INSTITUTE FOR SCIENCE AND INTERNATIONAL SECURITY

REPORT

Analysis of IAEA Iran Verification and Monitoring Report - March 2022

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This report summarizes and assesses information in the International Atomic Energy Agency's (IAEA) quarterly safeguards report for March 3, 2022, *Verification and monitoring in the Islamic Republic of Iran in light of United Nations Security Council resolution 2231 (2015)*, including Iran's compliance with the Joint Comprehensive Plan of Action (JCPOA).

The IAEA's latest report details Iran's rapidly advancing nuclear activities and inspectors' diminished ability to detect Iranian diversion of assets to undeclared facilities.

Highlights and Breakout Estimate

- Due to the growth of Iran's 20 and 60 percent enriched uranium stocks, breakout timelines have become dangerously short, far shorter than just a few months ago. Iran now has enough 20 and 60 percent enriched uranium (in the form of uranium hexafluoride (UF_6)) to use as feed for production of enough weapon-grade uranium (WGU) (taken as 25 kilograms (kg) per weapon) for two nuclear weapons, producing the first quantity of WGU in as little as two to three weeks after breakout commences, including a set up period, and producing the second quantity by the end of that month.
- In total, Iran has enough 60, 20, and 4.5 percent enriched uranium to make sufficient WGU for four nuclear weapons. The third quantity could be produced soon after the start of the second month after breakout commences, and the fourth in somewhat less than four months. The third and fourth quantities would depend on stocks of uranium enriched between 2 and 4.5 percent and would be produced significantly more slowly than the first two quantities of WGU.
- In essence, Iran is effectively breaking out slowly by producing 60 percent enriched uranium and continuing to accumulate it. As of February 19, Iran had a stock of 33.2 kg of near 60 percent enriched uranium (in uranium mass or U mass), or 49.1 kg (in hexafluoride mass). If Iran accumulated about 40 kg of 60 percent enriched uranium (U mass), it would have enough to be able to further enrich it and quickly produce 25 kg of WGU (U mass) in just a few advanced centrifuge cascades.

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- Alternatively, 40 kg of 60 percent enriched uranium is more than enough to fashion a nuclear explosive directly, without any further enrichment, although Iran's known nuclear weapons designs use WGU.
- Iran's current production rate of 60 percent enriched uranium is 4.5 kg per month (U mass), meaning that it could accumulate its first amount of 40 kg in less than two months from now.
- Iran is learning important lessons in producing WGU and breaking out to nuclear weapons, including by experimenting with skipping typical enrichment steps as it enriches up to 60 percent uranium-235 and building and testing out equipment to feed 20 percent enriched uranium and withdraw highly enriched uranium (HEU). It is starting from a level below 5 percent LEU and enriching directly to near 60 percent in one cascade, rather than using two steps in between, a slower process entailing the intermediate production of 20 percent enriched uranium. It has used temporary feed and withdrawal set ups to produce HEU from near 20 percent enriched uranium feed. Iran is also implementing a plan to allow IR-6 cascades to switch more easily from the production of 5 percent enriched uranium to 20 percent enriched uranium. As such, Iran is experimenting with multi-step enrichment while seeking to shortcut the process.
- Iran started to produce 20 percent enriched uranium in one cascade of IR-6 centrifuges at the Fordow Fuel Enrichment Plant (FFEP) in addition to the six IR-1 cascades that were already producing 20 percent enriched uranium.
- The production rate of 20 percent enriched uranium at the FFEP increased by 50 percent from a monthly average of 13.2 kg (U mass) or 19.5 kg (hex mass), to 19.7 kg (U mass) or 29.2 kg (hex mass).
- Iran has installed a second cascade of 166 IR-6 centrifuges at the FFEP, but has not yet fed it with UF_6. The installation of advanced centrifuges at the FFEP enhances Iran's ability to break out using a declared but highly fortified facility.
- As of February 19, Iran had an IAEA-estimated stock of 182.1 kg of 20 percent enriched uranium (U mass and in the form of UF_6), an increase from the previous reporting period's 113.8 kg of 20 percent enriched uranium in UF_6 form. Iran also has an additional stock of 36.5 kg (U mass) of 20 percent uranium in other chemical forms.
- Since the previous report, Iran has not produced any uranium metal.
- At the Natanz Fuel Enrichment Plant (FEP), Iran has installed 36 cascades of IR-1 centrifuges, six cascades of IR-2m centrifuges, and two cascades of IR-4 centrifuges. Of those, 31 IR-1 cascades, six IR-2m cascades, and two IR-4 cascades were being fed with uranium.
- Iran's current, total operating enrichment capability is estimated to be about 13,400 separative work units (SWU) per year, compared to 12,400 SWU per year at the end of the last reporting period.
- While average daily production of 5 percent LEU increased at the FEP, Iran's total usable stock of below 5 percent LEU decreased compared to the previous reporting period, as the average feed rate at the FFEP increased.
- Near 5 percent LEU production during this reporting period, which spanned 104 days at the Natanz FEP, totaled 596 kg (U mass), for a daily average production rate of 5.7 kg (U mass),

a slight increase from the previous reporting period's daily average production rate of 4.9 kg (U mass). This reflects Iran's slightly increased enrichment capacity at the FEP.

- Iran's overall reported stockpile of LEU increased due to a significant increase in Iran's stock of up to 2 percent enriched uranium, much of which was produced as tails in the production of 20 percent and 60 percent enriched uranium.
- On January 24, the IAEA visited Iran's centrifuge manufacturing workshop at a new location in Esfahan, relocated from the Karaj site, and installed surveillance cameras to replace those at the Karaj site. The IAEA will not have access to Esfahan or Karaj video recordings and data, which Iran claims it will keep in its custody, until it receives relief from sanctions. The IAEA, for more than one year, has not been able to monitor Iran's production of advanced centrifuges, particularly rotors and bellows, per JCPOA monitoring provisions, and faces a difficult challenge in reconstructing events should Iran turn over these data.
- The IAEA also faces a gap in knowledge about Iran's advanced centrifuge manufacturing activities from June 2021 until January 2022, raising doubt about its ability to ascertain whether Iran may have diverted centrifuge components.
- The IAEA report does not discuss the status of Iran's construction of a new advanced centrifuge assembly facility in a tunnel near the main Natanz complex.
- The IAEA does not report whether Iran has turned over a missing recording unit and storage data from a camera that was destroyed at Karaj in June 2021.
- Combined with outstanding safeguards issues in Iran, the IAEA has a significantly reduced ability to monitor Iran's complex and growing nuclear program, which notably has unresolved nuclear weapons dimensions. The IAEA's ability to detect diversion of nuclear materials, equipment, and other capabilities to undeclared facilities remains greatly diminished.

Part 1: Enriched Uranium Stocks

At the Natanz FEP, Iran produced approximately 882.2 kg of UF_6 enriched up to 5 percent U-235 during the reporting period, which spanned 104 days from November 6, 2021 to February 18, 2022. The report discusses this amount as kilograms of UF_6 in units of UF_6 mass, which the authors refer to as hex mass. The total uranium mass would be 596 kilograms, for a monthly average production rate of 172 kg U mass and a daily production rate of 5.7 kg U mass, above the last reporting period's average production rates, which were 147 kg U mass per month, and 4.9 kg U mass per day.[2]

At the FFEP, from November 6, 2021 to February 18, 2022, Iran produced 101.2 kg of UF_6 (hex mass) enriched up to 20 percent enriched uranium, or 68.4 kg U mass. It produced 566.6 kg of UF_6 hex mass (or 383 kg U mass) of up to 2 percent enriched uranium in tails. The daily average

[2] The fact that the production values are reported in uranium hexafluoride mass can only be verified by comparing the production values to the differences in stockpile from one reporting period to the next. The differences in stockpile are consistently two-thirds of the given produced quantity, showing that the former is in uranium mass and the latter in uranium hexafluoride mass.

production rate of 20 percent enriched uranium at the FFEP increased by 50 percent during this reporting period to 0.97 kg (hex mass) or 0.65 kg (U mass). At this rate, Iran could produce 29.2 kg of near 20 percent enriched uranium per month (hex mass) or 19.7 kg (U mass). Annually, Iran could produce 355 kg (hex mass) or 240 kg (U mass).

At the PFEP, Iran produced 2 percent enriched uranium, up to 5 percent enriched uranium, and up to 60 percent enriched uranium stock during the reporting period. It did not produce any 20 percent enriched uranium at the PFEP. Between November 6, 2021 and February 18, 2022, the PFEP produced 22.9 kg hex mass of near 60 percent enriched uranium (equivalent to 15.5 kg U mass); 360.9 kg hex mass of up to 5 percent LEU (244 kg U mass); and 663.6 kg hex mass of uranium enriched up to 2 percent U-235 (448.6 kg U mass).

The 60 percent enriched uranium production rate during this reporting period was 15.5 kg (U mass) over 104 days, resulting in a daily average production rate of 0.149 kg (U mass) or a monthly average production rate of 4.5 kg (U mass), or 6.6 kg (hex mass). This rate is an increase from the previous reporting period's monthly average production rate of 3.5 kg, or an increase of about 30 percent. Annually, Iran could produce 54 kg of 60 percent enriched uranium (U mass).

Of the 2 percent LEU, Iran produced 167.3 kg hex mass (113.1 kg U mass) in PFEP lines 2, 3, and 5, and 496.3 kilograms hex mass (335.5 kg U mass) enriched up to 2 percent as tails in line 1.

Due to reduced monitoring measures, the IAEA can only verify the amount of LEU removed from the process as a product and not the amount that is still in process, but it is able to reliably estimate total amounts.

Estimates of additional amounts of LEU in oxides and intermediate products, fuel assemblies and rods, and in scrap, add up to 313.9 kg U mass, more than the amount of the previous reporting period. This increase applies mostly to the uranium oxide and intermediate estimate (124.1 kg increase) and the uranium in liquid and solid scrap (11.1 kg increase). The report specifies that out of the 313.9 kg enriched to unspecified levels (U mass), 139.7 kg are up to 5 percent LEU and 36.5 kg are up to 20 percent LEU.

Of its near 5 percent LEU stock, Iran fed 668.7 kg hex mass (or 452 kg U mass) into the cascades at Fordow, for an average feed rate of about 6.4 kg per day hex mass, or 4.3 kg U mass. It dumped 0.8 kg near 5 percent LEU feed (hex mass), or about 0.5 kg in uranium mass, representing less than one percent of the total feed. It also fed 876.5 kg of near 5 percent hex mass (592.5 kg U mass) into PFEP R&D lines 1, 4, and 6, slightly more than during the last reporting period considering the different lengths of time, for a daily average feed rate of 8.4 kg (hex mass) or 5.7 kg U mass per day compared to the previous 8.1 kg (hex mass) or 5.4 kg (U mass).

Based on this information, Iran's new stockpile of near 5 percent LEU in uranium mass should be the sum of 1622.3 kg U mass from the last reporting period, 596 kg from the FEP, and 244 kg from the PFEP, with the feed of 1044.5 kg subtracted, resulting in 1417.8 kg. Subtracting the 139.7 kg not in the form of UF_6 and adding the 0.5 kg (U mass) dumped at the FFEP, this total becomes

1278.6 kg, almost matching the 1277.9 kg U mass of near 5 percent LEU in UF_6 form that the IAEA reported.

Up until November 17, 2021, Iran fed an unspecified amount of its near 20 percent enriched uranium stock into a variety of advanced centrifuges at the PFEP. Since Iran was not accumulating enriched uranium, and was instead combining the product and tails, the levels of enriched uranium achieved are not included in the report and may also not be known to the IAEA.

The net overall enriched uranium stock, including all levels of enrichment and all chemical forms, increased by 707 kg from 2490 kg U mass to 3197 kg (see Table 1), a significant change from the two previous reporting periods, where it first decreased by 800 kg between May and August 2021, and then increased only slightly by 49 kg between August and November 2021. The near 5 percent LEU stock in the form of UF_6 decreased by 344 kg, twice as much the previous reporting period's 152.5 kg (U mass). Taking into account the 139.7 kg in different chemical forms, the overall near 5 percent LEU stockpile decreased by 204.3 kg (U mass) compared to 49.1 kg during the last reporting period. Starting during the last reporting period, Iran continued to grow its near 2 percent LEU stock, this time more dramatically by 830 kg, to 1390 kg (U mass). The near 20 percent enriched uranium stock increased by 68.3 kg, from 113.8 kg to 182.1 kg (U mass), and the near 60 percent enriched uranium stock increased by 15.5 kg to 33.2 kg (U mass). The remaining discrepancy in the overall enriched uranium stock increase is due to an increase in uranium in other chemical forms.

Iran continued to use a combination of R&D lines 1, 4, and 6 to feed 5 percent LEU into lines 4 and 6 to produce 60 percent enriched uranium, and feed those tails in line 1 to produce 5 percent LEU. During this reporting period, spanning November 6, 2021 to February 18, 2022, of the 876.5 kg (hex mass) of 5 percent LEU fed into lines 4 and 6, Iran turned 22.9 kg (2.6 percent) into 60 percent enriched uranium, 360.9 back into 5 percent enriched uranium (41 percent), and 496.3 kg (56.6 percent) remained as tails enriched up to 2 percent.

During the previous reporting period, spanning August 30, 2021 to November 5, 2021, of the 562.3 kg (hex mass) of 5 percent LEU fed into lines 4 and 6, Iran turned 11.4 kg (2 percent) into 60 percent enriched uranium, 294.5 kg back into 5 percent enriched uranium (52 percent), and 256.5 kg (46 percent) remained as tails enriched up to 2 percent. The product to feed ratio increased slightly for the 60 percent production.

Table 1. Enriched Uranium Quantities,* including less than 5 %, up to 20 %, and up to 60 % enriched uranium (all quantities in uranium mass)

Chemical Form	February 16, 2021	May 22, 2021	August 30, 2021	November 6, 2021	March 3, 2022
UF_6 (kg)	2933.1	3206.3	2372.9	2313.4	2883.2
Uranium oxides and their intermediate products (kg)	13.3	13.3	34.5	125.4	249.5
Uranium in fuel assemblies and rods (kg)	10.5	10.5	21.1	35.4	37.8
Uranium in liquid and solid scrap (kg)	10.9	10.9	12.8	15.5	26.6
Enrichment Level Subtotals					
Uranium enriched up to 5 percent (kg) but more than 2 percent	1890	1773.2	1774.8	1622.3	1277.9
Uranium enriched up to 2 percent (kg)	1025.5	1367.9	503.8	559.6	1390
Uranium enriched up to 20 percent (kg)	17.6	62.8	84.3	113.8	182.1
Uranium enriched up to 60 percent (kg)	0	2.4	10	17.7	33.2
Uranium in chemical forms other than UF_6 with unspecified enrichment level (kg) (including 139.7 kg up to 5 % LEU and 36.5 kg up to 20 % LEU)	34.7	34.7	68.4	176.3	313.9
Totals of Enriched Uranium in UF_6, <5 % (kg)	2915.5	3141.1	2278.6	2181.9	2667.9
Totals of Enriched Uranium in UF_6, including near 20 % and near 60 % (kg)	2933.1	3206.3	2372.9	2313.4	2883.2
Totals of Enriched Uranium in all chemical forms, <5 % <20 % and <60 % enriched	**2967.8**	**3241**	**2441.3**	**2489.7**	**3197.1**

*These totals do not include undisclosed stocks of enriched uranium exempted by the JCPOA Joint Commission.

Part 2: Enrichment capacity

Natanz Fuel Enrichment Plant

As of February 22, 2022, in total, 36 cascades of IR-1 centrifuges, six cascades of IR-2m centrifuges, and two cascades of IR-4 centrifuges were installed to enrich natural UF_6 up to 5 percent. At that time, 31 IR-1 cascades (up from 28 cascades at the end of the previous reporting period), six IR-2m cascades (same amount), and two IR-4 cascades (same amount) were being fed with natural UF_6. The IAEA also reported that the installation of centrifuges in the four additional IR-4 cascades and one IR-6 cascade had yet to begin.

The quantity of IR-1 centrifuges Iran withdrew from JCPOA-mandated storage is not available for this reporting period because of Iran's refusal since February 2021 to provide the IAEA with access to the data and recordings collected by IAEA equipment.

Fordow Fuel Enrichment Plant

Since January 2021, Iran has been using three sets of two interconnected IR-1 cascades, with 1044 centrifuges, to produce 20 percent enriched uranium from up to 5 percent LEU. One IR-1 centrifuge was installed for the separation of stable isotopes.

IR-6 Cascades. In the first half of 2021, Iran announced that it would install two IR-6 cascades to produce five percent feed for the tandem IR-1 cascades in the FFEP. On July 27, 2021, however, Iran informed the IAEA that it intended to make "some modifications on the configuration" of the two IR-6 cascades. The new configuration of the two IR-6 cascades will either be fed with natural UF_6 to produce UF_6 enriched up to 5 percent U-235 or with UF_6 enriched up to 5 percent U-235 to produce UF_6 enriched up to 20 percent U-235. The modification to the sub-headers of the two IR-6 cascades will enable Iran to "change the configuration of the cascades more easily." The modifications were completed on the "second cascade" by October 12, 2021. Iran also informed the IAEA at that time that the first cascade would not be modified, remaining in its original, fixed configuration.

As of November 9, 2021, Iran had installed 166 IR-6 centrifuges in the unmodified IR-6 cascade. As of February 23, 2022, Iran had installed 166 IR-6 centrifuges to the second, modified cascade, where at the end of the last reporting period, only 13 IR-6 centrifuges had been installed. This second cascade had been fully modified to allow more flexible operation.

As of February 23, 2022, Iran was enriching uranium to 20 percent in the unmodified IR-6 cascade. The modified IR-6 cascade had not yet been fed with uranium.

Pilot Fuel Enrichment Plant

Iran has not progressed further with earlier plans to transfer its enrichment research and development activities to a segregated area of Building A1000 at the FEP. Iran earlier completed

the installation of sub-headers for 18 cascades in this new area, an increase of three-fold from the six lines in the above ground PFEP. On November 8, 2021, the IAEA verified that Iran had made "very limited progress" in the installation of infrastructure for these 18 cascades since August. It reported similarly in its latest report. The report does not provide an anticipated start date for this new area. Given its three-fold greater size, one must ask if this area could be devoted to production-scale enrichment in case of a surge in enriched uranium production or a breakout.

60 Percent Enriched Uranium Production in Lines 1, 4, and 6. Iran continued to use lines 1, 4, and 6 for the production of 60 percent enriched uranium and re-enrichment of tails, principally in a variety of cascade arrangements of IR-4 and IR-6 centrifuges. Since 60 percent production started on April 17, 2021, Iran has changed the mode of production several times, several of which were described in previous IAEA reports.

On February 21, 2022, the IAEA verified that Iran was continuing to feed up to 5 percent LEU into the two cascades in lines 4 and 6, comprising up to 164 IR-4 and up to 164 IR-6 centrifuges, respectively, producing up to 60 percent enriched uranium. The tails from these two cascades were fed into the cascades of IR-5 and IR-6s centrifuges in line 1 to produce up to 5 percent enriched uranium. The assay of the tails is likely about 2-3 percent.

The IR-4 cascade in line 4 has an estimated enrichment output of about 607 SWU per year, and the IR-6 cascade in line 6 has a total estimated enrichment output of about 870 SWU per year, where the enrichment outputs of these two centrifuge types in production-scale cascades are taken from an Institute report.[3] The two lines together have an estimated output of 1477 SWU per year, or the equivalent of about 1768 IR-1 centrifuges.

Lines 2 and 3. Last year, Iran implemented a new mode of operation in line 2, feeding either 5 or near 20 percent enriched uranium into single advanced centrifuges, intermediate cascades of 10 advanced centrifuges, and intermediate cascades of 20 advanced centrifuges. During the last reporting period, only near 20 percent enriched uranium was used as feed. Although the product and tails streams were re-combined, with no product collected, the experience gained in this procedure was likely important, particularly in the production of HEU in key advanced centrifuges when using near 20 percent enriched uranium feedstock. In fact, this was the first time Iran started feeding a cascade with uranium enriched higher than 5 percent at any of its enrichment plants, possibly gaining irreversible knowledge in the set up and use of feed equipment designed for smaller quantities and higher enriched uranium levels.

In a new development, the IAEA reported that as of November 17, 2021, Iran had stopped feeding near 20 percent enriched uranium into line 2. It added that Iran had removed the associated temporary feeding and withdrawal set up, a set up likely required because of the smaller quantities of enriched uranium and concerns about criticality of HEU product. The IAEA does not

[3] David Albright, Sarah Burkhard, and Spencer Faragasso, "A Comprehensive Survey of Iran's Advanced Centrifuges," *Institute for Science and International Security*, December 2, 2021, https://isisonline.org/isis-reports/detail/a-comprehensive-survey-of-irans-advanced-centrifuges.

state where this set up is stored or how many such set ups exist. These set ups could be critically important in a breakout and allow for a more rapid conversion from producing LEU to producing HEU. As such, their use in line 2 represents the use of additional equipment and experience gained relevant to breakout. It is unclear if a new nuclear deal would require the destruction of this equipment or merely its storage, or alternatively, not address such equipment.

According to the IAEA, line 2 (from November 17, 2021) and line 3 (throughout the reporting period) continued to accumulate uranium enriched up to 2 percent through feeding of natural uranium hexafluoride. On February 21, 2022, the IAEA verified that Iran had been using, for this purpose, single cascades of up to: nine IR-4 centrifuges; seven IR-5 centrifuges; five IR-6 centrifuges, (two cascades of) ten IR-6 centrifuges; 19 IR-6 centrifuges; and ten IR-s centrifuges.

The following single centrifuges were being tested with natural uranium hexafluoride but not accumulating enriched uranium: three IR-2m centrifuges, two IR-4 centrifuges; three IR-5 centrifuges; five IR-6 centrifuges; one IR-6s centrifuge; one IR-7 centrifuge; one IR-8 centrifuge; one IR-8B centrifuge; and one IR-9 centrifuge.

Line 5. Iran was feeding natural uranium into an intermediate cascade of 18 IR-1 centrifuges and an intermediate cascade of 33 IR-2m centrifuges (up from 32) in line 5 to produce uranium enriched up to 2 percent U-235.

Capacity of Centrifuges Enriching Uranium

Table 2 lists the estimated enrichment capacity by facility for those centrifuges enriching, leading to a total of 13,402 SWU per year, or the equivalent of 14,891 IR-1 centrifuges. This total number is slightly higher from the previous reporting period's 12,414 SWU per year, since Iran is now enriching uranium in an additional IR-6 cascade at Fordow. The estimate includes only those cascades inspectors observed to be enriching in February 2022, instead of all the installed cascades, which would include five additional IR-1 cascades at Natanz and one additional IR-6 cascade at Fordow. Centrifuge numbers for line 1 are taken from the previous report, as they are not specified in this recent report. The total enrichment capacity used in breakout calculations is slightly different and higher in this case, since for breakout also installed but not yet enriching cascades are included. Further, the advanced centrifuges in the PFEP would likely not contribute meaningfully to the quick production of enough WGU for a nuclear explosive, starting with up to five percent or near 20 percent enriched uranium. However, see below for the case of 60 percent enriched uranium feed. Breakout scenarios and timelines are discussed below.

Table 2. Quantity of enriching centrifuges and enrichment capacity

	Quantity of centrifuges	Enrichment capacity in SWU/yr	IR-1 equivalent
Natanz	6620	9856	10951
Fordow	1210	1554	1726
Natanz PFEP*	508	1992	2214
Lines 2 & 3	See text		
Lines 1, 4, 5, & 6	See text		
Total centrifuges enriching	8338	13402	**14891**

*The values for lines 1, 2, 3, and 5 of the PFEP are rough estimates based on the use of estimated and measured values for the separative output of these centrifuges in cascades, as drawn from IAEA and Iranian information.

Practicing Breakout by Producing Highly Enriched Uranium

During this reporting period, Iran continued to produce 60 percent enriched uranium, or HEU. This level of enrichment is associated with a key step in the traditional stepwise process of climbing from natural uranium to 90 percent enriched uranium, or WGU. Although Iran stopped producing additional HEU, albeit on a limited scale, by feeding 20 percent enriched uranium into a small number of IR-4 and IR-6 centrifuges, it likely learned important information relevant to breakout through these experiments.

It is important to point out that 60 percent enriched uranium can be used directly in nuclear weapons. About 40 kg (U mass) is more than enough to make a nuclear explosive, compared to the less than 25 kg (U mass) of 90 percent enriched uranium the Institute uses as sufficient for Iran to manufacture a nuclear explosive. Iran's accumulation of 60 percent enriched uranium remains a highly provocative, dangerous step.

Moreover, the manner in which Iran has proceeded to enrich to 60 percent, starting from near 5 percent enriched material, is innovative, suggesting Iran continues to gain valuable experience in producing HEU, and by extension even WGU. It is practicing breakout under a civilian cover, and also learning to reduce the number of steps that it would need to go from natural uranium to WGU.

Although Iran's process of creating 60 percent enriched uranium is far from ideal, the Iranian process has demonstrated certain advantages over the last several months, including being within its technical reach and recycling the tails down to the level of near two percent enriched or even natural uranium, while producing 5, 20, and 60 percent enriched uranium. More importantly, it is

practicing multi-step enrichment arrangements key to breaking out. Moreover, the Iranians are experimenting with transferring enriched UF_6 as a gas from one step to the next, instead of having to solidify the intermediate product gas and turn it back into a gas in the next step. All this experimentation is leading Iran to be more capable of breaking out to produce 90 percent enriched uranium, if the leadership orders its production or moves toward the construction of nuclear weapons. Meanwhile, Iran continues to accumulate 60 percent HEU, which can be used directly in a nuclear explosive or further enriched quickly to weapon-grade in relatively few advanced centrifuges. After all, 60 percent enriched uranium is 99 percent of the way to WGU.

Target Production. According to the IAEA report, on February 25, 2022, the IAEA received an updated design information questionnaire (DIQ) for the FPFP to enable the production of mini-plates (targets) using 60 percent enriched uranium. The process declared by Iran for manufacturing targets using HEU enriched up to 60 percent is identical to that used for uranium enriched up to 20 percent U-235. On February 28, 2022, the IAEA verified that Iran had begun the conversion of HEU enriched in the form of uranium hexafluoride into UO_2F_2.

Although Iran has sent 23.3 kg of 60 percent enriched uranium (U mass) to the FPFP, it is expected that only a tiny fraction will be converted into targets. As such, the production of targets will not remove the proliferation and breakout risks posed by Iran's stockpile of HEU. This step should be viewed as a cynical attempt by Iran to place a civilian mask on an inherently military material and lay a precedent for future production of HEU.

Part 3: Current Breakout Estimates

Because of the growth of stocks of Iran's 20 and 60 percent enriched uranium, breakout timelines have become dangerously short, far shorter than just a few months ago. Iran now has enough 20 and 60 percent enriched uranium to use as feed for the production of enough WGU (taken as 25 kg per weapon) for two nuclear weapons, producing the first quantity of WGU in as little as two to three weeks after breakout commences, including a set up period and producing the second quantity by the end of that month.

Iran has enough 60, 20, and 4.5 percent enriched uranium to make sufficient WGU for four nuclear weapons. The third quantity could be produced soon after the start of the second month after breakout commences, and the fourth quantity in somewhat less than four months. The third and fourth quantities would depend on stocks of uranium enriched between 2 and 4.5 percent and would be produced significantly more slowly than the first two quantities of WGU.

The Institute's breakout calculator is used to estimate the worst-case breakout time, as in previous reports. The methodology is described in earlier Institute reports. The production of WGU from the 20 and 60 percent enriched uranium stocks can proceed in parallel, significantly reducing the timeline for production of 25 kg of WGU. As before, the total enrichment contribution from small cascades of advanced centrifuges installed at the PFEP is not included, as their use in a breakout would be complicated and likely would not contribute to reducing breakout timelines. However, one exception is that Iran's stock of 60 percent enriched uranium is taken as further enriched to

weapon-grade in the IR-6 and IR-4 production-scale cascades at the PFEP. The production of WGU in the PFEP would proceed in parallel to the further, stepwise enrichment of near 20 percent enriched uranium to WGU, here taken as involving two steps. Stocks of less than 2 percent enriched uranium are not used, since to do so would require additional modifications of the cascades to handle the lower enrichments, likely significantly slowing or contributing only slightly, rather than speeding up breakout timelines. Only enriched uranium hexafluoride stocks are used; chemical conversion of other stocks is seen as too time consuming to include in the breakout estimate.

The breakout timelines are worst-case estimates, likely representing the shortest timeline to breakout, with longer timelines possible. Uncertainties include ongoing ones, such as the exact enrichment level of the uranium stock enriched between 2 and 5 percent and operational efficiencies of the advanced centrifuges, particularly the IR-4 and IR-6 cascades.

Part 4: Centrifuge Manufacturing, Mechanical Testing, and Component Inventory

Iran has augmented centrifuge manufacturing and mechanical testing activities in violation of the JCPOA, while halting IAEA monitoring. Since February 2021, Iran has not provided declarations about its production and inventory of centrifuge rotor tubes, bellows, and rotor assemblies or allowed IAEA verification, as specified in the JCPOA. The IAEA has also "not been able to access the data and recordings collected by its surveillance equipment installed to monitor both the manufacturing of rotor tubes and bellows," and consequently has no ability to take inventory. Further developments related to Iran's production of advanced centrifuges are in Part 7.

Since January 2021, Iran has been using an existing workshop at Natanz to conduct mechanical testing of centrifuges, a location the IAEA notes was not listed in the JCPOA. This work is likely not subject to IAEA video surveillance. The IAEA reports that it has not been able to access data and recordings which monitor Iran's mechanical testing of centrifuges at the PFEP and Tehran Research Center, as provided for in the JCPOA.

Further, since February 2021, the IAEA has not been able to verify the number of IR-1 centrifuges Iran withdrew from storage or newly produced to replace broken ones withdrawn from the cascade areas in the enrichment plants. Under Iran's comprehensive safeguards agreement (CSA), the IAEA typically knows the quantity of centrifuges withdrawn from the cascade areas due to continuous surveillance of the cascade areas and the fact that broken centrifuges contain small amounts of uranium, but the quantity of centrifuges is not typically given in the reports. This quantity could be substantial during the last several months, depending on the damage caused during the April 11, 2021, event at the Natanz FEP, estimated to have damaged 15 cascades of IR-1 centrifuges and three cascades of IR-2m centrifuges, or roughly half of Iran's centrifuges operating at the FEP at the time of the incident.

Part 5: Enriched uranium metal production halted

In December 2020, Iran informed the IAEA that it would begin producing uranium metal, including uranium metal enriched up to 20 percent, in violation of its JCPOA commitments. Iran is using the uranium metal in civil applications, including for experimental fuel rods for the Tehran Research Reactor (TRR). However, Iran has no pressing need to develop this fuel or to use this material for other civilian activities, lending weight to concern that Iran is installing the wherewithal to make uranium metal to increase its nuclear weapons capabilities and is producing it as a way to practice the manufacture of enriched uranium metal components of nuclear weapons. Prior to 2003, under the Amad Plan, Iran was constructing both pilot and large-scale uranium metallurgy facilities to make nuclear cores and was practicing with surrogate materials for WGU.[4]

On February 2, 2021, Iran began producing uranium metal using natural uranium in a laboratory experiment at the Esfahan FPFP. As of August 14, 2021, the IAEA verified that Iran had begun producing enriched uranium metal from 20 percent enriched UF_6. It produced 200 grams of enriched uranium metal, starting with 257 grams of enriched uranium in tetrafluoride form. During the last reporting period, Iran stated the enriched uranium metal is for use in silicide fuel for the TRR. During that reporting period, Iran produced "two batches of uranium silicide" containing 0.43 kg of uranium enriched to 20 percent. Assuming this is in uranium mass, the uranium silicide contains twice the amount of metal that was reported previously (430 grams compared to 200 grams). On November 2, 2021, the IAEA verified that Iran had "manufactured two fuel plates using uranium silicide." At the time, the fuel plates had not yet undergone quality control.

On February 21, 2022, the IAEA verified that the installation of equipment for production of enriched uranium tetrafluoride from uranium hexafluoride at the FPFP, while almost complete, had progressed only slightly during the last reporting period.

At the nearby Uranium Conversion Facility at Esfahan, by the end of May 2021, Iran had finished installing equipment for producing depleted and natural uranium metal. It told the IAEA that the facility was ready to operate with uranium, but no nuclear material had been introduced into the production area. On February 12, 2022, the IAEA verified that no nuclear material had been introduced into the production area.

Since the previous report, Iran has produced no uranium metal. On February 28, 2022, the IAEA verified that Iran had converted the remaining 900 grams of uranium in the form of UF_4 enriched up to 20 percent, previously intended for the production of uranium metal, into U_3O_8.

[4] David Albright with Sarah Burkhard and the Good ISIS Team, *Iran's Perilous Pursuit of Nuclear Weapons* (Washington, D.C.: Institute for Science and International Security Press, 2021); David Albright, Sarah Burkhard, and Frank Pabian, "Shahid Mahallati: 'Temporary' Plant for Manufacturing Nuclear Weapon Cores," *Institute for Science and International Security*, April 8, 2020, https://isis-online.org/isis-reports/detail/shahid-mahallati-temporary-plant-for-manufacturing-nuclear-weapon-cores/8.

Part 6: Heavy water, Arak reactor, and Fuel fabrication

The IAEA reports that since February 2021, it has not been able to ascertain the status of Iran's Heavy Water Production Plant (HWPP) or the production and inventory of heavy water. Based on commercial satellite imagery, the IAEA assesses that the HWPP continued to operate during this reporting period.

The IAEA reports that Iran has not pursued construction of the Arak heavy water research reactor, now called the Khondab Heavy Water Research Reactor (KHRR), based on its original design. However, questions remain about the irreversibility of technical modifications carried out to date by Iran's partners in the JCPOA Arak reactor working group. Moreover, as of the current report, a wide range of construction activities were taking place at the reactor, including ongoing work on the construction of the "control room for the refueling machine." In addition, the IAEA reported work on the equipment airlock and that lining of the spent fuel pond with steel plates was ongoing.

Last fall, Iran began making enriched uranium fuel for the Arak reactor in violation of the JCPOA. On September 25, 2021, at the Enriched UO_2 Powder Plant (EUPP) at Esfahan, the IAEA "verified that Iran had converted 103 kg of uranium in the form of UF_6 enriched up to 3.5 % U-235, which had been transferred from Natanz, into UO_2F_2. In its previous report, the IAEA indicated that on September 18, 22, and 29, "the Agency verified that 105.0 kg of uranium in the form of UO_2F_2 had been transferred to FPFP to be converted into [ammonium uranyl carbonate] AUC and subsequently to [the Uranium Conversion Facility or] UCF for the production of uranium dioxide powder and to Fuel Manufacturing Plant (FMP) at Esfahan for the production of fuel for the Khondab Heavy Water Research Reactor (KHRR)." On November 13, the FMP received UO_2 enriched up to 4 percent to manufacture several fuel assemblies for the KHRR.

In its latest report, the IAEA writes that on November 21, 2021, it "verified the receipt at [the] EUPP from FEP of 141.1 kg of uranium in the form of UF6 enriched up to 3.5% U-235, of which 139.7 had been converted in December 2021 into UO2F2." The IAEA reports, "In December 2021, the Agency verified that 134.7 kg of uranium in the form of UO_2F_2 had been transferred to FPFP to be converted into AUC, which had subsequently been transferred to UCF for the production of UO2 powder and to FMP for the production of fuel for KHRR." On December 19, "the Agency also verified at EUPP the receipt of 143.1 kg of uranium in the form of UF_6 enriched up to 3.5% U-235 from FEP" and kept this nuclear material under agency seal. On February 21, 2022, the IAEA "verified at [the] FMP 52 kg of uranium in the form of UO_2 powder and fuel pellets enriched up to 3.5% U-235 for KHRR."

Part 7: Additional Protocol & JCPOA monitoring

This quarterly report is the fourth since Iran stopped implementing the AP to its CSA and the JCPOA's additional monitoring arrangements on February 23, 2021. Iran also stopped implementing modified Code 3.1 to the CSA.

The IAEA can no longer carry out daily visits to Iran's enrichment facilities, receive updated declarations, or conduct "complementary access" to sites. It has not "had access to data gathered by on-line enrichment monitors and electronic seals, or access to recordings registered by its installed measurement devices." It no longer receives data and recordings of test stands for conducting quality control tests of advanced centrifuge rotor assemblies, prior to their installation at Natanz and Fordow enrichment plants. It also no longer has information about Iran's production of uranium ore concentrate (UOC) or its transfer to the Esfahan facility for conversion, or about UOC obtained from any other source. Annex I to the IAEA report describes these and other reduced provisions, many of which fall under JCPOA enhanced monitoring provisions.

The IAEA also reports that it cannot verify Iran's JCPOA commitments under Sections D, E, S, and T. The Section T commitments relate to prohibited nuclear weapons development activities.

During the reporting period, the IAEA did not attend any meetings of the Procurement Working Group of the JCPOA Joint Commission, which oversees Iran's imports of nuclear-related equipment. Tehran is likely not complying with the JCPOA's procurement channel provisions, given recent evidence of illicit procurements.[5]

Status of the February 2021 Agreement

On September 12, 2021, the IAEA and Iran released a joint statement providing that the "IAEA's inspectors are permitted to service the identified equipment and replace their storage media which will be kept under the joint IAEA and AEOI seals in the Islamic Republic of Iran. The way and the timing are agreed by the two sides."[6] The IAEA reports that from September 20 to 22, the IAEA serviced surveillance and monitoring equipment and replaced storage media "at all necessary locations in Iran with the exception of the centrifuge component manufacturing workshop at the TESA Karaj complex…where the agency was not provided with access."

During a fall IAEA Board of Governors meeting, on September 27, Iran notified the IAEA for the first time that "in its view the equipment related to the workshop was not included in the 'servicing' referred to in the Joint Statement…" The Director General responded in a letter on September 29 that "the agreement reached...did not in any way exclude certain locations and equipment and that [this] had been very clear in all of the Director General's discussions" with

[5] The alleged illicit procurements occurred from 2018 to 2020, raising the possibility that Iran has not been complying all along with the JCPOA procurement channel provisions. Spencer Faragasso and Sarah Burkhard, "Iranian Illicit Procurement Scheme to Acquire Controlled Spectrometry Systems Busted," *Institute for Science and International Security*, September 14, 2021, https://isis-online.org/isis-reports/detail/iranian-illicit-procurement-scheme-to-acquire-controlled-spectrometers. Another set of illicit procurements occurred from 2015 to 2018. See: Simon Mairson and Valerie Lincy, "U.S. Targets Procurement Network Supplying Machine Tools to Iran," *Wisconsin Project on Nuclear Arms Control*, October 21, 2019, https://www.wisconsinproject.org/u-s-targets-procurement-network-supplying-machine-tools-to-iran/.

[6] IAEA Director General, *Verification and Monitoring in the Islamic Republic of Iran in light of United Nations Security Council Resolution 2231 (2015)*, GOV/INF/2021/42, September 12, 2021, https://www.iaea.org/sites/default/files/21/09/govinf2021-42.pdf.

Iran. During October, the IAEA sought access on two occasions "to install new cameras and/or to confirm that the production of centrifuge rotor tubes and bellows had not resumed therein." Iran refused access both times.

Iran next sent a communication to the IAEA that was circulated to all member states reiterating its view about the TESA Karaj workshop exception, stating these monitoring commitments were not "legal obligations" and "cannot and should not be considered by the Agency as one of its entitlements." Iran also stated that its authorities were "investigating whether the terrorists [referring to the June 2021 sabotage incident via drone strike] have used the Agency cameras to launch an attack on the complex." It asked for the IAEA's cooperation "including through waiving the cameras immunity to be available for further investigation."

The Director General stated in his previous report that "Iran has unilaterally interpreted the terms of the Joint Statement to exclude, ex post facto" the TESA Karaj facility and emphasized that it is "indispensable that the agreement covers all facilities and locations in Iran in order to maintain continuity of knowledge…[and] for the Agency to be in a position to resume the necessary verification and monitoring activities in Iran in relation to the JCPOA." The Director General also "categorically reject[ed] the idea that Agency cameras played a role in assisting any third party to launch an attack…" He stated that the cameras were "under continuity of knowledge" from the moment they are delivered to the IAEA and later installed. The Director General "agreed that, if Iran so requested, the Iranian authorities could inspect the cameras in the presence of Agency inspectors."

In its November 2021 report, the IAEA also concluded that the "repeated prolongation of the agreement, which has now been in place for around nine months, is becoming a significant challenge to the Agency's ability to restore...continuity of knowledge." The IAEA also stated that the absence of cameras at the TESA facility was "seriously affecting the Agency's ability to restore continuity of knowledge at the workshop, which has been widely recognized as essential in relation to a return to the JCPOA."

In its latest report, the IAEA provides an update on this situation. On December 19, the IAEA "made available a sample camera and related technical information to Iran for analysis by its relevant security and judiciary officials, in the presence of the Agency inspectors." It reports that "by the end of December 2021, the Agency had reinstalled cameras to replace those removed from the workshop at Karaj and performed other related technical activities, including the replacement of all storage media in JCPOA-related cameras."

On January 19, Iran informed the IAEA of its intention to move the TESA Karaj facility to a new location in Esfahan, although it did not identify the location, which could involve the Esfahan tunnel complex. On January 24, the IAEA visited the facility and installed surveillance cameras to replace those at the Karaj site. The IAEA on January 22 also applied seals on all production machines at the Karaj site and removed those cameras.

However, the IAEA will still not have access to Esfahan or Karaj video recordings and data, which Iran claims it will keep in its custody until it receives relief from sanctions. The IAEA, for more than one year, has not been able to monitor Iran's production of advanced centrifuges, particularly rotors and bellows per JCPOA monitoring provisions, and faces a difficult challenge in reconstructing events, should Iran turn over these data. The IAEA does not report whether Iran has turned over to the IAEA a missing recording unit and storage data from a camera that was destroyed at the Karaj centrifuge manufacturing facility, covering the period February until June 2021. The IAEA also faces a gap in knowledge about Iran's advanced centrifuge manufacturing activities from June 2021 until January 2022, raising doubt about its ability to exclude Iran's diversion of centrifuge equipment to a clandestine facility.

The IAEA report does not discuss the status of Iran's construction of a new advanced centrifuge assembly facility in a tunnel near the main Natanz complex.