Institute for Science and International Security

ISIS Report

Update on Iran's Total Near 20 Percent Enriched Uranium Stock: Nearly Enough for a Bomb, if Further Enriched[1]

By David Albright, Patrick Migliorini, Christina Walrond, and Houston Wood

March 11, 2014

New data in the February 20, 2014 International Atomic Energy Agency (IAEA) safeguards report allow for a more accurate determination of Iran's total stock of near 20 percent low enriched uranium (LEU).[2] In particular, this information allows the portion of that stock that will endure well into the future, which will be in oxide form, to be better quantified. Iran has importantly committed to stop making more near 20 percent LEU and eliminate its stock of near 20 percent LEU hexafluoride, the form readily usable to further enrich to weapon-grade in a breakout, by equal parts dilution into less than five percent LEU and conversion into oxide forms. In the short-run, this commitment is beneficial, but the step of converting the LEU material into oxide is reversible. Iran can accomplish this reconversion in a straightforward manner using its existing technology and facilities. Although Iran's commitment to undertake this conversion into oxide is important in the short-run, in the long run, the size of the total stock matters just as much. In the future, Iran could reconvert its LEU stock back into hexafluoride form and further enrich it in a breakout to nuclear weapons. Thus, limiting the total size of the near 20 percent LEU stock is also important in negotiating a final nuclear arrangement with Iran.

At the end of the six-month interim period of the Joint Plan of Action (JPA), Iran will have about 235 kilograms (kg) of near 20 percent LEU oxide. If it were reconverted into hexafluoride form, this would total about 350 kg of near 20 percent LEU hexafluoride, the chemical form used in gas centrifuge enrichment plants. Of this total stock, at least 135-170 kg of near 20 percent LEU oxide will be relatively easy to convert back to the hexafluoride form for further enrichment at the end of the interim period and for many years afterwards. This amount, if reconverted, would

[1] This report provides new information on the size of the near 20 percent enriched uranium stock based on recent IAEA reporting and discusses this new information using the results and content of an earlier report by David Albright, Patrick Migliorini, Christina Walrond, and Houston Wood, *Maintaining a Six-Month Breakout Timeline in Iran*, ISIS Report, February 17, 2014. http://isis-online.org/uploads/isis-reports/documents/20_pct_stock_cap_17Feb2014-final.pdf The reader is referred to this report for more detailed discussion of breakout calculations involving the near 20% enriched uranium stock and a more extensive discussion of the importance of reducing the size of the near 20 percent enriched uranium stock.

[2] Director General, International Atomic Energy Agency, *Implementation of the NPT Safeguards Agreement in the Islamic Republic of Iran*, GOV/2014/10, February 20, 2014, http://isis-online.org/uploads/isis-reports/documents/iaea-iranreport-02202014.pdf.

result in about 200-250 kg of near 20 percent hexafluoride, nearly the amount, if further enriched, to yield enough weapon-grade uranium for a nuclear weapon.

Since reconversion to the hexafluoride form is straightforward, the size of this LEU stock could dramatically shorten in a long-term arrangement the time Iran would need to breakout, or produce enough weapon-grade uranium (WGU) for a nuclear weapon. Thus, a comprehensive, long term arrangement under the Joint Plan of Action should reduce the size of this stock significantly to no more than the equivalent of 100 kg of near 20 percent LEU hexafluoride, or about 70 kg of near 20 percent LEU oxide. With this reduced stock of near 20 percent LEU, a cap of 4,000 IR-1 centrifuges would result in a breakout time that exceeds six months, which ISIS assesses is a minimum breakout time for an acceptable long-term arrangement.[3]

Background

Under the interim steps implemented in the Joint Plan of Action Iran agreed to dilute half of its stock of near 20 percent low enriched uranium hexafluoride to below five 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.

The conversion of LEU hexafluoride to oxide is a significant confidence building measure during the interim period of the JPA, 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,[4] at ninety percent uranium 235, would occur before Iran would have time to reconvert the near 20 percent LEU oxide back into hexafluoride form, an action estimated to take several months. Thus, with so many centrifuges available, conversion into oxide actually serves to lengthen breakout times in the interim period.[5]

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—in several months, if it reneged on its commitment not 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 break out, namely to further enrich this LEU to weapon-grade in sufficient quantity for a bomb, even with reduced numbers of centrifuges.[6]

Stock of Near 20 Percent LEU

[3] Ibid; and also see figure 2 on p. 7 below.
[4] Twenty five kilograms of WGU is mass of only the enriched uranium; it is equivalent to 37 kg of WGU hexafluoride. It should be noted that other sources use 25 kg of uranium 235 in ninety percent enriched uranium as the WGU definition. This would translate to 27.8 kg of WGU in terms of uranium mass.
[5] Patrick Migliorini, David Albright, Houston Wood, and Christina Walrond, *Iranian Breakout Estimates, Updated September 2013*, ISIS Report, October 24, 2013.
[6] For a discussion of relevant breakout scenarios, see *Maintaining a Six-Month Breakout Timeline in Iran*, op. cit.

As of February 2014, according to the IAEA report, Iran had approximately 161 kg near 20 percent LEU hexafluoride and had ceased enriching to this level as of January 20, 2014. Iran had also blended down under the terms of the JPA about 22.9 kg near 20 percent LEU hexafluoride into less than five percent LEU hexafluoride as of early February 2014. In addition, Iran had fed a total of 262.7 kg of 19.75 percent enriched uranium hexafluoride (or about 175 kg of near 20 percent LEU (uranium mass)) into the process lines at Esfahan and produced U_3O_8 containing about 120.6 kg of enriched uranium (uranium mass)[7] This amount of U_3O_8 in terms of uranium mass is *equivalent* to about 180 kg of near 20 percent LEU hexafluoride.

Table 1 lists the total production of near 20 percent LEU hexafluoride and its fate, namely the amount stored, fed into the uranium conversion facility at Esfahan, and downblended to less than five percent LEU.

Table 1: February 2014 Inventory and Fate of UF_6 Enriched up to 20 Percent LEU (hexafluoride mass)

Produced at FFEP and PFEP	447.8 kg
Fed into conversion process at Esfahan	262.7 kg
Downblended	24.5 kg*
Stored as uranium hexafluoride (UF_6)	160.6 kg

***** The figure includes 1.6 kg that was previously downblended and the downblended amount as of February 9.

Source: IAEA February 20, 2014 safeguards report

Under the interim deal, Iran agreed to convert half of its stockpile of 19.75 percent LEU hexafluoride into oxide. Based on the data from the November 2013 and February 2014 IAEA safeguards reports, ISIS estimates that approximately 95 kg of near 20 percent LEU hexafluoride is slated in total for conversion into oxide under the interim deal.[8] That translates to about 63 kg of near 20 percent LEU oxide (uranium mass). As stated above, Iran had downblended about 22.9 kilograms near 20 percent LEU hexafluoride under the JPA as of February 9, 2014. About one month later, as of March 3, 2014, Iran had "reached the half-way mark" in the process of diluting the agreed upon proportion of this inventory.[9] However, the IAEA did not release the amount downblended as of March 3. But using the data in the IAEA report, Iran is estimated to blend down another 72 kilograms from February 9, 2014 to the end of the JPA's interim period. It is also estimated to feed another 89 kg of near 20 percent LEU hexafluoride into the conversion process at Esfahan during this period.

---

[7] We routinely 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. In addition, sometimes the amount in oxide form is converted to the amount in hexafluoride form to ease comparisons.

[8] Based on available data, we could not determine the precise size of the stockpile to be split between conversion and downblending. The number used in the text represents a midpoint between the estimated amount of material slated for downblending based on the November 2013 stockpile (approximately 98 kg) and the lowest possible level of this earmarked stockpile represented by the February 2014 report (approximately 92 kg).

[9] *Introductory Statement to Board of Governors by IAEA Director General Yukiya Amano*, IAEA Board of Governors, Vienna, Austria, March 3, 2014. http://www.iaea.org/newscenter/statements/2014/amsp2014n04.html

In total, by the end of the interim period Iran is expected to have fed into the conversion line about 351 kg of near 20 percent LEU hexafluoride, containing about 235 kg of enriched uranium (uranium mass) (see table 2).[10] Almost all of this near 20 percent LEU is relatively easily reconvertable to the hexafluoride form.

Table 2: Inventory and Fate of UF_6 Enriched up to 20 Percent LEU at End of Six Month Interim Arrangement under JPA (hexafluoride mass)

Produced at FFEP and PFEP	447.8 kg
Fed into conversion process	351 kg*
Downblended	96.6 kg**
Stored as UF_6	~0 kg***

* Estimated.
** Estimated. This figure includes 1.6 kg that was downblended prior to the JPA implementation.
*** Small quantities may remain in pipes or tanks.
Source: IAEA February 20, 2014 safeguards report and see text.

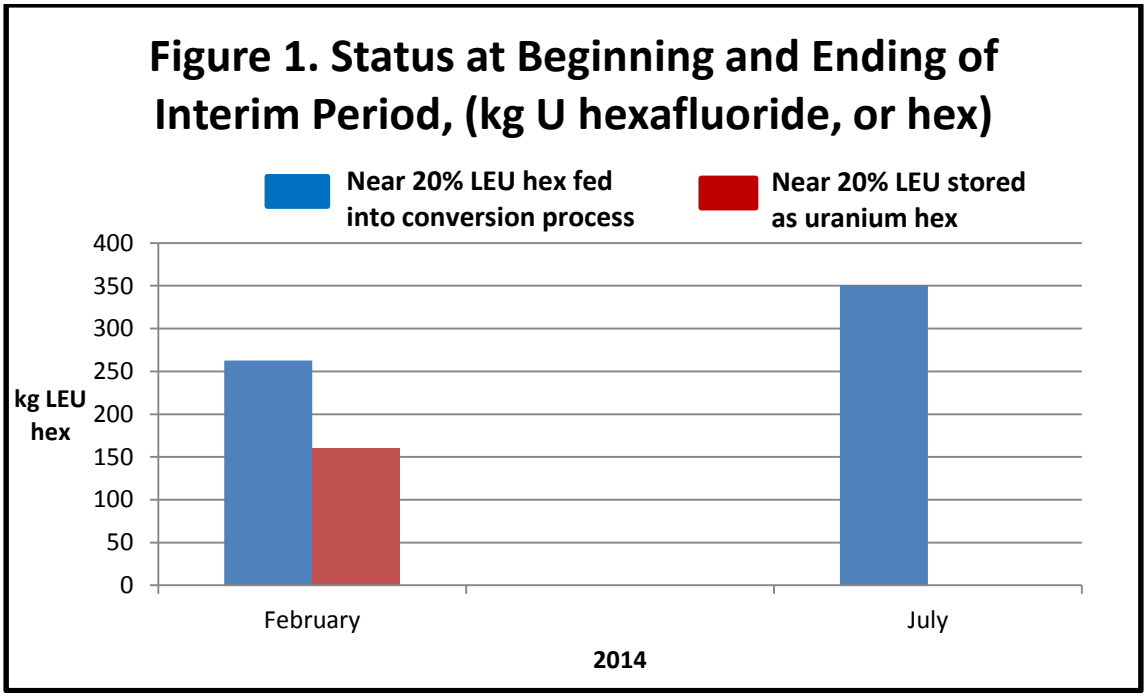


Figure 1 illustrates the inventories of near 20 percent LEU uranium hexafluoride at the beginning of the initial six month period and at the end of this period (It is based on tables 1 and 2). The

[10] This number is slightly higher than an earlier ISIS estimate made in November 2013, which assumed that a smaller amount of near 20 percent enriched uranium would be converted into oxide form. In fact, between that November report and the beginning of the implementation of the Joint Plan of Action on January 20, 2014, Iran converted approximately 49 kg of near 20-percent enriched uranium hexafluoride. An advantage of doing more conversion is that it allows Iran to retain a larger stock of near 20 percent LEU and blend down less to below five percent.

red bar represents the inventory of the near 20 percent LEU hexafluoride stored at the Natanz and Fordow enrichment plants and most readily available to be further enriched. As can be seen, under the interim deal, Iran has agreed to reduce this stock to zero by the end of the six month period, and it represents a major accomplishment of the JPA. To accomplish this goal, another 72 kg of this inventory will be blended down into less than five percent LEU and about 89 kg will be sent to the Esfahan facility and fed into the conversion process, where it will be chemically converted from hexafluoride to oxide form. The blue bars represent the total amount fed into the conversion process at the start and end of the interim period. The bar on the left gives the amount of near 20 percent LEU hexafluoride that had been fed into the uranium conversion facility by February 2014 and the one on the left provides the amount by July 2014. Once the latter is completed, about 350 kg would have been fed into the conversion process. This figure illustrates that while one chemical form of LEU is being reduced to zero the other chemical form will increase.

Less Easily Reconvertable Stocks

As a result of processing the LEU in the uranium conversion facility, a fraction of it does not end up as U_3O_8. Or when the U_3O_8 is further processed, not all of it ends up in a final product. This is normal in industrial processes, where in this case, some of the LEU becomes liquid or solid scrap or is held up in-process in the conversion facility. LEU in scrap would not be as easily reconvertable into hexafluoride form. Material in-process would also be less reconvertable.

The February 2014 report provides a snapshot of these forms. The IAEA stated that it had verified 36.8 kilograms of near 20 percent LEU (uranium mass) in liquid or solid scrap form. The amount of LEU held up in-process or in other unspecified forms can be estimated from the available information, resulting in an estimated 17.6 kilograms of near 20 percent LEU (uranium mass) held up in the process or in different forms.[11]

Another difficult to recover LEU material is that which has been irradiated in the Tehran Research Reactor (TRR). Once irradiated, the LEU fuel poses a radiation risk and would need to be separated in heavily-shielded facilities, a difficult and time consuming process. By February 2014, Iran had irradiated 11 kilograms of near 20 percent LEU (uranium mass) in the TRR.

For comparison purposes, these values are converted into their equivalent hexafluoride mass form, although it should be remembered that the LEU in oxide or other chemical forms is not in fact in hexafluoride form and would need to be reconverted prior to further enrichment. The result is that the equivalent of almost 56 kilograms of near 20 percent LEU hexafluoride were in scrap form, almost 27 kilograms in-process or in other forms, and about 17 kilograms irradiated. The total *equivalent* amount is about 100 kilograms of near 20 percent LEU hexafluoride.

Iran's Enduring Stock of Near 20 Percent LEU

[11] This value is derived by subtracting the amount in scrap and in the form U_3O_8 from the amount fed into the conversion process.

During the six-month interim period, as Iran feeds a total of about 89 kg of near 20 percent LEU hexafluoride into the conversion process, about 70 kg of this amount would be expected to end up as U_3O_8 and the rest in scrap based on current overall conversion efficiencies. There may be some addition to the amount in-process but this value is not expected to change significantly. Thus, Iran would be expected to have produced by the end of the interim period the equivalent of about 250 kg of near 20 percent LEU hexafluoride in the form of U_3O_8. This form would be straightforward to reconvert into hexafluoride form.

Iran has historically had a low yield rate in its conversion process, resulting in a relatively large amount of near 20 percent LEU scrap. But this scrap has significant value, and Iran would be expected to recover much of this material for conversion into usable U_3O_8. It would also be expected to reduce the amount of LEU in the conversion process lines to near zero after it finishes processing the near 20 percent LEU into U_3O_8. Although some of this LEU will remain in scrap or in-process and may not end up being readily convertible into hexafluoride form, most of the LEU in scrap and in-process is expected to be recovered and add to the total LEU amount reconvertable to hexafluoride form. The total amount of recovered LEU is estimated to be the *equivalent* of up to almost 65 kilograms of near 20 percent LEU hexafluoride, or 43 kg in uranium mass units.[12]

However, Iran will continue to irradiate more near 20 percent LEU oxide in the Tehran Research Reactor (TRR) as Iran continues to fuel this research reactor. Thus, Iran would be unlikely to be able to draw upon its entire estimated stock of converted LEU oxide, as mentioned above irradiated LEU is much more difficult to recover than the unirradiated U_3O_8 for further enrichment. Over the next several years, however, the TRR, which is a small reactor, is expected to irradiate less than the equivalent of tens of kilograms of near 20 percent LEU hexafluoride and much less than that by the end of the interim period.

Yet, based on these considerations, at the end of the interim period and lasting for many years, Iran's more easily reconvertable stock is likely to exceed 135-170 kg of near 20 percent LEU oxide, or the *equivalent* of at least 200-250 kilograms of near 20 percent LEU hexafluoride. This estimate assumes during this same period that up to the equivalent of about 100-150 kg of near 20 percent LEU hexafluoride would be irradiated or remain in scrap or be in-process. This material could also be reconverted into hexafluoride form but with greater difficulty and time commitment.

This quantity of more easily reconvertable material is at the often cited threshold of approximately 240-250 kilograms of near 20 percent LEU hexafluoride needed by itself to produce 25 kilograms of weapon-grade uranium, if reconverted to hexafluoride form and further enriched to weapon-grade (90 percent uranium 235). Thus, Iran's standing stockpile of near 20 percent low uranium oxide is enough to substantially reduce breakout times. The length of time Iran would need to break out and produce this amount of WGU would depend on the number of centrifuges it retains. But breakout times would be considerably reduced, if Iran retains such a

[12] The maximum value assumes that about 70 percent of the LEU in the scrap will be recovered and about 50 percent of the in-process inventory. This estimate also states that 23.5 kgU are not recovered, which is equivalent to about 35 kg LEU hexafluoride.

stock and reconverts it. Figure 2 shows that if Iran retained 4,000-6,000 centrifuges, it could break out in two to three months using this amount of near 20 percent LEU.[13]

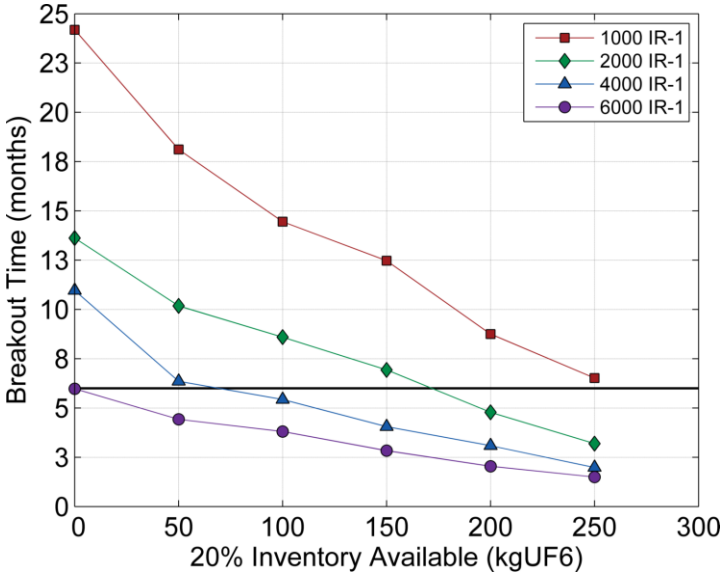
To maintain a six month or longer breakout time, Iran's stock of near 20 percent LEU in the oxide form should be significantly reduced in any long-term comprehensive solution under the JPA. As discussed in other ISIS reports,[14] a fundamental goal is constraining Iran's nuclear program so that it would need 6-12 months to produce enough weapon-grade uranium for a nuclear weapon. The result recommended by ISIS is that Iran should have a domestic stock no larger, and possibly significantly less, than the *equivalent* of 100 kilograms of near 20 percent LEU hexafluoride, or about 65 kilograms of near 20 percent LEU (uranium mass) in the form of oxide, where Iran retains no more than 4,000 IR-1 centrifuges (see figure 2). (Near 20 percent LEU irradiated in a reactor would be exempted from this limit.) The excess near 20 percent LEU stockpile can be blended down to below five percent LEU or shipped overseas, returning only if a need to fuel a reactor is verifiably demonstrated.

In this derivation, the actual amount of retained near 20 percent LEU depends on the number of centrifuges accepted in a final, comprehensive deal. If other choices are made, then the values would change. If Iran retained fewer than 4,000 IR-1 centrifuges, for example, a larger stock of near 20 percent LEU could be accepted.[15]

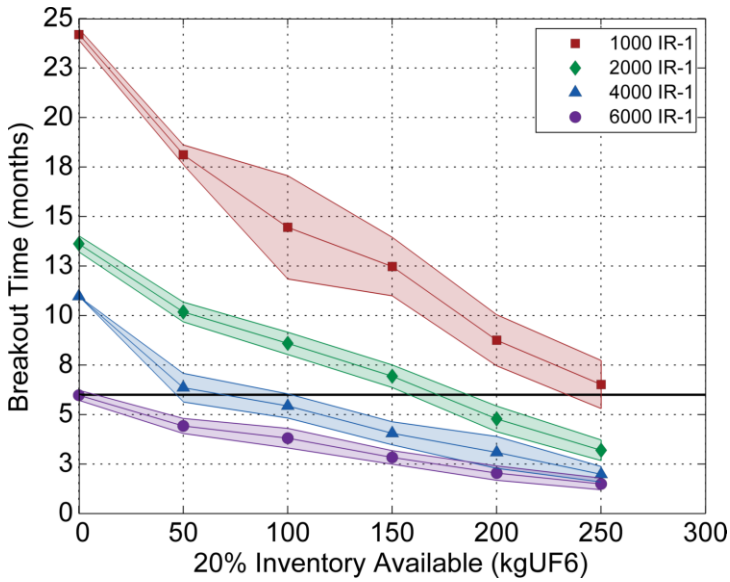
[13] These estimates also require a certain amount of 3.5 percent LEU, and thus it is assumed that Iran has sufficient amounts of this LEU as well.

[14] Institute for Science and International Security, *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 and *Maintaining a Six-Month Breakout Timeline in Iran*, op. cit.

[15] Again, sufficient stocks of 3.5 percent LEU are assumed.



(a)



(b)

Figure 2: Breakout estimates showing (a) mean breakout time (b) mean breakout time with one standard deviation range. Included in the breakout times is a two weeks set-up time. Solid line marks six month breakout. The estimates also involve using 3.5 percent LEU to supplement, when needed, the stock of near 20 percent LEU in order to ensure that 25 kg of WGU are produced. In practical terms, these estimates assume that Iran retains sufficient stocks of 3.5 percent LEU. Since Iran is expected to continue producing 3.5 percent LEU in a long term arrangement, this assumption is reasonable.

Source: David Albright, Patrick Migliorini, Christina Walrond, and Houston Wood, *Maintaining a Six-Month Breakout Timeline in Iran*, ISIS Report, February 17, 2014. http://isis-online.org/uploads/isis-reports/documents/20_pct_stock_cap_17Feb2014-final.pdf