	8
Third PFEP & FFEP**	89.4% 20 kg	55.4% 39.0 kg	21
Total			57***

* Includes 123 kilograms of 19.7% enriched uranium that Iran has already stockpiled and 19 kilograms of 19.7% enriched uranium from the tails of the PFEP and FFEP. Plant inventory at the FEP is 2 kilograms.
** The combined plant inventory at the PFEP and FFEP is 0.8 kilogram.
***Includes six days to account for equilibrium and cascade fill time.

In the first step, Iran needs to produce 229 kilograms of 19.7% enriched uranium (including 2 kilograms for the plant inventory in the second step). However, since it has already produced 123 kilograms of 19.7% enriched uranium, and the tails from the third step are 19.7% enriched uranium, Iran needs only to produce an additional 87 kilograms. This step requires 1,025 kilograms of 3.5% enriched uranium as feed but Iran's current stockpile well exceeds this figure. In the second step, the 19.7% enriched uranium is further enriched at the FEP to 55.4% enriched uranium. This step requires the production of 39.8 kilograms of 55.4% enriched uranium (including the 0.8 kilograms for the plant inventory at the PFEP and FFEP). In the third step, the

55.4% enriched uranium is enriched to the 20 kilograms of 89.4% enriched uranium needed for a nuclear weapon. For this last step I assume that fourteen of the fifteen cascades that are ready to operate at the FFEP are used and function as seven interconnected cascades and that the one set of interconnected cascades at the PFEP is used as well. The total time required is 57 days which is about 8 weeks or about two months.

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

Table 5

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

Cycle and Enrichment Plant	Product Enrichment and Quantity	Feed Enrichment and Quantity	Time for Cycle (Days)
First FEP	19.7% 210 kg	3.5% 2,480 kg	53
Second FEP	55.4% 39.8 kg	19.7% 227 kg*	8
Third PFEP & FFEP**	89.4% 20 kg	55.4% 39.0 kg	21
Total			88***

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

Though much attention has been focused on Iran's growing stockpile of 19.7% enriched uranium, most of the reason why Iran can produce the HEU for a nuclear weapon as quickly as it can is because of its growing enrichment capacity and not its growing 19.7% enriched uranium stockpile. As is shown in Table 5, even if Iran did not have a stockpile of 19.7% enriched uranium, it could still produce a weapon's worth of HEU in just under 3 months (twelve and one half weeks) which is only somewhat longer than the two months (eight weeks) that would be required given Iran's current stockpile of 19.7% enriched uranium (Table 4). As is shown in

Appendix 2, continued growth of Iran's centrifuge enrichment capacity, even if Iran does not stockpile 19.7% enriched uranium, means that the time required for Iran to produce the HEU required for a nuclear weapon will become quite short. This is not to say that Iran's growing stockpile of 19.7% enriched uranium is unimportant, but rather focusing only on the 19.7% enriched uranium and not Iran's growing enrichment capacity as well will not provide a solution to the problem of Iran's ability to quickly produce the HEU required for a nuclear weapon

It should also be noted that Iran's stockpile of 3.5% enriched uranium has become large enough that Iran can now produce enough HEU for two nuclear weapons by batch recycling. Iran could produce 20 kilograms of HEU using the method shown in Table 4 and still have 3,272 kilograms of 3.5% remaining. Using this material Iran could produce a second 20 kilograms of HEU by using the method shown in Table 5. The whole process could be accomplished in 122 days which is about four months.[30]

Table 6

Time, Product and Feed Requirements for the Production of HEU by Batch Recycling at the FEP (operating all 13,555 IR-1 centrifuges) and Using Advanced Centrifuges at the PFEP & FEP (~12,000 SWU per year)
Final Step Using Interconnected Cascades at PFEP and FFEP
(8 sets of two interconnected cascades at the FFEP)

Cycle and Enrichment Plant	Product Enrichment and Quantity	Feed Enrichment and Quantity	Time for Cycle (Days)
First FEP & Advanced Centrifuges at PFEP	19.7% 87 kg	3.5% 1025 kg	13
Second FEP &Advanced Centrifuges at PFEP	55.4% 39.8 kg	19.7% 227 kg*	4
Third Interconnected Cascades at PFEP & FFEP**	89.4% 20 kg	55.4% 39.0 kg	19
Total			42***

* Includes 123 kilograms that Iran has already stockpiled and kilograms that Iran has already stockpiled and 19 kilograms of 19.7% enriched uranium from the tails of the PFEP and FFEP. Plant inventory at the FEP is 2 kilograms.
** The combined plant inventory at the PFEP and FFEP is 0.8 kilogram.
***Includes six days to account for equilibrium and cascade fill time.

[30] The times in Table 4 and Table 5 are not additive since while the third cycle in Table 4 is being performed using the FFEP and the PFEP, the first cycle in Table 5 can be started at the FEP.

Another concern is that Iran has installed a great number of IR-1 centrifuges at the FEP that it is not operating. Only 8892 centrifuges are operating at this site even though 13,555 centrifuges are installed. Iran could start operating these installed centrifuges in the next few months. Iran could also start operating the four cascades of IR-2m centrifuges that it has installed at the FEP. Further Iran has indicated that it plans to start producing enriched uranium with the two cascades of advanced centrifuges (IR-2m and IR-4) at the PFEP. In addition, Iran could easily complete the last cascade at the FFEP and complete an eighth interconnected cascade at this site. If Iran were to take all of these steps, it could significantly shorten the time to produce the HEU for a nuclear weapon to only one and one half months (six weeks). See table 6 (for these calculations I assume that the IR-2m and IR-4 centrifuges produce twice the separative work of an IR-1 centrifuge—this is probably a conservative assumption.)

Table 7 shows the same case but assuming that Iran has no stockpile of 19.7% enriched uranium. To produce a weapon's worth of HEU would require only about eight and one half weeks (about two months). This is only two and one half weeks longer than the case using Iran's current stockpile of 19.7% enriched uranium. Further as Iran continues to install more IR-1 and IR-2m centrifuges at the FEP, these times are only going to decrease. Iran could carry out the enrichment as shown in Tables 6 & 7 and produce 40 kilograms of HEU (enough for two nuclear weapons) in just 81 days (two and two thirds months).

Table 7

Time, Product and Feed Requirements for the Production of HEU by Batch Recycling at the FEP (operating all 13,555 IR-1 centrifuges) and Using Advanced Centrifuges at the PFEP& FEP (~12,000 SWU per year)
Using 3.5% Enriched Uranium as the Starting Material
Final Step Using Interconnected Cascades at PFEP and FFEP
(8 sets of two interconnected cascades at the FFEP)

Cycle and Enrichment Plant	Product Enrichment and Quantity	Feed Enrichment and Quantity	Time for Cycle (Days)
First FEP & Advanced Centrifuges at PFEP	19.7% 210 kg	3.5% 2,480 kg	31
Second FEP &Advanced Centrifuges at PFEP	55.4% 39.8 kg	19.7% 227 kg*	4
Third Interconnected Cascades at PFEP & FFEP**	89.4% 20 kg	55.4% 39.0 kg	19
Total			60***

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

Currently the fastest way for Iran to produce the HEU for a number of nuclear weapons is by using batch recycling at the FEP combined with a clandestine "topping" enrichment plant. This method would allow Iran to produce a weapon's worth of HEU in just one month (four weeks). Since Iran continues to refuse to implement the Additional Protocol to its safeguards agreement, as well as the Modified Code 3.1, the IAEA would find it very difficult to locate a clandestine enrichment plant—a fact that the IAEA has continued to confirm.[31] While this has been a theoretical possibility since 2007, its salience increased with the discovery in September 2009 that Iran was actually building such a clandestine enrichment plant (the FFEP near Qom).

In this case, the 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 3,000 IR-1 type centrifuges (about the number deployed at the FFEP) to be able to produce the 20 kilograms of HEU required for a nuclear weapon in just one months (see Table 8.) Since Iran has shown the capability to mass produce IR-1 type centrifuges and has installed 3,141 at the FEP in just the last six months, Iran could easily provide enough centrifuges for a small clandestine enrichment plant.

Table 8

Time, Product and Feed Requirements for the Production of HEU at a 3,000 Centrifuge (IR-1 type) Clandestine Plant (0.90 SWU per centrifuge-year)

Enrichment Plant	Product Enrichment and Quantity	Feed Enrichment and Quantity	Time for Cycle (Days)
Clandestine	90.0% 20 kg	19.7% 93.8 kg*	30**
Total			30

* There is additional processing of the tails of the clandestine plant at the PFEP and FFEP.
** Includes two days to account for equilibrium and cascade fill time.

Iran already has sufficient 19.7% enriched uranium to produce more than enough HEU for one nuclear weapon. By using the FEP to produce additional 19.7% enriched uranium, Iran could produce additional HEU. Given its current stockpile of 3.5% enriched uranium Iran could produce a total of 104 kilograms of HEU which would be enough for about five nuclear weapons. Since the FEP can produce 19.7% enriched uranium faster than the clandestine plant would use it, each weapon's worth of HEU would be produced at one month intervals and Iran

[31] "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/2013/27, May 22, 2013, p.13.

could have a five weapon arsenal in five months. As Iran builds more of its advanced centrifuges (such as the IR-2m), the time required for the production of HEU would only drop. For example, if Iran were to use 2,000 IR-1 centrifuges and 1,000 IR-2m centrifuges instead of 3,000 IR-1 centrifuges at a clandestine enrichment plant, the time required to produce a weapons worth of HEU (20 kilograms) would drop to 23 days (three weeks). Since Iran has already installed 1,015 IR-2m and IR-4 centrifuges at the FEP and PFEP and plans to build a total of 3,000 advanced centrifuges at the FEP, again it is well within Iran's ability to provide enough centrifuges for this clandestine enrichment plant.

Nor is a multi-step enrichment process the only pathway for Iran to produce the fissile material required for nuclear weapons, though it is the process that allows Iran to produce HEU most quickly. Iran could produce HEU at a clandestine enrichment plant designed to produce 90% enriched uranium from natural uranium feed.

A clandestine enrichment plant containing 3,800 IR-1 centrifuges (0.90 SWU per centrifuge-year) could produce around 20 kilograms of HEU (the amount required for one nuclear weapon) each year using natural uranium as feed. Since this option does not require any overt breakout from safeguards, the relatively slow rate of HEU production would not necessarily be of any concern to Iran. Such production could be going on right now and the West might well not know. A clandestine enrichment plant would need a source of uranium but Iran is producing uranium at a mine near Bandar Abbas.[32] Since Iran has refused to implement the Additional Protocol to its IAEA safeguards, this uranium mining is unsafeguarded and the whereabouts of the uranium that Iran has produced there is unknown. A drawback to this stand-alone clandestine enrichment plant is that it requires more centrifuges than would the 3,000 centrifuge clandestine plant discussed above. However Iran's rapid installation of centrifuges at the FFEP and FEP means that this possibility cannot be ruled out.

Iran then, has a number of methods whereby it could produce the HEU required for a nuclear weapon. By batch recycling at the FEP, PFEP and the FFEP (Table 4), Iran could produce enough HEU for a nuclear weapon in about two months (eight weeks). Even if Iran were to give up its current stockpile of 19.7% enriched uranium (Table 5), the time required for Iran to produce the HEU for a nuclear weapon would be just under three months (twelve and one half weeks). Using its current stockpiles of 3.5% and 19.7% enriched uranium, Iran could produce enough HEU for two nuclear weapons in about four months.

If Iran were to starting operating all of the centrifuges that it has installed, these times would significantly decrease. Iran could then produce enough HEU for a nuclear weapon in just one and one half months (six weeks, Table 6) and even if it did not have any 19.7% enriched uranium it could still produce enough HEU for a nuclear weapon in just eight and one half weeks (about two months, Table 7)—a difference of only two and one half weeks. Using its current stockpiles of 3.5% and 19.7% enriched uranium, Iran could produce enough HEU for two nuclear weapons in about two and two thirds months.

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[32] *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.

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 using IR-1 centrifuges (Table 8), then it could produce a weapon's worth of HEU in one month (four weeks) and enough HEU for five weapons in five months. Using more advanced centrifuges at a clandestine enrichment plant, Iran could produce a weapon's worth of HEU in just three weeks and enough HEU for five weapons in three and one half 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.

Iranian Production of Plutonium

The IAEA has also reported that Iran has made significant progress on its construction of its plutonium production reactor (the IR-40 at Arak). Iran has delivered the reactor vessel to the site and has installed the moderator and primary coolant heat exchangers and piping. Iran has produced a test fuel assembly for this reactor that it is irradiating in the Tehran Research Reactor. Iran has also produced over 12 metric tons of uranium dioxide (using natural uranium) which is probably enough for the first core of this reactor. Iran has transferred over six metric tons of this material to its Fuel Manufacturing Plant. Iran has stated that it plans to begin to operate this reactor in the third quarter of 2014. This schedule may slip and even if Iran can meet this scheduled startup, it would still take about another year before Iran would be able to produce and separate enough plutonium for a nuclear weapon. Still Iran's steady progress on this reactor shows that in a few years it will have the ability to produce plutonium as well as HEU for nuclear weapons.

Appendix 2

Limiting Iran to Producing and Stockpiling Less Than 5% Enriched Uranium Does Not Prevent Easy Access to HEU

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

But as was shown in Appendix 1 (Table 5), even if Iran were to give up its current stockpile of 19.7% enriched uranium, Iran could still produce the HEU required for a nuclear weapon in just under three months (twelve and one half weeks). The problem is Iran's growing enrichment capacity. Furthermore, Iran's current enrichment effort is quite small compared to that needed for most peaceful nuclear activities such as providing fuel for a single nuclear power reactor. A diplomatic solution could provide Iran with the justification for greatly expanding its current enrichment facilities as well as removing sanctions. Under these circumstances, Iran might receive assistance to expand its enrichment facilities (from say China or Pakistan) as part of normal nuclear commerce. These greatly expanded facilities would provide Iran easy access to the HEU needed for nuclear weapons.

For example, even if Iran produced only 4.1% enriched uranium[33] and expanded its current enrichment capacity by about a factor of 12 (100,000 SWU/yr), it would only produce about 15 metric tons of enriched uranium per year. This amount would still be less than that needed to fuel a single large power reactor yet, using batch recycling, these enrichment facilities could produce enough HEU for a nuclear weapon in just two weeks. This process is shown in Table 9.

In the first step, 4.1% enriched uranium is processed into 20.2% enriched uranium. In the second step, this uranium is processed into 60.2% enriched uranium and the third step completes the process by producing the 20 kilograms of 90% enriched uranium needed for a nuclear weapon. Each step produces not only the material needed to be processed in the next step but the material needed for the plant inventory which in this case is 30 kilograms per step.

Instead of just producing enough HEU for one nuclear weapon, Iran could produce enough HEU for five nuclear weapons (100 kilograms) in a single batch recycling campaign. This process would take about five weeks and is shown in Table 10. This process would require starting with 6,090 kilograms of 4.1% enriched uranium but since the plant will be producing about 15,000 kilograms per year, it would not be hard for Iran to stockpile this quantity of enriched uranium.

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

[33] With tails of 0.2%.

Table 9

Time, Product and Feed Requirements for the Production of 20 kg of HEU by Batch Recycling at a Centrifuge Enrichment Plant Designed to Produce 4.1% Enriched Uranium (100,000 SWU per year total)

Cycle	Product Enrichment and Quantity	Feed Enrichment and Quantity	Time for Cycle (Days)
First	20.2% 304 kg	4.1% 1,990 kg	7.5
Second	60.2% 69.5 kg	20.2% 274 kg	1.7
Third	90.0% 20 kg	60.2% 39.5 kg	0.5
Total			16*

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

Table 10

Time, Product and Feed Requirements for the Production of 100 kg of HEU by Batch Recycling at a Centrifuge Enrichment Plant Designed to Produce 4.1% Enriched Uranium (100,000 SWU per year total)

Cycle	Product Enrichment and Quantity	Feed Enrichment and Quantity	Time for Cycle (Days)
First	20.2% 929 kg	4.1% 6,090 kg	23
Second	60.2% 228 kg	20.2% 899 kg	5.6
Third	90.0% 100 kg	60.2% 198 kg	2.5
Total			37*

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