Maintaining at Least a Six-Month Breakout Timeline: Further Reducing Iran's near 20 percent Stock of LEU

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Under the interim steps implemented in the Joint Plan of Action (JPA), Iran agreed to dilute half of its stock of near 20 percent low enriched uranium (LEU) hexafluoride to below 5 percent enriched uranium and to convert the remaining half into near 20 percent LEU oxide. After the interim period, Iran is projected to have no near 20 percent LEU in the form of hexafluoride. However, Iran will possess a stock of near 20 percent LEU in the form of oxide that is enough for a nuclear weapon, taken here as 25 kilograms of weapon-grade uranium (WGU), if the near 20 percent LEU oxide is reconverted to the fluoride form and further enriched to weapon-grade level (90 percent U235).

Iran's stock of near 20 percent LEU in the oxide form needs to be significantly reduced in any long-term comprehensive solution under the JPA. The goal should be a domestic stock no larger than the *equivalent* of less than 100 kilograms of near 20 percent LEU hexafluoride, or about 65 kilograms of near 20 percent LEU (uranium mass), in the form of oxide.[1] Near 20 percent LEU irradiated in a reactor would be exempted from this limit. This limit is derived based on limiting Iran's nuclear program so that Iran would need 6-12 months to breakout and produce enough weapon-grade uranium for a nuclear weapon.[2]

The justification for at least a six month breakout time is based on having sufficient warning time to allow an international response if Iran reneges on the agreement and breaks out. The time must be sufficient to respond in time to stop Iran well before it finishes making sufficient weapon-grade uranium for a nuclear weapon. If breakout times were less than six months, the success of such a response would be in serious doubt. That would mean that only unilateral military options would likely stop Iran before it had produced enough material for a bomb. Although such options are currently threatened as part of a U.S. policy to prevent Iran from gaining nuclear weapons, such a policy is neither sustainable nor preferable in a long-term solution.

The authority to strike militarily could be encoded in U.S. legislation or a U.N. Security Council resolution as part of the process of implementing a comprehensive solution. However, future U.S.

[1] We use two different units as is customary in this discussion. The first, the hex form, is the mass of both the uranium and the fluorine, namely UF_6. The second, the oxide form, is given as the mass of only the uranium in oxide forms, partly to reflect the presence of more than one oxide form.

[2] ISIS, *Defining Iranian Nuclear Programs in a Comprehensive Solution under the Joint Plan of Action*, ISIS Report, January 15, 2014. http://www.isis-online.org/uploads/isis-reports/documents/Elements_of_a_Comprehensive_Solution_20Jan2014_1.pdf

Presidents may be reluctant to pursue this option unilaterally. Therefore, avoiding this option is important, which requires limits to Iran's nuclear programs that provide sufficient warning time to organize an international approach in case Iran reneges on the deal and breaks out.

LEU Oxide

The conversion of LEU hexafluoride to oxide makes near 20 percent LEU suitable for further refining into fuel elements and assemblies for the Tehran Research Reactor (TRR). Moreover, LEU in oxide form cannot be enriched in gas centrifuges since it is not a gas. This conversion is thus important and a significant confidence building measure during the interim period, a timeframe during which Iran maintains over 19,000 centrifuges. With this many centrifuges, breakout to enough weapon-grade uranium for a nuclear weapon, or 25 kilograms of WGU, would occur before Iran would have time to reconvert the near 20 percent LEU oxide back into hexafluoride form, an action we estimate to take several months. Thus, with so many centrifuges available, conversion into oxide actually serves to lengthen breakout times in the interim period from at least 1.0-1.6 months to at least 1.9-2.2 months by the end of the interim period.[3]

But the value of converting the near 20 percent LEU into oxide decreases as breakout times lengthen. Since conversion to LEU oxide is reversible; it does not prevent Iran from re-converting the LEU oxide to hexafluoride form for further enrichment. Although Iran would be expected to commit in a comprehensive solution not to build any conversion lines to reconvert the near 20 percent LEU oxide into hexafluoride form, it could build such a capability relatively rapidly if it reneged on its commitment not to do so. We estimate that Iran could build a reconversion line and start producing LEU hexafluoride in several months at most. Iranian officials have stated that Iran is capable of reconverting this stock into a fluorine form although they have not provided an estimate of the time needed to do so. In the case of longer breakout times, this LEU oxide stock, if reconverted to hexafluoride, would reduce the time needed for Iran to breakout, namely to further enrich this LEU to the level of weapon-grade in sufficient quantity for a bomb.

Iran could break out and divert the near 20 percent LEU from safeguards and enrich it up to weapon-grade at a declared, or possibly even a covert, centrifuge plant, substantially decreasing the time it needs to produce one weapon's worth of weapons-grade uranium. In one scenario, Iran could remove this near 20 percent LEU oxide stock from safeguards, which would of course be detected by the IAEA, and reconvert it while it breaks out starting with 3.5 percent LEU hexafluoride, which it is expected to continue producing under a comprehensive solution. In this scenario, Iran would break out, diverting and further enriching 3.5 percent LEU and then starting to also use near 20 percent LEU as it is reconverted back into hexafluoride form. Another scenario involves Iran reconverting this near 20 percent LEU stock under safeguards after building a reconversion line. Such a step would be a clear violation of the comprehensive solution but not Iran's safeguards agreement, even the Additional Protocol. Iran may calculate that the violation would not undo the deal. By itself, such a violation would likely not be sufficient to trigger the re-imposition of economic sanctions or other actions able to stop the reconversion. Once the material is reconverted, Iran could then break out. This scenario would lead to a shorter breakout time than the first scenario.

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[3] Patrick Migliorini, David Albright, Houston Wood, and Christina Walrond*, Iranian Breakout Estimates, Updated September 2013*, ISIS Report, October 24, 2013.

To preserve at least a six-month breakout time, a comprehensive solution needs to reduce Iran's stock of near 20 percent LEU oxide. The near 20 percent LEU stockpile can be significantly reduced via blending down to below five percent enriched, irradiating it in a reactor, or shipping it overseas. Of the three options, significant irradiation in the relatively small Tehran Research Reactor looks to be the option least likely to substantially and permanently reduce this stock. However, it will take years to irradiate even the equivalent of 100 kilograms of near 20 percent LEU hexafluoride. More down blending and shipment overseas pending use in a reactor remain viable.

Size of Near 20 Percent LEU Stock

As of November 2013, Iran had approximately 195.3 kg near 20 percent LEU hexafluoride, according to the IAEA.[4] Iran had also fed a total of 213.5 kg of 19.75 percent enriched uranium hexafluoride (or about 144 kg of near 20 percent LEU (uranium mass)) into the process lines at Esfahan and produced U_3O_8 containing about 88.4 kg of enriched uranium (uranium mass). The IAEA verified 28.7 kilograms of near 20 percent LEU (uranium mass) in liquid or solid scrap form. Thus, an estimated 26.9 kg of near 20 percent LEU (uranium mass) remained held up in the process or in different forms, as of this date.

Since November, Iran has produced more near 20 percent LEU hexafluoride and may have converted more into oxide form. The upcoming IAEA safeguards report should clarify these values. Ignoring what Iran has produced or converted since early November 2013, 97.7 kg near 20 percent LEU hexafluoride is slated for conversion into oxide under the interim deal. That translates to about 65 kg near 20 percent LEU oxide (uranium mass).

In total, again ignoring production and conversion since November, at the end of the interim period Iran is expected to possess 209 kg of near 20 percent LEU (uranium mass) in various forms, although mostly in oxide form. This amount is the equivalent of approximately 310 kg near 20 percent LEU hexafluoride. Some of this LEU is in scrap and may not be readily convertible into hexafluoride form. Some has been irradiated in the TRR and is unlikely to be recovered easily. But these amounts will be only a small percentage of the total LEU. Moreover, Iran would be expected to reduce the amount in scrap, increasing the amount available for reconversion. Over the next several years, the TRR, which is a small reactor, is expected to irradiate less than the equivalent of 50 kilograms of near 20 percent LEU hexafluoride. Thus, well over half of the LEU fed into the process lines at Esfahan will likely be stored in oxide form with no imminent use in a reactor. Based on a consideration of Iran's processing of the LEU into oxide, we estimate that Iran's reconvertable stock of near 20 percent LEU at above the equivalent of 200 kilograms of near 20 percent LEU hexafluoride, is enough to substantially reduce breakout times when combined with the use of 3.5 percent LEU.

Acceptable Stock in a Comprehensive Solution

To reduce breakout times and build a more stable, verifiable comprehensive solution, a priority is achieving not only a reduction in the number of centrifuges but also of the total near 20 percent LEU stock. ISIS recommends a stock of no more than the equivalent of 100 kg of near 20 percent LEU

[4] IAEA Director General, *Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran,* GOV/2013/56, November 14, 2013. http://isis-online.org/uploads/isis-reports/documents/IAEA_Iran_Safeguards_Report_14Nov2013.pdf

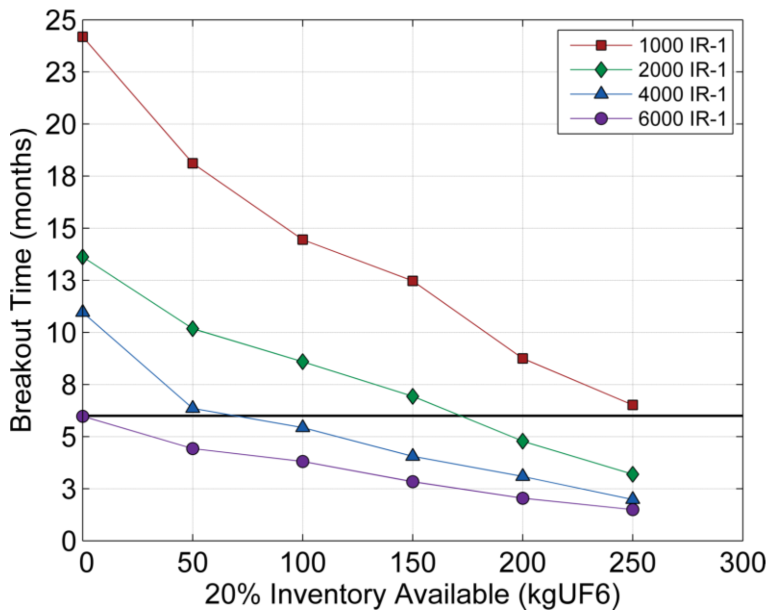
hexafluoride in the converted oxide form. This recommendation is derived from a consideration of the time Iran would need to break out using its IR-1 centrifuges with the goal of preserving at least a six month breakout timeline in declared centrifuges.

Translated into the total number of IR-1 centrifuges, a six-month breakout would equate to about 5,500-6,000 IR-1 centrifuges if no near 20 percent LEU were used in the breakout. However, with near 20 percent LEU available in a breakout, that number of centrifuges would achieve a breakout in less than six months, even when including set-up times. If Iran first converts its stock of 100 kg of near 20 percent LEU hexafluoride before starting a breakout, it could subsequently use 5,500 IR-1 centrifuges to breakout, using both the 3.5 percent and near 20 percent LEU, in 3.2 to 4.7 months, where set-up time is included.[5] In the scenario where Iran breaks out and simultaneously moves to build a new conversion line to reconvert the near 20 percent LEU oxide, it could produce enough weapon-grade uranium in about 4.75 months.[6] The breakout estimate in the latter scenario falls at the upper bound of the range of breakout estimates for the first scenario. However, careful preparation can shorten the estimate of 4.75 months in the second scenario. Thus, in the following calculations, we model the first scenario.

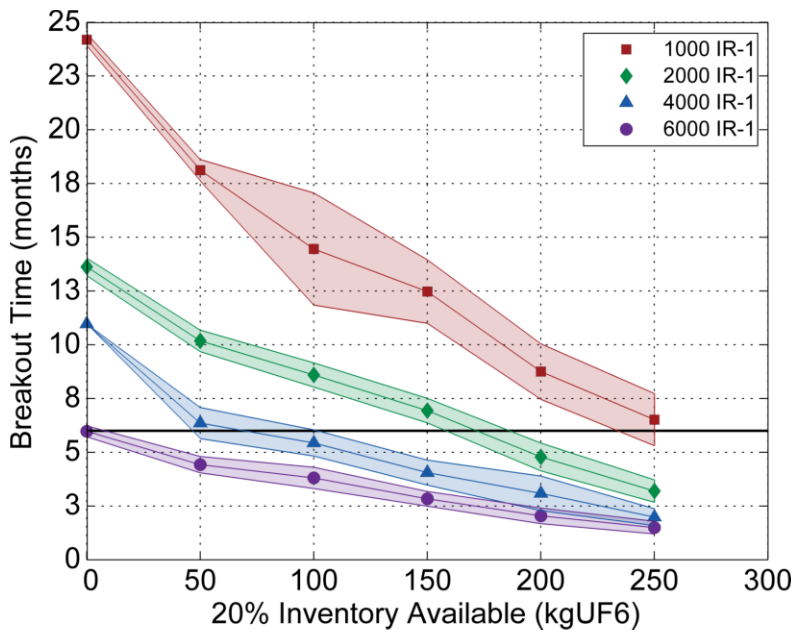
Figure 1 shows the predicted enrichment times, including a two week set-up time, for a three step breakout process using 1,000, 2,000, 4,000, and 6,000 IR-1 centrifuges with varying amounts of near 20 percent LEU hexafluoride and sufficient 3.5 percent LEU inventories.[7] Figure 1(a) shows the mean predicted breakout estimates and Figure 1(b) includes the mean estimate and uncertainty in that estimate. Based on these plots, the predicted enrichment time is roughly a linear function of the available 20 percent inventory.[8] For example, if Iran maintains a near 20 percent oxide stock equivalent to 200 kilograms of near 20 percent LEU hexafluoride, and it has 6,000 IR-1 centrifuges, it could break out in less than three months.

To preserve a six month breakout, several choices are possible. Selecting 4,000 IR-1 centrifuges and less than 100 kg of near 20 percent LEU hexafluoride preserves a six month breakout period. If the number of centrifuges is reduced further, e.g. to 2,000 IR-1 centrifuges, then a larger stock of almost 150 kg could be tolerated. On the other hand, if the number of IR-1 centrifuges is 6,000, then a six month breakout period cannot be assured, if Iran has almost any amount of near 20 percent LEU.

[5] Two weeks is included in this estimate, which is a time period that Iran would require to switch over production to weapon-grade uranium, commonly called a set-up time.
[6] *Defining Iranian Nuclear Programs in a Comprehensive Solution under the Joint Plan of Action*, op. cit.
[7] The methodology for these estimates is explained in Patrick Migliorini, David Albright, Houston Wood, and Christina Walrond*, Iranian Breakout Estimates, Updated September 2013*, ISIS Report, October 24, 2013; P. J. Migliorini, H. G. Wood. "A Study of Multicomponent Streams in Off-Design Centrifuge Cascades." Separation Science and Technology, 47(1), 921-928, 2012; W. C. Witt, P. J. Migliorini, D. Albright, H. G. Wood. "Modeling Iran's Tandem Cascade Configuration for Uranium Enrichment by Gas Centrifuge." Proceedings of the 54th Annual Meeting of the International Nuclear Materials Management, Palm Desert, CA, USA, July 14-18, 2013; H. G.Wood, P. J. Migliorini. "Fixed Plant Proliferation Analysis of Iran's Natanz Plant." Proceedings of the 53rd Annual Meeting of the International Nuclear Materials Management, Orlando, FL, USA, July 15-19, 2012.
[8] It should be noted that for larger quantities of near 20 percent LEU the graph may not be linear and would most likely approach an asymptotic value, as these inventories exceed the amount needed for producing 25 kg of WGU.



(a)



(b)

Figure 1: Breakout estimates showing (a) mean breakout time (b) mean breakout time with one standard deviation range. The mean and standard deviation are obtained by removing outliers, which are scenarios which are judged as unrealistic. Included in the breakout times is a two weeks set-up time. Solid line marks six month breakout.

Note: For the 1000 IR-1 centrifuges case, to produce a converged solution, many different configurations were considered (by changing the number of centrifuges per cascade in Steps 3 and 4). The results for the other cases only include 173 IR-1 cascades in all steps.