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Iranian Breakout Estimates, Updated September 2013

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Read the detailed summary of this report here.

1. Background

Since October 2012 when we last published detailed breakout assessments about Iran's gas centrifuge uranium enrichment program, Iran has steadily expanded its number of IR-1 centrifuges installed at both its Fordow and Natanz gas centrifuge plants.[2] Additionally, it has started installing its more advanced centrifuge model, the IR-2m centrifuge, at the Natanz Fuel Enrichment Plant (FEP). These substantial changes merit updating our previous breakout estimates of the time Iran would need to produce one significant quantity (SQ) of weapon-grade uranium (WGU), taken as 25 kilograms of WGU, using its existing safeguarded nuclear facilities and low enriched uranium (LEU) stocks as of August 2013.

For several years, experts at ISIS and the School of Engineering and Applied Science at the University of Virginia (UVA) have quantified Iran's ability to adapt its enrichment program to produce WGU. Iran maintains a number of options should it choose to breakout of the Nuclear Nonproliferation Treaty (NPT). This report evaluates those options in various realistic combinations to examine Iran's current ability to produce WGU. We also look for the first time in this report at breakout times in the case of Iran having a covert centrifuge plant of advanced centrifuges.

Since the last iteration of these calculations in October 2012, Iran has not enriched uranium beyond 20 percent; however, it has growing stockpiles of LEU enriched up to both 3.5 percent and near 20 percent. The size of its LEU stocks exceeds any realistic assessment of Iran's need for reactor fuel in the short and near-term. Combined with its dramatically increased centrifuge capability, these stockpiles bolster Iran's latent capability to manufacture a nuclear weapon.

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[2] William C. Witt, Christina Walrond, David Albright, and Houston Wood, *Iran's Evolving Breakout Potential*, ISIS Report, October 8, 2012.
http://isis-online.org/uploads/isis-reports/documents/Irans_Evolving_Breakout_Potential.pdf

Given the growth in Iran's centrifuge capabilities over the last two years, Iran may aim to create the capability to produce sufficient WGU for a nuclear weapon faster than IAEA inspectors could detect the production of one or two SQs. ISIS defines the date when Iran achieves such a breakout capability as a "critical capability". In other reports, ISIS has estimated that Iran could achieve critical capability in mid-2014.[3]

As in the October 2012 iteration, the estimates in this report do not include the additional time that Iran would need to convert WGU into weapons components and manufacture a nuclear weapon. This extra time could be substantial, particularly if Iran wanted to build a reliable warhead for a ballistic missile. However, these preparations would most likely be conducted at secret sites and would be difficult to detect. If Iran successfully produced enough WGU for a nuclear weapon, the ensuing weaponization process might not be detectable until Iran tested its nuclear device underground or otherwise revealed its acquisition of nuclear weapons. Therefore, the most practical strategy to prevent Iran from obtaining nuclear weapons is to prevent it from accumulating sufficient nuclear explosive material, particularly in secret or without adequate warning. This strategy depends on knowing how quickly Iran could make WGU.

Centrifuge Numbers as of August 2013

This report bases its calculations on data in the August 2013 IAEA Safeguards Report.[4]

Number of Centrifuges Enriching: According to the August 2013 report, Iran was enriching uranium hexafluoride (UF_6) in 9,494 IR-1 centrifuges at Natanz (including producing 3.5 percent LEU at the FEP and near 20 percent LEU at the Pilot Fuel Enrichment Plant) and 696 IR-1 centrifuges at the Fordow Fuel Enrichment Plant producing near 20 percent LEU. In total, as of August 2013, Iran had 10,190 enriching IR-1 centrifuges.

Centrifuges Installed but not Enriching: In addition to the IR-1 centrifuges that were enriching, Iran had a number of centrifuges installed and available to begin enriching uranium quickly. As of August 10, 2013, Iran had 6,250 centrifuges installed but not enriching at the Natanz Fuel Enrichment Plant for a total of 15,744 IR-1 centrifuges at the FEP. At Fordow, an extra 2,014 IR-1 centrifuges were installed for a total of 2,710 IR-1 centrifuges. In total, Iran had a total of 18,454 IR-1 centrifuges in roughly 110 cascades. As of August 2013, Iran had also installed 1,008 IR-2m centrifuges and was making preparations to install an additional 2,088 machines. So, Iran has an installed centrifuge capacity that exceeds 19,000 centrifuges.

Amount of LEU Hexafluoride Stockpiled: As of the August 2013 safeguards report, Iran had a net stockpile of 6,774 kilograms of 3.5 percent LEU hexafluoride and 186 kilograms of near 20 percent LEU hexafluoride. Iran also had a stock of near 20 percent LEU in the form of oxide, which totaled up

[3] David Albright and Christina Walrond, *Critical Capability*, ISIS Report, July 30, 2013. http://isis-online.org/isis-reports/detail/critical-capability/8; and David Albright and Christina Walrond, *Iran's Critical Capability in 2014: Verifiably Stopping Iran from Increasing the Number and Quality of its Centrifuges*, ISIS Report, July 17, 2013. http://isis-online.org/uploads/isis-reports/documents/Iran_critical_capability_17July2013.pdf

[4] IAEA Director General, *Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran,* GOV/2013/40, August 28, 2013. http://isis-online.org/uploads/isis-reports/documents/Iran_DG_Report_-_gov2013-40.pdf

to about 130 kilograms as of August 2013.[5] This oxide stock is not included in the calculations in this report. ISIS does not assess Iran's large natural uranium hexafluoride stockpile to be a bottleneck in its production of WGU.

2. Methods

ISIS and UVA experts evaluated a range of breakout scenarios based on the current enriching IR-1 centrifuges and LEU stockpiles, total installed IR-1 centrifuges, and a possible covert facility containing IR-2m centrifuges. For each scenario, a number of configurations were considered for the multistep enrichment process (the number of cascades in each step were varied). This evaluation leads to a range of predicted breakout times for which the range is determined by the mean of all of the predictions plus or minus one standard deviation.[6] This provides a range of the most-likely minimal breakout times.

To account for setup time and other inescapable delays, this analysis adds two weeks to each raw prediction. This time period allows for a range of necessary modifications. It assumes the operators would modify or change the cold traps in some of the withdrawal sections of the plants so that they could hold 60 and 90 percent enriched uranium safely without an undue risk of the HEU becoming critical, a serious accident which would threaten the entire breakout operation. IAEA inspectors would typically notice these types of changes. As a result, Iran would likely wait to start making them until just after inspectors finished an inspection. In the future, Iran may be able to reduce this preparation time to about one week.

Basic data for these calculations follows:

Current Enriching Centrifuges and LEU hexafluoride stocks

- 10,092 IR-1 centrifuges at Natanz and Fordow (approximately 58 cascades)
- LEU Stockpile: 6,774 kg 3.5 percent LEU hexafluoride and 185.8 kg near 20 percent LEU hexafluoride, taken as 19.75 percent in the calculations.

Enriching and Installed Infrastructure

- 18,454 IR-1 centrifuges at Natanz and Fordow (approximately 106 cascades)
- LEU Stockpile: 6,774 $kgUF_6$ at 3.5 percent and 185.8 $kgUF_6$ at 19.75 percent

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[5] This stock of near 20 percent LEU oxide is almost entirely in the form of powder and in fresh fuel for the Tehran Research Reactor (TRR). A small amount of the oxide material has been made into fuel and inserted and irradiated into the TRR, making its reconversion into hexafluoride form much more difficult. However, all the material in powder and fresh fuel can be reconverted back into hexafluoride form in a straightforward manner, although it would require time, likely at least a few months. See David Albright, Christina Walrond, and Andrea Stricker, *ISIS Analysis of IAEA Iran Safeguards Report*, ISIS, August 28, 2013. http://isis-online.org/uploads/isis-reports/documents/ISIS_Analysis_IAEA_Safeguards_Report_28August2013_Final_newgraph.pdf

[6] In a few cases, some predictions are not included in the calculation of the mean, for example, configurations where the predicted breakout time was determined to be unrealistic or an outlier.

Covert Plant of IR-2m Centrifuges

- 3,000 IR-2m centrifuges at covert plant (approximately 187 cascades)
- Estimated enrichment output of an individual IR-2m centrifuge : 3 SWU/yr or 5 SWU/yr

Despite IAEA inspections, many aspects of Iran's centrifuge program remain unknown, making it difficult to gauge centrifuge performance. The primary source of uncertainty is the performance of the IR-1 and IR-2m centrifuges. While Iran has operated the IR-1 for nearly seven years, this centrifuge's performance has varied. Over the past few years, Iran has achieved approximately the same level of output. However, this performance varies when placed into different cascade structures. While the centrifuges producing 3.5 percent enriched uranium at Natanz, arranged into 164 and 174 machine cascades, the machine achieves approximately 0.75 swu/centrifuge-year. However, when oriented in tandem cascades to produce near 20 percent enriched uranium, as is the IR-1 in the PFEP and at Fordow, it achieves nearly one swu/centrifuge-year. In a breakout scenario, the performance of the IR-1 centrifuge is expected to vary further. In the calculations, each IR-1 centrifuge is assumed to have a separative output of 0.9 SWU/yr.

As of the last quarterly safeguards report, Iran had installed approximately 1,000 IR-2m centrifuges, but had not yet begun enriching in these machines. Without data about product enrichment level and performance, approximating the performance of the IR-2m is even more difficult than doing so for the IR-1 centrifuge. The IR-2m centrifuge is assumed by ISIS as having 3-5 times the current enrichment output of the IR-1. This nominally puts the separative power of the IR-2m centrifuge between 3 and 5 SWU/year. To develop a performance profile of the IR-2m centrifuge, it is assumed that the nominal enrichment level achieved in the IR-2m centrifuge cascade is the same as in the IR-1 centrifuge cascade. A semi-empirical approach is taken to develop two performance maps for the IR-2m centrifuge.[7]

2.1 Breakout Scenarios

Considering that the Natanz Fuel Enrichment Plant, near the city of Natanz, and the Fordow Fuel Enrichment Plant, near the city of Qom, are roughly two hours apart by car (approximately 115 miles), this study considers the plants in parallel. In the subsequent analysis, the number of centrifuges from both plants is combined, assuming enriched material could be transported relatively quickly between the two sites. For the breakout scenarios, this analysis utilizes a modified form of the well-known four-step enrichment process that was developed under A.Q. Khan in Pakistan's centrifuge program and transferred to other countries, such as Iran.[8] Using all four steps, Iran would enrich natural uranium to 3.5 percent in step one, then to 20 percent in step two, then to 60 percent in step three, and finally to WGU in step four. This analysis considers the four-step, three-step, and two-step process also with use of existing LEU stockpiles.

[7] For more information on this approach, see: Migliorini, PJ, Witt, WC, Wood, HG. "Semi-Empirical Method for Developing a Centrifuge Performance Map," To Appear in *Separation Science and Technology*. 2013. DOI: 10.1080/01496395.2013.805229.

[8] David Albright, *Peddling Peril* (New York: Free Press, 2010).

Breakout Process

Four-Step with LEU Stockpiles: The original Khan procedure can be enhanced by using existing LEU stockpiles to supplement the feed into the second and third steps of the enrichment process. By including the stockpiles, Iran could shift cascades from the first step to the second and third steps, increasing the production rate. This process is stockpile dependent, and once the inventory is exhausted, Iran would need to re-assign cascades to form a more efficient four-step process.

Three-Step with LEU Stockpiles: With a sufficient supply of LEU, Iran could skip the first step of the Khan enrichment process and utilize all available centrifuges to produce WGU in three steps. In this case, Iran would continue to produce near 20 percent LEU from its stockpile of 3.5 percent LEU, but it would not use any centrifuges to produce new 3.5 percent material. Iran has stockpiled enough LEU to pursue this option; however, absent a tails recycling strategy, Iran could only produce a handful of SQs this way. After depleting its LEU stockpile, Iran would have to revert to the slower four-step process to continue producing WGU, dramatically constraining its ability to produce more SQs in a timely manner.

Two-Step with Stockpiles: With a large enough near 20 percent uranium hexafluoride stockpile, Iran could forgo both steps one and two in a rapid dash to one significant quantity of WGU. Iran could not employ this strategy until after it enriched sufficient near 20 percent enriched uranium for more than one significant quantity, perhaps significantly more, since some losses are inevitable with IR-1 cascades. In this scenario, all centrifuges would be devoted to producing 60 and 90 percent enriched uranium, and Iran would not replenish its near 20 percent or 3.5 percent stockpiles. As of August 2013, Iran in practice did not possess enough near 20 percent LEU hexafluoride to pursue this option, but if its stockpile grows, it could employ this option. As will be discussed below in the results section on the two-step process under scenario 2, if Iran uses lesser amounts of near 20 percent LEU hexafluoride, the breakout times would be greater than if it used a larger stock. In addition, with a smaller stock, this effort may fail. Problems in centrifuge performance could lead to multiple evacuations of the uranium hexafluoride in individual cascades, resulting in not producing enough WGU for a nuclear weapon before the near 20 percent LEU stock is exhausted. With larger amounts, the breakout time could increase but it would still produce one SQ of WGU. In general, depending on minimal amounts of near 20 percent LEU is risky.

2.2 Covert IR-2m Facility

This report also evaluates breakout scenarios using safeguarded LEU stocks involving a covert plant consisting of 3,000 IR-2m centrifuges. Though no concrete evidence of construction of a covert facility has emerged, official Iranian statements imply that a gas centrifuge plant is under construction. Iran has declared its intention to build up to 10 centrifuge facilities. On August 16, 2010, Ali Akbar Salehi claimed that “studies for the location of 10 other uranium enrichment facilities” had ended, and that “the construction of one of these facilities will begin by the end of the (current Iranian) year (March 2011) or start of the next year.”[9] Succeeding nuclear head Fereydoun Abbassi-Davani said in mid-2011 that construction on additional enrichment plants was delayed by two years.[10] Based on this timeline, Iran may be constructing a facility that could dramatically impact its ability to breakout. So

[9] Fars News Agency, “Iran Specifies Location for 10 New Enrichment Sites,” August 16, 2010.
[10] Siavosh Ghazi, “Iran atomic chief says fuel swap talks over: IRNA,” AFP, Aug 29, 2011.

far, there have been no Iranian public statements denying or confirming the construction of another centrifuge plant. If Iran were now building a centrifuge plant in secret, would it intend to continue hiding it after it is finished or eventually declare it to the IAEA and place it under safeguards, as required?

This report assumes that Iran would outfit a covert facility with its more advanced machine, the IR-2m centrifuge. ISIS assesses that Iran has succeeded in procuring sufficient carbon fiber, a critical component of this centrifuge design.[11]

The calculations in this scenario use LEU stocks as of August 2013. If Iran used a covert plant to breakout, it would probably do so when it had larger LEU stocks. Nonetheless, calculations based on more current inventories provide an indication of the speed at which this scenario could lead to one or more SQs of WGU.

The Optimized WGU Cascade

If Iran does have a clandestine plant, it could be optimized to produce WGU from natural feed stocks or LEU stockpiles. In this scenario, Iran would develop one, quasi-ideal cascade with all available IR-2m centrifuges. Using a quasi-ideal cascade, this analysis considers clandestine cascades designed to produce WGU from natural feed, a 3.5 percent stockpile, and a near 20 percent stockpile. Because a quasi-ideal cascade is capable of producing WGU more quickly and efficiently, Iran may be tempted to use this cascade orientation at a covert facility. However, if detected, with this cascade orientation, Iran could not reasonably conceal its intentions to produce WGU at the covert facility. Moreover, the use of one long cascade poses risks that are avoided by using many smaller cascades. A failure of a few centrifuges can, under certain circumstances, cause an entire cascade to fail, or at least major sections of it.

Breakout Process at Covert Facility

Alternately, Iran could choose an ambiguous path to its design of a covert facility by using cascade designs similar to those in centrifuge plants at Natanz of Fordow. Iran could construct the facility in secret while maintaining the option of plausibly denying any intended role in its centrifuge program, if detected. In this scenario, Iran would likely orient its cascades to make WGU in a tandem or single cascades structure. Thus, in this case, Iran would have to operate a breakout scenario process similar to those discussed above for the Natanz and Fordow plants. For these scenarios, the four-step, three-step, and two-step process is considered with 3,000 IR-2m centrifuges operating with both 3 SWU/yr and 5 SWU/yr.

3. Results

Based on each scenario, the calculations produced a range of breakout estimates. Using its current infrastructure and stocks, Iran today remains limited by its stockpile of near 20 percent LEU

[11] David Albright, Andrea Stricker, and Houston Wood, *Future World of Illicit Nuclear Trade: Mitigating the Threat*, ISIS, July 29, 2013. http://www.nps.edu/Academics/Centers/CCC/PASCC/Publications/2013/Albright_Future_World_of_Illicit_Nuclear_Trade_PASCC.pdf

hexafluoride. In addition, the breakout estimates represent minimum estimates, in the sense that they are more likely to be longer rather than shorter. Centrifuge breakage or emergency cascade evacuation in particular can cause the estimates to lengthen.

3.1 Current Breakout Potential

ISIS assesses that presently, using its current infrastructure and LEU stockpiles, Iran could break out with a four-step process or a three-step process. The breakout scenarios considered would occur using both plants in parallel.

The two-step process remains in practical terms unavailable to Iran at this time, unless Iran reconverted its stocks of many tens of kilograms of near 20 percent LEU oxide back into hexafluoride form. But reconversion would likely take at least a few to several months today, adding significantly to total breakout times.

Scenario 1: Breakout with only enriching centrifuges at Natanz and Fordow

The four-step process with only the enriching centrifuges as of August 2013 at Natanz and Fordow is simulated with and without the use of LEU inventory. Without using this inventory, Iran would be able to produce one SQ of WGU in approximately 9.0 – 9.6 months. By using available LEU stockpiles, Iran could potentially reduce this breakout time to as little as 2.3 – 3.2 months for one SQ. After this SQ is obtained, the near 20 percent LEU hexafluoride stockpile would be depleted and Iran would have to resort back to an approach using only stocks of 3.5 percent LEU, resulting in increased breakout times. However, Iran's stocks of 3.5 percent LEU are large and thus it could produce several SQs of WGU in total.

To employ the three-step process, Iran would need to leverage its LEU stockpile. ISIS predicts that the time for Iran to produce one SQ of WGU using the three-step process is approximately 1.3 – 2.3 months.

Iran does not currently have an adequate near 20 percent LEU stockpile to pursue the two-step process and it is not considered in the first scenario.

Scenario 2: Breakout with all installed centrifuges at Natanz and Fordow

With all the installed centrifuges at Natanz and Fordow as of August 2013, Iran could continuously produce one SQ of WGU in 5.4 – 6.8 months without inventory using the four-step enrichment process. By utilizing its LEU stockpile as of August, Iran could reduce this time to 1.7 – 2.3 months in a dash for one SQ.[12]

[12] An additional calculation is made for Scenario 2 to include the effect of the 1,000 installed IR-2m centrifuges by adding an equivalent number of IR-1 centrifuges (3,000 and 5,000) to the number of installed IR-1 centrifuges. By using the four-step process and LEU stockpiles, Iran could produce 1 SQ in 1.4 – 2.2 months assuming the IR-2m performs at 3 SWU/year or 1.4 – 1.9 months assuming 5 SWU/year. By using the three-step process and LEU stockpiles, this time can be reduced to 0.9 – 1.4 months for both separative power values.

Using the three-step process with all installed centrifuges, Iran could produce one SQ of WGU in 1.0 – 1.6 months before exhausting its stock of near 20 percent LEU. If Iran chose to employ the three-step process without using its near 20 percent stockpile, it could produce one SQ of WGU in 1.9 – 2.2 months. Iran currently has enough 3.5 percent inventory to produce approximately 4 SQs using this method.

Again, Iran does not currently have enough near 20 percent LEU to pursue the two-step enrichment process. However, Iran may be able to increase its inventory in the near future. Table 1 summarizes the breakout time to one SQ of WGU for several assumed near 20 percent LEU inventories. As can be seen, Iran can break out with less than 250 kg of near 20 percent LEU hexafluoride, the figure typically mentioned as sufficient. However, the breakout times increase and the risk of failure may also increase.

Table 1: Predicted breakout times for the two-step process with future infrastructure

Available 19.75% Inventory [kgUF6]	Breakout Time [months]
205	1.0 – 1.2
215	0.8 – 1.2
225	0.7 – 0.9
250	0.7 – 0.8
275	0.7 – 0.8
300	0.6 – 0.8
350	0.6 – 0.8

Table 1: The predicted breakout times for the two-step process using all installed centrifuges are based on assumed values of available 19.75 percent LEU inventory.

Scenario 3: Covert Facility of IR-2m Centrifuges Optimized for WGU Production

Table 2 shows the estimated enriching times for the clandestine optimized cascade to produce WGU from natural uranium, 3.5 percent LEU feed, and near 20 percent LEU feed. In this scenario, Iran would not require additional setup time because the cascade is already designed to produce WGU. To produce one SQ the fastest, Iran could devote all of its IR-2m centrifuges to the 19.75 percent to 90 percent enrichment process. However, this would use up most of the 19.75 percent inventory unless Iran were using Natanz and Fordow to replenish the stockpile. The 3.5 percent to 90 percent enrichment process can be used to obtain roughly eight SQs without replenishment. ISIS estimates that, using a covert enrichment plant that was optimized for WGU production, Iran would require 0.25 – 4.25 months to produce one SQ of WGU assuming a separative power of 3 SWU/yr and 0.15 – 2.55 months assuming 5 SWU/yr.

Table 2: WGU Optimized Covert Facility

	0.7% to 90%		3.5% to 90%		19.75% to 90%	
IR-2m Separative Power	3 SWU	5 SWU	3 SWU	5 SWU	3 SWU	5 SWU
Enriching Time (month)	4.25	2.55	1.22	0.73	0.25	0.15
Inventory Used (kgUF6)	-	-	803	803	132	132

Table 2: Predicted enriching time for a cascade of 3,000 IR-2m centrifuges that is optimized to produce WGU from natural uranium, a 3.5 percent stockpile, and a near 20 percent stockpile.

Scenario 4: Covert Facility of IR-2m Centrifuges Using Multi-Step Breakout Procedure

Scenario 4A: Assumed Separative Power – 3 SWU/yr
At a potential covert site with 3,000 IR-2m centrifuges operating at 3 SWU/yr, Iran could produce one SQ of WGU in 10.4 – 11.3 months continuously using the four-step breakout procedure without using its existing stockpile. By using its LEU inventory, Iran could make a quick dash and produce one SQ in 2.3 – 2.6 months using the four-step breakout method.

By employing the three-step process, Iran could produce one SQ in 1.8 – 2.3 months before using up its near 20 percent LEU stockpile. Without using its 20 percent stockpile, Iran could produce 1 SQ in 3.3 – 4.5 months with enough 3.5 percent inventory for approximately 4 SQs.

Table 3 summarizes the two-step process with varying, assumed available near 20 percent inventory.

Table 3: Covert plant with IR-2m operating at 3 SWU/yr

Available 19.75% Inventory [kgUF6]	Breakout Time [months]
205	1.6 – 2.3
215	1.1 – 1.7
225	1.0 – 1.6
250	0.9 – 1.4
275	0.8 – 1.3
300	0.8 – 1.3
350	0.8 – 1.2

Table 3: The predicted breakout times for the two-step process at a covert IR-2m enrichment plant assuming a separative power of 3 SWU/yr. The breakout time is a function of the available 19.75 percent inventory.

Scenario 4B: Assumed Separative Power – 5 SWU/yr

At a potential covert site with 3,000 IR-2m centrifuges operating at 5 SWU/yr, Iran could produce one SQ of WGU in 6.4 – 7.0 months continuously utilizing the four-step breakout procedure without using its existing stockpile. By using its LEU inventory, Iran could make a quick dash and produce one SQ in 1.6 – 1.8 months using the four-step breakout method.

By employing the three-step process, Iran could produce one SQ in 1.3 – 1.6 months before using up its near 20 percent LEU stockpile. Without using its 20 percent stockpile, Iran could produce 1 SQ in 2.2 – 3.1 months with enough 3.5 percent inventory for approximately 4 SQs.

Table 4 summarizes the two-step process with varying, assumed available 19.75 percent inventory.

Table 4: Covert plant with IR-2m operating at 5 SWU/yr

Available 19.75% Inventory [kgUF6]	Breakout Time [months]
205	1.1 – 1.6
215	0.8 – 1.2
225	0.8 – 1.1
250	0.7 – 1.0
275	0.7 – 1.0
300	0.7 – 1.0
350	0.7 – 0.9

Table 4: The predicted breakout times for the two-step process at a covert IR-2m enrichment plant assuming a separative power of 5 SWU/yr. The breakout time is a function of the available 19.75 percent inventory.

Summary of Major Results and Implications for Negotiations

Table 5 lists the major estimated breakout times of the four scenarios considered above. Today, Iran could break out most quickly using a three-step process with its installed centrifuges and its LEU stockpiles as of August 2013. In this case, Iran could produce one SQ in as little as approximately 1.0–1.6 months, if it uses all of the near 20 percent LEU hexafluoride stockpile. Using only 3.5 percent LEU, Iran would need at least 1.9 to 2.2 months and could make approximately 4 SQs of WGU using all of its existing 3.5 percent LEU stockpile.

A covert plant offers Iran additional options for cascade configuration and relatively fast breakout times, where the calculations utilize LEU stocks as of August 2013. The estimates vary based on cascade configuration and the actual separative capacity of the IR-2m centrifuge. In the ideal scenario with optimized cascade structure and very good centrifuge performance, it is possible that Iran could use a covert plant to break out in as little as approximately one to two weeks. However, it's more likely that Iran would require more time and the covert plant would have a less optimal cascade arrangement. In that case, breakout times would increase. With LEU inventory as of August 2013, Iran could breakout in as little as 1.3-2.6 months in a covert plant with a more realistic cascade organization. In the case where only a stock of 3.5 percent LEU is used, Iran could break out in as little as 2.2-4.5 months. These times would be relatively long in the case of a breakout at declared centrifuge plants, where detection would be relatively prompt and where the enrichment would occur at a known location. However, when the enrichment is carried out at a secret location, these breakout times offer less assurance. Even though the IAEA would detect the diversion of the safeguarded LEU, the location of the enrichment site would be unknown, severely complicating any response aimed at stopping further enrichment.

If Iran had a stock of about 250 kg of near 20 percent LEU hexafluoride, breakout times are significantly shorter in the two step process than in the three step arrangement. However, when the stock of near 20 percent LEU hexafluoride falls to about 205 kg, then the three step process with the use of the LEU inventory is about the same as the two step process with 205 kg of near 20 percent LEU hexafluoride.

The shortening breakout times have implications for any negotiation with Iran. An essential finding is that they are currently too short and shortening further, based on the current trend of centrifuge deployments. As a result, the current negotiations should result in:

- lengthening the breakout times,
- shortening the time to detect breakout, and
- gaining assurance that a secret centrifuge plant is unlikely to be built or finished.

Increased transparency. There are several additional transparency measures that are important, although a discussion of these measures is outside the scope of this report. But two points are worth mentioning. The first is that transparency measures by themselves have inherent limits and cannot address fully the risk posed by short breakout times.[13] Nonetheless, Iran should be pressed to increase the frequency of inspections at enrichment plants, install remote camera monitoring at enrichment plants, implement early notification of the construction of nuclear plants[14], ratify the Additional Protocol, and establish full inspections of its centrifuge research, development, and manufacturing complex.

Lengthening breakout. A negotiation should be guided by the need to lengthen breakout times significantly from their current values. A reasonable minimum breakout time should be six months or preferably longer. If breakout took greater than or equal to six months, the IAEA could clearly detect it long before one SQ is produced, and the international community would have time to marshal a response to stop Iran producing enough WGU for a nuclear weapon.

The process of lengthening breakout times involves several variables. The key ones are the number of centrifuges, the stocks of LEU, the enrichment level of the LEU, and the type of centrifuges installed. In practical terms, a six month breakout at declared sites could be achieved several ways.

[13] *Critical Capability*, ISIS Report, op. cit. http://isis-online.org/isis-reports/detail/critical-capability/8 ;

[14] More formally implement modified code 3.1. of the Subsidiary Arrangements to Iran's Comprehensive Safeguards Agreement.

Based on the estimates in this report, four cases are evaluated that result in a breakout time of at least six months.

1) The near 20 percent LEU hexafluoride stock is frozen at an August 2013 level and no further near 20 percent is produced. Any amount of near 20 percent LEU hexafluoride in excess of the August level is blended down to 3.5 percent LEU hexafluoride or shipped out of the country. All existing near 20 percent LEU oxide is shipped out of the country or irradiated in the Tehran Research Reactor (TRR), since this stock could be reconverted into hexafluoride form well within six months and used in a breakout. No IR-2m centrifuges are involved in enriching uranium. And stocks of 3.5 percent LEU are not affected. In this case, extrapolating one of the subcases of Scenario 2, namely the three-step process with the use of all installed IR-1 centrifuges and all near 20 percent LEU hexafluoride inventory, a six month breakout limit would necessitate Iran having no more than 3,000-5,000 centrifuges at Natanz and Fordow.

2) Iran no longer has near 20 percent LEU. In this case, Iran would need to blend down or ship out of the country all its stock of near 20 percent LEU, other than what is irradiated in the TRR. In addition, only IR-1 centrifuges would be enriching uranium. Extrapolating Scenario 2, in this case the three-step process with all installed IR-1 centrifuges and only a 3.5 percent LEU stock, a six month breakout limit would necessitate Iran having no more than 5,800 to 6,800 IR-1 centrifuges.

3) There is no inventory of LEU in Iran. In this case, Iran would need to blend down or ship out all its stocks of 3.5 percent and near 20 percent stocks of LEU, leaving in Iran only those stocks irradiated in the TRR. Any new 3.5 LEU produced would need to be rapidly blended down or shipped out of Iran. In addition, no IR-2m centrifuges are involved in enriching uranium. Extrapolating Scenario 2, namely the four-step process with all installed centrifuges, a six month breakout limit would require Iran having no more than 16,600 to 20,900 IR-1 centrifuges. However, this case is not realistic in a centrifuge plant with so many centrifuges. There would be expected to be several product tanks in the plant that would receive 3.5 percent LEU from the cascades. And these product tanks would be expected to hold at least one tonne of 3.5 percent LEU hexafluoride.

4) One tonne of 3.5 percent LEU hexafluoride in the centrifuge plant and no near 20 percent LEU. The other conditions include no IR-2m centrifuges deployed and rapid blend down of the LEU or shipment of the LEU out of the country. In this case, breakout using the four-step process and all installed IR-1 centrifuges as of August 2013 would take an estimated 2.5 to 3.0 months.[15] Extrapolating this calculation, a six month breakout would require Iran having no more than 7,700-9,200 IR-1 centrifuges.

These cases show that limiting the numbers of centrifuges and eliminating the near 20 percent LEU stock are the most important goals if breakout times are to be lengthened significantly. One major implication is that Iran should not have more than about 9,000 IR-1 centrifuges and considerably fewer IR-1 centrifuges if Iran keeps a stock of near 20 percent LEU whether in the form of hexafluoride or unirradiated uranium oxide.

[15] In this case, the four-step process is used, since there is not enough 3.5 percent LEU to produce one SQ of WGU. Above an inventory of about 1.5 tonnes of 3.5 percent LEU, then case 2 applies.

If Iran substitutes IR-2m centrifuges for IR-1 centrifuges, then the equivalent limits would be roughly one fifth to one third smaller. So, a limit of 9,000 IR-1 centrifuges would be equivalent to 1,800-3,000 IR-2m centrifuges. However, a more effective goal is to seek a halt to the deployment and use of IR-2m centrifuges in Iran.

Reducing chances of a covert centrifuge plant. Increasing the probability that there are not additional, covert enrichment plants cannot be achieved solely by increasing transparency, such as ratifying the Additional Protocol, despite its critical value. More important is an Iranian commitment to confine its enrichment activities to Natanz, halt further centrifuge manufacturing except to replace broken ones or build new ones for declared, agreed-upon centrifuge expansions at Natanz needed to produce LEU for near-term insertion in a reactor, halt the development and deployment of advanced centrifuges, and commit not to conduct illicit nuclear smuggling to obtain centrifuge-related goods.

All of these steps are achievable and reasonable if Iran is committed to convincing the world that its nuclear program is indeed peaceful.

Table 5 Estimated Minimal Breakout Times, in months, as of August 2013

Scenario 1: Breakout with only enriching centrifuges at Natanz and Fordow

Four step	
Without use of LEU inventory	9.0-9.6
With use of LEU inventory	2.3-3.2
Three step	1.3-2.3
Two step	n.a.

Scenario 2: Breakout with all installed centrifuges at Natanz and Fordow

Four step	
Without use of LEU inventory	5.4-6.8
With use of LEU inventory	1.7-2.3
Three step	
With use of both 3.5% and near 20%	1.0-1.6
With use of 3.5% LEU and no 20% LEU	1.9-2.2
Two step (not enough near 20 percent as of August but close)	
If 205kg near 20% LEU hexafluoride	1.0 – 1.2
If 250 kg near 20% LEU hexafluoride	0.7 – 0.8

Scenario 3: Covert Facility of IR-2m Centrifuges Optimized for WGU Production with Separative power of 3-5 SWU/yr

From 0.7% to 90%	2.55-4.25
From 3.5% to 90%	0.73-1.22
From 19.75% to 90%	0.15-0.25

Scenario 4: Covert Facility of IR-2m Centrifuges Using More Realistic, Multi-Step Cascade Setup and Separative Power of 3-5 SWU/yr

Four step	
Without use of LEU inventory	6.4-11.3
With use of LEU inventory	1.6-2.6
Three step	
With use of both 3.5% and near 20%	1.3-2.3
With use of 3.5% LEU and no 20% LEU	2.2-4.5
Two step	
With 250 kg near 20% LEU hexafluoride	0.7-1.4
With 205 kg near 20% LEU hexafluoride	1.1-2.3