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Iran's Uranium Enrichment Program Making Strides but Still At Least Six Months From Being Able to Produce Enough HEU for a Nuclear Weapon

In July 2015 an agreement, known as the Joint Comprehensive Plan of Action (JCPOA), was reached between Iran and the E3/EU+3[2] to temporarily restrict Iran's nuclear program. These restrictions focused mainly on Iran's centrifuge enrichment program and its construction of a heavy water moderated, natural uranium fueled reactor which would produce significant amounts of plutonium. In May 2018 the United States withdrew from this agreement. Iran initially continued to abide by the terms of the JCPOA but in May 2019 said that it would no longer be bound by the agreement. In July 2019 it began to operate its centrifuge enrichment facilities beyond the limits of the JCPOA and has taken further steps through January 2020 to expand its centrifuge uranium enrichment program.

On March 3, 2020 the International Atomic Energy Agency (IAEA) published its latest safeguards update on Iran's nuclear program.[3] This update gives a clear view of the current state of Iran's centrifuge uranium enrichment program. Iran has increased its level of uranium enrichment from 3.67% to 4.5%, has begun to use experimental cascades of advanced centrifuges to produce enriched uranium and has started producing enriched uranium from the six cascades at the formerly clandestine site of Fordow. These steps have led some to claim that Iran is now in a position to be able to produce enough Highly Enriched Uranium (HEU) to manufacture a nuclear weapon whenever it wants.[4] Fortunately, this is not the case.

Iran has expanded its centrifuge enrichment capacity so that it could produce a weapon's worth of HEU in just two to two and a half months *provided that it has a large enough stockpile of 4.5% enriched uranium* to use as feed. (See Appendix) However, at present it does not. At its current rate of production of 4.5% enriched uranium, Iran will not have a sufficiently large stockpile until January 2021. Iran could shorten this time by installing additional centrifuges but it has not yet started to do so. Given the time needed to install and start operating these additional centrifuges, Iran could not produce a large enough stockpile of 4.5% enriched uranium for at least six months.

The issue of whether Iran is in a position to immediately produce sufficient HEU for a nuclear weapon has an impact on the overall U.S. policy to try to prevent Iran from acquiring nuclear weapons. The incorrect belief that Iran is already able to produce enough HEU for a nuclear

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[2] These are China, Russia, the United States, France, Germany and the United Kingdom.

[3] "Verification and monitoring in the Islamic Republic of Iran in light of United Nations Security Council resolution 2231 (2015)," GOV/2020/5, International Atomic Energy Agency, March 3, 2020. https://www.iaea.org/sites/default/files/20/03/gov2020-5.pdf

[4] David E. Sanger and William J. Broad, "Iran Crosses a Key Threshold: It Again Has Sufficient Fuel for a Bomb," *New York Times*, March 3, 2020.

weapon could lead to the erroneous conclusion that the current U.S. policy of maximum pressure to get Iran to give up its centrifuge enrichment program has failed and that the U.S. should return to upholding the JCPOA. However, since this is not the case, there are at least another six months for the maximum pressure policy to work. Further, since Iran is unlikely to actually produce the HEU immediately even when it does have enough 4.5% enriched uranium, there are probably a number of years remaining for the maximum pressure policy to achieve its goal.

Moreover, events of the last few years have shown additional problems with the JCPOA, decreasing the desirability of the U.S. returning to compliance with this agreement. Some had hoped during the JCPOA negotiations that the 15 year term of the JCPOA would provide a sufficient interval for the Iranian government to moderate its behavior, and eventually it might give up its nuclear weapon ambitions. If anything, the current Iranian government is more hardline now than it was in 2015 and has shown no qualms about slaughtering its own citizens to remain in power.

Nor was the JCPOA the restraint on Iran's centrifuge enrichment program that many had hoped. The almost immediate increase in the enrichment level of its centrifuges from 3.67% to 4.5% and the rapid restart of its enrichment at Fordow shows that Iran was not only maintaining but improving its enrichment capabilities even while nominally abiding by the terms of the JCPOA.

A further problem with the JCPOA is the way it dealt with Iran's past illicit nuclear activities. It is well-known that before 2004 Iran had a full-fledged nuclear weapon program which it has implausibly continued to deny. In the overwhelming desire to sign the JCPOA, the United States did not require Iran to end its stonewalling of the IAEA about its past nuclear weapon program as a condition for the agreement. Indeed, in September 2015 the IAEA was instructed to complete its investigations into Iran's nuclear weapon program by December 2015 regardless of whether Iran came clean.[5] Iran continued its stonewalling for another three months and the IAEA was required to give Iran a pass so as to not stand in the way of the JCPOA.

In April 2018, Israel revealed that it had acquired roughly 20% of the documents in a large archive in Iran containing detailed information on Iran's pre-2004 nuclear weapon program. These documents showed that Iran had progressed further than was previously thought. The continued preservation of this archive would significantly shorten any time required for Iran to build and deploy a nuclear weapon and is another indicator that Iran has not given up its desire for nuclear weapons.

The matter of Iran's past activities continues to be relevant today. In the summer of 2019, the IAEA invoked its authority under the Additional Protocol of Iran's IAEA safeguards agreement to ask Iran if it had failed to declare past nuclear activities at three locations in Iran.[6] Iran appeared to be trying to "sanitize" part of one such location. Iran initially did not respond to the IAEA's questions, but in January 2020 Iran said, "…the Islamic Republic of Iran will not

[5] "Road-map for the Clarification of Past and Present Outstanding Issues regarding Iran's Nuclear Programme," GOV/2015/59, International Atomic Energy Agency, September 21, 2015, p. 3. https://www.iaea.org/sites/default/files/gov-2015-59.pdf

[6] "NPT Safeguards Agreement with the Islamic Republic of Iran," GOV/2020/15, International Atomic Energy Agency, March 3, 2020. https://isis-online.org/uploads/iaea-reports/documents/IAEA_Iran_NPT_March_2020_report.pdf

recognize any allegation on past activities and does not consider itself obliged to respond to such allegations."[7] Iran appears to believe that in 2015 it was granted a pass on all past illicit nuclear activities and feels free to flout its IAEA safeguards obligations today.

These events only reinforce the view that the JCPOA was simply an attempt to delay when Iran would acquire nuclear weapons and make the problem of Iranian nuclear weapons the concern of some other administration. By taking the pressure of sanctions off Iran, the JCPOA would help ensure that Iran would have the resources to quickly acquire nuclear weapons once the agreement began to lapse. Further, this time is drawing ever closer as over four years of the agreement have already passed. Under the terms of the JCPOA some restrictions on Iran's centrifuge enrichment program would lapse in less than four years from today and all restrictions on the number and types of centrifuges at the FEP in less than six years.

In contrast, the current U.S. program of maximum pressure appears to be the only chance to prevent an Iranian nuclear weapon in the long-term. Whether this policy will succeed is unclear but it has already imposed serious costs on Iran. The recent sharp decline in oil prices will only further increase this pressure. Even if this effort fails, by making Iran's nuclear program very costly it will discourage other countries from wanting to follow in Iran's footsteps.

Further, it will probably be many years after Iran does attain the capability to produce a weapon's worth of HEU before it actually constructs and deploys nuclear weapons. Iran will want to build up the number of weapons it can make before taking such a step. The economic costs imposed by the maximum pressure policy could well slow the speed with which Iran could deploy a nuclear arsenal. Therefore, any delay in Iran's acquiring nuclear weapons that might occur by returning to the JCPOA will be slight compared to continuing the policy of maximum pressure. Only this latter policy has a realistic hope for permanently ending Iran's nuclear weapons effort and should be maintained.

[7] *Ibid.*, p. 2.

Appendix

Detailed Analysis of the IAEA March 3, 2020 Safeguards Report and Methods Whereby Iran Could Produce HEU for Nuclear Weapons

Iran has three sites where it has installed centrifuges that can enrich uranium. Iran's main site is the Fuel Enrichment Plant (FEP) at Natanz. Under the terms of the JCPOA, the FEP is limited to 5,060 IR-1 type centrifuges. Iran has another site, the Fordow Fuel Enrichment Plant (FFEP). This was originally a clandestine site designed to upgrade low enriched uranium to the HEU needed to produce nuclear weapons. Under the terms of the JCPOA this site is allowed to have 1,044 IR-1 type centrifuges but was not to conduct any uranium enrichment. Also at Natanz is the Pilot Fuel Enrichment Plant (PFEP) which is used to develop and test advanced centrifuges. Under the terms of the JCPOA this site was not to produce any enriched uranium product.

The centrifuges are organized into cascades. Iran's standard cascade contains either 164 or 174 IR-1 centrifuges. Such a cascade could process natural uranium into uranium enriched to about 3.5%, while producing tails of 0.40% enrichment.

In response to the United States' withdrawal from the JCPOA in May 2018, Iran initially continued to comply with the terms of the JCPOA but in July 2019 Iran began to enrich beyond the terms of the JCPOA. Iran's first step, on July 8, 2019, was to begin producing 4.5% enriched uranium at the FEP though the JCPOA limited Iran to an enrichment level no higher than 3.67%.[8] Iran has not added any additional centrifuges to its standard cascade design. Rather, it appears to have somehow improved the IR-1's performance to achieve this higher degree of enrichment. Assuming that a similar improvement was carried out to the stripping section of the cascade, then Iran's standard cascade now produces 4.5% enriched uranium from natural uranium while producing tails with 0.31% enrichment.

Iran's second step, in September 2019, was to start to reconfigure the piping and install additional centrifuges at the PFEP. Since that time this site has been accumulating enriched uranium product. Lines 2 and 3 at the PFEP consist of a number of relatively small cascades which can only produce uranium enriched to no more than 2%. However, lines 4, 5 and 6, which consist of a cascade of 164 IR-4 centrifuges, a cascade of 164 IR-2m centrifuges and a cascade of 72 IR-6 centrifuges respectively, can produce uranium enriched up to 4.5%.[9]

Iran's third step, on November 6, 2019, was to transfer a cylinder of natural uranium hexafluoride from the FEP to the FFEP and by November 9, two of the six cascades at the FFEP had started producing uranium enriched up to 4.5%. On November 25 two more cascades at the FFEP started operation and on January 22, 2020, the last two cascades began operation.

[8] "Verification and monitoring in the Islamic Republic of Iran in light of United Nations Security Council resolution 2231 (2015)," GOV/INF/2019/9, International Atomic Energy Agency, July 8, 2019. https://www.iaea.org/sites/default/files/19/07/govinf2019-9.pdf

[9] Line 1 at the PFEP is not operational.

The latest IAEA safeguards update[10] allows the calculation of the current state of Iran's enrichment capacity and how close it is to being able to produce sufficient HEU to manufacture a nuclear weapon. As of February 19, 2020, Iran's enriched uranium stockpile consisted of 996.5 kg in the form of uranium hexafluoride. Of this, 268.5 kg was uranium that was enriched only up to 2%. This enriched uranium was produced in lines 2 and 3 at the PFEP. A further 214.6 kg enriched up to 3.67% is the enriched uranium that Iran was permitted to have under the terms of the JCPOA.

Between July 2019 and January 2020, the FEP, FFEP and lines 4, 5 and 6 at the PFEP started producing uranium enriched up to 4.5%, and this enriched uranium will be the focus of my analysis. As of February 19, 2020, Iran possessed 537.8 kg of uranium enriched up to 4.5%, of which 408.6 kg were produced since November 3, 2019.[11] Assuming that all of this uranium is enriched to 4.5% and the enrichment tails are 0.31%, then the enrichment capacity between November 3, 2019 and February 19, 2020 was about 2,500 SWU, which gives an annual rate of 8,460 SWU. The 4.5% enriched uranium was produced at the rate of 3.78 kg per day.

During this time interval, the FFEP averaged four cascades (696 centrifuges) in operation. As mentioned, the last two cascades at the FFEP came on line in the latter part of January. Assuming that each of the IR-1 centrifuges in these two cascades produces 1 SWU per centrifuge-year, then Iran's total enrichment capacity has been increased to 8,810 SWU per year and the rate of production of 4.5% enriched uranium to 3.94 kg per day.

A major concern regarding centrifuge enrichment plants, including those in Iran, is that even if they are configured to produce only low enriched uranium, they can easily be used to produce HEU using a batch recycling process.[12] In the case of Iran, the 4.5% enriched uranium product would be sent through the plant three more times. In the first step, the enrichment would be increased to 23.7%, the second step to 67.1% and the third step to 93.1%.[13] Only minor modifications to the centrifuge plant are needed to carry out this process. An example of how Iran could do this is shown in Table 1. As can be seen, starting with 1,845 kilograms of 4.5% enriched uranium, Iran could produce 20 kilograms of 93.1% enriched uranium, which is a sufficient quantity to produce a nuclear weapon.

Iran's cascades are designed to produce 4.5% enriched uranium from natural uranium feed. Such a cascade is tapered improperly to operate optimally at higher enrichments. If the taper cannot be changed, then, given Iran's current enrichment capacity, it would take 77 days (about 2.5 months) to produce a weapon's worth of HEU. If the uranium hexafluoride gas flow can be adjusted so that the centrifuge plant can operate optimally, then it would only take 59 days

[10] "Verification and monitoring in the Islamic Republic of Iran in light of United Nations Security Council resolution 2231 (2015)," GOV/2020/5, International Atomic Energy Agency, March 3, 2020. https://www.iaea.org/sites/default/files/20/03/gov2020-5.pdf

[11] As compared to the prior IAEA safeguard update: "Verification and monitoring in the Islamic Republic of Iran in light of United Nations Security Council resolution 2231 (2015), GOV/2019/55, International Atomic Energy Agency, November 11, 2019. https://www.iaea.org/sites/default/files/19/11/gov2019-55.pdf

[12] "Safeguards Training Course: Nuclear Material Safeguards for Enrichment Plants, Part 4. Gas Centrifuge Enrichment Plant: Diversion Scenarios and IAEA Safeguards Activities," K/ITP--156/P4/R1, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee, October 1988, p.178. https://www.osti.gov/servlets/purl/5567442

[13] The tails for these three steps are 2.0%, 11.8% and 46.9% respectively.

(about 2.0 months) to produce a weapon's worth of HEU. Either way the time required is fairly short.

The real limiter on Iran being able to produce a weapon's worth of HEU is its stockpile of 4.5% enriched uranium. The process would require 1,845 kilograms of 4.5% enriched uranium, but as of February 19, 2020, Iran only had 537.8 kilograms. At its current rate producing 3.94 kilograms of 4.5% enriched uranium per day, it would take Iran around 11 months from mid-February (that is, January 2021) to produce enough enriched uranium. Iran could shorten this time by deploying more centrifuges, but thus far it has not done so. At any rate, it would take some months to get these new centrifuges running, and then they would have to operate for a number of months to produce sufficient 4.5% enriched uranium. Therefore, Iran is at least six months away from being able to produce sufficient HEU for a nuclear weapon.

Table 1

Time, Product and Feed Requirements for Iran to Produce of 20 kg of HEU by Batch Recycling (Current Enrichment Capacity 8,810 SWU per year)

Cycle	Product Enrichment and Quantity	Feed Enrichment and Quantity	Time for Cycle (Days)
First	23.7% 212.6 kg	4.5% 1,845 kg	46 to 54*
Second	67.1% 45.7 kg	23.7% 212.6 kg*	6 to 12
Third	93.1% 20 kg	67.1% 45.7 kg	1 to 5
Total			59 to 77**

* The range depends on whether Iran can adjust the taper of the cascade to operate optimally at high enrichments. See discussion in the text.
**Includes six days to account for equilibrium and cascade fill time.

If Iran has built a clandestine enrichment plant (as it already did once at Fordow) optimally designed to produce HEU from 4.5% enriched uranium, then it already has enough low enriched uranium to produce 20 kilograms of HEU. Such a clandestine plant would require only 488 kilograms of 4.5% enriched uranium as feed, less than the 538 kilograms Iran already possesses.[14] However, it would take 1,000 SWU to produce the 20 kilograms of HEU. If the clandestine plant had an enrichment capacity of 1,000 SWU per year, then it would take one year before the HEU was produced. The diversion of Iran's 4.5% enriched uranium stockpile to this plant would be discovered long before then. Even if the clandestine plant had a capacity of 4,000 SWU per year, it would still take three months to produce the HEU and again the diversion of the 4.5% enriched uranium would be discovered before the HEU could be produced. Further, it is unlikely that Iran could build such a large clandestine plant without it being discovered, as this capacity is almost half of Iran's currently known enrichment capacity.

[14] Product enrichment 93.1%, tails enrichment 0.711%, i.e. the level of natural uranium.

If Iran had a clandestine enrichment plant designed to enrich natural uranium to HEU, it would not be necessary to divert any 4.5% enriched uranium. However, then it would require about 4,000 SWU to produce 20 kilograms of HEU.[15] Even a 4,000 SWU per year clandestine plant would require a year to produce 20 kilograms of HEU and a more plausible 1,000 SWU per year clandestine plant would require four years. Therefore, regardless of whether Iran uses 4.5% enriched uranium or natural uranium as the feed, a clandestine plant does not appear to be a plausible means for Iran to quickly produce HEU for a nuclear weapon.

[15] Product enrichment 93.1%, tails 0.3%.