INSTITUTE FOR SCIENCE AND INTERNATIONAL SECURITY

REPORT

Analysis of IAEA Iran Verification and Monitoring Report - September 2023

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Background

- This report summarizes and assesses information in the International Atomic Energy Agency's (IAEA's) quarterly report, dated September 4, 2023, *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). It also covers findings from a separate IAEA report, *NPT Safeguards Agreement with the Islamic Republic of Iran,* issued also on September 4, 2023.

Findings

- Iran retains the ability, using 40 kilograms (kg) of 60 percent highly enriched uranium (HEU) and three or four advanced centrifuge cascades, to break out and produce enough weapon-grade enriched uranium for a nuclear weapon in 12 days. Currently, Iran would only need one-third of its existing stock of 60 percent enriched uranium. This breakout could be difficult for the IAEA to detect promptly, if Iran delayed inspectors' access.
- Using more of its remaining stock of 60 percent enriched uranium in the same three or four cascades, and its stock of near 20 percent enriched uranium in the vast bulk of its production-scale cascades, Iran could produce enough weapon-grade uranium (WGU) for an additional five nuclear weapons within the first month of a breakout, bringing the total to enough WGU for six nuclear weapons, or an increase of one since May 2023. Thus, Iran has increased its breakout capability, despite only a small increase in its 60 percent stock (see below), because its near 20 percent and less than five percent LEU stocks increased.
- In the second month, using its remaining stock of 60 percent material and part of its stock of less than 5 percent low enriched uranium (LEU), Iran could produce enough WGU for an additional two weapons. Using the rest of its stock of less than 5 percent LEU) (but greater than 2 percent enriched uranium), Iran could produce enough WGU for a ninth weapon by the end of the third month, and a tenth by the end of the fourth month.

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- In summary, Iran could produce enough WGU for six nuclear weapons in one month, eight in two months, nine in three months, and ten in four months.
- Iran's stockpile of 60 percent HEU was 121.6 kg (Uranium mass, or U mass) or 179.9 kg uranium hexafluoride mass (hex mass) as of August 19.
- The amount of 60 percent HEU produced during this most recent reporting period was about half of the amount produced during the previous reporting period, despite comparable timespans. The average production rate dropped from 9 kg (U mass) per month to 4.3 kg.
- The IAEA reports that from mid-June onwards, Iran reduced the production rate of near 60 percent HEU "by approximately two-thirds," indicating that during this reporting period, which spans mid-May to mid-August, one month at full production was followed by two months of reduced production.
- Of note, Iran only recently doubled its production of near 60 percent HEU when it started, in November 2022, to enrich to near 60 percent HEU in two advanced centrifuge cascades at Fordow. Thus, for six months, from December 2022 to June 2023, it accumulated about double the monthly average amount compared to the previous year and may still be able to hit an annual production target even if it were to stop producing 60 percent altogether for the next six months.
- The IAEA also reports that Iran downblended 6.4 kg (Uranium mass) of its near 60 percent stock by mixing it with near 5 percent LEU to produce 22.2 kg of 20 percent enriched uranium. Because it was not downblended to natural uranium or to at least near 5 percent LEU, the downblending had little impact on the breakout timelines.
- Overall, neither the slow-down in 60 percent production nor the downblending improved the breakout situation; in fact, the situation worsened.
- Iran continued to produce 60 percent HEU from 5 percent LEU feed in advanced centrifuge cascades at the above-ground Pilot Fuel Enrichment Plant (PFEP) and the below-ground Fordow Fuel Enrichment Plant (FFEP); the latter includes an IR-6 centrifuge cascade that is easily modifiable to change operations. This cascade was at the center of an IAEA-detected undeclared mode of operation in January 2023. It was interconnected with another IR-6 cascade to produce HEU, and subsequently, the IAEA detected the presence of near-84 percent HEU particles at the cascade's product sampling point.
- The IAEA has "accepted Iran's explanation for the origin of these particles" and verified that no diversion of declared uranium and no accumulation of uranium enriched to more than 60 percent took place. At the same time, the IAEA sought increased access and intensification of verification activities at the FFEP. In a May 2023 report on Iran's compliance with the Nuclear Non-Proliferation Treaty (NPT), the IAEA reported that it installed enrichment monitoring devices (EMD) at both the FFEP and at the PFEP to "monitor the enrichment level of the HEU being produced by Iran." These monitors are not JCPOA-related but are installed pursuant to Iran's comprehensive safeguards agreement (CSA) with the agency. IAEA Director General Rafael Grossi confirmed in a press conference that the EMD data will notify the IAEA of "another oscillation or otherwise" in the enrichment level in "real-time." The IAEA reports, "The evaluation of the data collected confirmed the general good functioning of the systems." However, "adjustments

and changes to operational procedures required to enable their commissioning [...] are being discussed with Iran."

- Iran continues to keep the majority (83 percent) of its stock of 60 percent HEU and nearly 85 percent of its stock of 20 percent enriched uranium at the Esfahan Fuel Plate Fabrication Plant (FPFP), where Iran maintains a capability to make enriched uranium metal. Iran's storage of so much proliferation-sensitive material at the FPFP, which may not be as thoroughly monitored as Natanz and Fordow, requires enhanced IAEA safeguards to detect and prevent diversion to a secret enrichment plant. For example, there should be stepped up inspector presence and remote camera surveillance.
- As of August 19, 2023, Iran had an IAEA-estimated stock of 535.8 kg of 20 percent enriched uranium (U mass and in the form of UF_6), equivalent to 792.6 kg (hex mass), representing an increase of 64.9 kg from 470.9 kg (U mass). Iran also had a stock of 33 kg (U mass) of 20 percent uranium in other chemical forms.
- The average production rate of 20 percent enriched uranium at the FFEP increased slightly to 13.2 kg (U mass) or 19.6 kg (hex mass) per month.
- Iran's number of installed advanced centrifuges has remained fairly steady since February 2023. It now has a total of about 6100 advanced centrifuges at Natanz and Fordow, where most are deployed at the Natanz Fuel Enrichment Plant (FEP) (see Figures 1 and 2).
- Including the installed IR-1 centrifuges at Natanz and Fordow brings the total number of installed centrifuges to about 13,330 centrifuges. It should be noted that many of the advanced centrifuges are deployed but not enriching uranium, and the IR-1 centrifuges have far less ability to enrich uranium than the advanced ones.
- During this reporting period, Iran installed one additional cascade of IR-4 centrifuges at the Natanz Fuel Enrichment Plant (FEP), where Iran now has a total of 36 cascades of IR-1 centrifuges, 21 cascades of IR-2m centrifuges, five cascades of IR-4 centrifuges, and three cascades of IR-6 centrifuges installed. An additional seven IR-4 centrifuge cascades are planned, and the installation of one IR-4 cascade was ongoing.
- Iran did not install any additional advanced centrifuge cascades at the FFEP, where it is currently operating six IR-1 centrifuge cascades and two IR-6 centrifuge cascades, although it plans to install up to 14 additional IR-6 centrifuge cascades.
- This lull in deployment was preceded by a spike in advanced centrifuge deployment from August 2022 to February 2023. A slowing of advanced centrifuge deployments and enrichment using those machines may be one reported term of an informal nuclear understanding with the United States, although this is unverified. It is unclear whether this means Iran is produced fewer centrifuges than expected, implying possible manufacturing difficulties, or is keeping newly produced machines in unmonitored storage instead.
- Iran's current, total operating enrichment capability is estimated to remain at about 19,100 separative work units (SWU) per year, where only cascades enriching uranium during this reporting period are included in this estimate. As of this reporting period, Iran was not yet using its fully installed enrichment capacity at the FEP.
- Iran's overall reported stockpile of enriched uranium decreased by 949 kg (U mass) from 4744.5 kg to 3795.5 kg (U mass) (see Table 1). This decrease largely stems from a decrease in uranium enriched to less than 2 percent, while all other stocks grew.

- Iran's stockpile of near 5 percent LEU increased by 610.7 kg (U mass) to 1950.9 kg (U mass) or 2885.9 kg (hex mass). Average production of near 5 percent LEU at the FEP increased, while the feed rate for 20 percent and 60 percent enriched uranium production decreased.
- Despite the increase during this reporting period in the amount of uranium enriched between two and five percent, Iran has not prioritized stockpiling this material over the past two and a half years. In addition, it has not made planned progress on the Enriched Uranium Powder Plant, a key civil facility to convert less than five percent enriched uranium hexafluoride into a uranium oxide powder for use in nuclear power reactor fuel. These two choices are at odds with Iran's contention that its primary goal is to accumulate 4-5 percent enriched uranium for use in nuclear power reactor fuel. Instead, Iran has used this stock extensively to produce near 20 percent and 60 percent enriched uranium, far beyond Iran's civilian needs.
- The IAEA reported no progress by Iran on resolving a discrepancy in Iran's natural uranium inventory at the Uranium Conversion Facility (UCF). The IAEA previously reported a shortfall in Iran's declaration, which may indicate that Iran mixed into the UCF inventory undeclared uranium it used in the past at the Lavisan-Shian site during its early-2000s nuclear weapons program. After acknowledging a discrepancy, Iran insisted that the discrepancy is "inaccurate" and "baseless," and that "differences" are "predictable" and that "the matter is considered as resolved." The IAEA did not agree with Iran's claim.
- The IAEA reports that Iran has not started commissioning the Arak reactor, now called the Khondab Heavy Water Research Reactor (KHRR), or IR-20. Iran previously informed the IAEA that it expected to commission the reactor in 2023 and start operations in 2024, but construction efforts on the reactor continue.
- The IAEA underscores that "for more than two and a half years Iran has not provided updated declarations and the Agency has not been able to conduct any complementary access under the Additional Protocol to any sites and locations in Iran."
- The IAEA reports no new progress on installing new surveillance cameras at Iran's nuclear-related facilities, including centrifuge manufacturing and assembly sites. Iran also has not turned over data or footage associated with monitoring devices and cameras, as it committed in an IAEA/Iran Joint Statement from March 2023.
- The absence of monitoring and surveillance equipment, particularly since June 2022, has caused the IAEA to doubt its ability to ascertain whether Iran has diverted or may divert advanced centrifuges. A risk is that Iran could accumulate a secret stock of advanced centrifuges, deployable in the future at a clandestine enrichment plant or during a breakout at declared sites. Another risk is that Iran will establish additional centrifuge manufacturing sites unknown to the IAEA. Iran has proven its ability to move manufacturing equipment to new, undeclared sites, further complicating any future verification effort and contributing to uncertainty about where Iran manufactures centrifuges.
- Iran's refusal to implement the non-voluntary Modified Code 3.1 to its CSA raises doubts about whether Iran will report the construction of a new enrichment plant or provide design information to the IAEA as soon as it decides to construct such a facility. Iran is building a new facility in the mountains near Natanz that is deeply buried and could be a potential site for a new enrichment plant.

- The IAEA concludes that "Iran's decision to remove all of the Agency's equipment previously installed in Iran for JCPOA-related surveillance and monitoring activities in relation to the JCPOA has [had] detrimental implications for the Agency's ability to provide assurance of the peaceful nature of Iran's nuclear programme."
- Concern about Iran's installation of advanced centrifuges at an undeclared site increases as its 60 percent HEU stocks grow. Such a scenario is becoming more worrisome and viable, since a relatively small number of advanced centrifuge cascades would suffice for the rapid enrichment of the 60 percent HEU to weapon-grade. This hybrid strategy involves the diversion of safeguarded HEU and the secret manufacture and deployment of only three or four cascades of advanced centrifuges. With greater uncertainty about the number of advanced centrifuges Iran is making, there is a greater chance of Iran hiding away the requisite number of advanced centrifuges to realize this scenario.
- According to a separate NPT report, Iran held discussions with the IAEA in August but did not make progress in addressing the IAEA's remaining questions about undeclared nuclear weapons activities and undeclared nuclear material found at two sites, Varamin and Turquz-Abad. Iran is stone-walling the IAEA.
- Combined with Iran's refusal to resolve outstanding safeguards violations, 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.

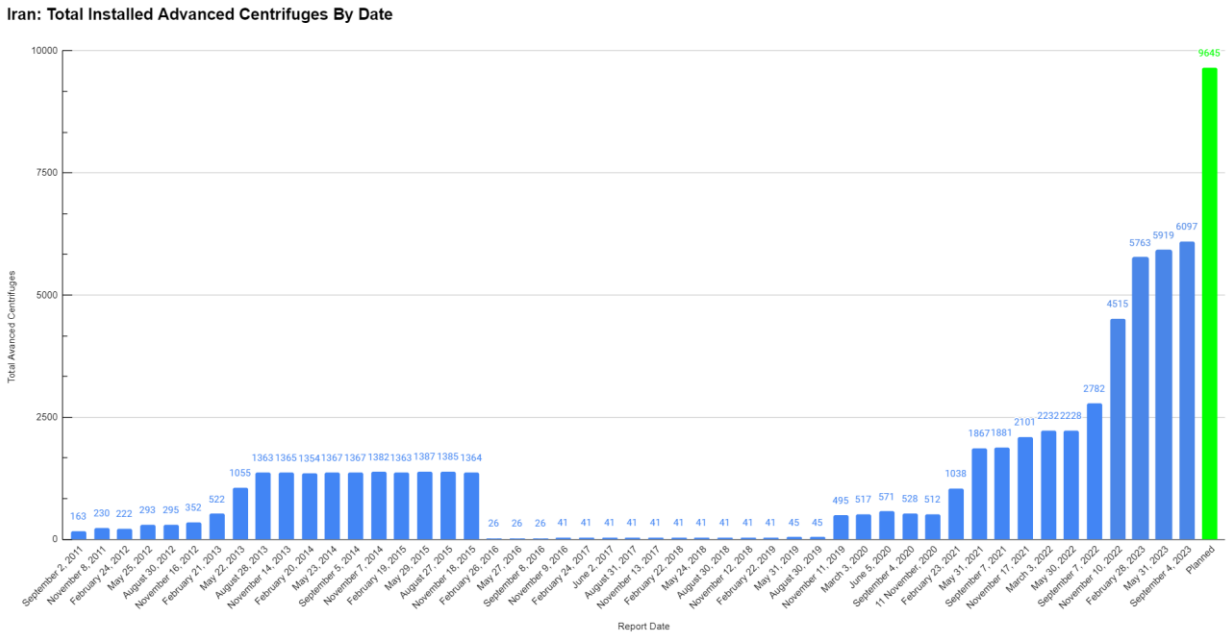

Figure 1. The total number of advanced centrifuges installed at all three enrichment facilities. One cascade of IR-4 centrifuges was reportedly added during this quarterly report. As can be seen, centrifuge installation has been relatively minimal since February 2023.

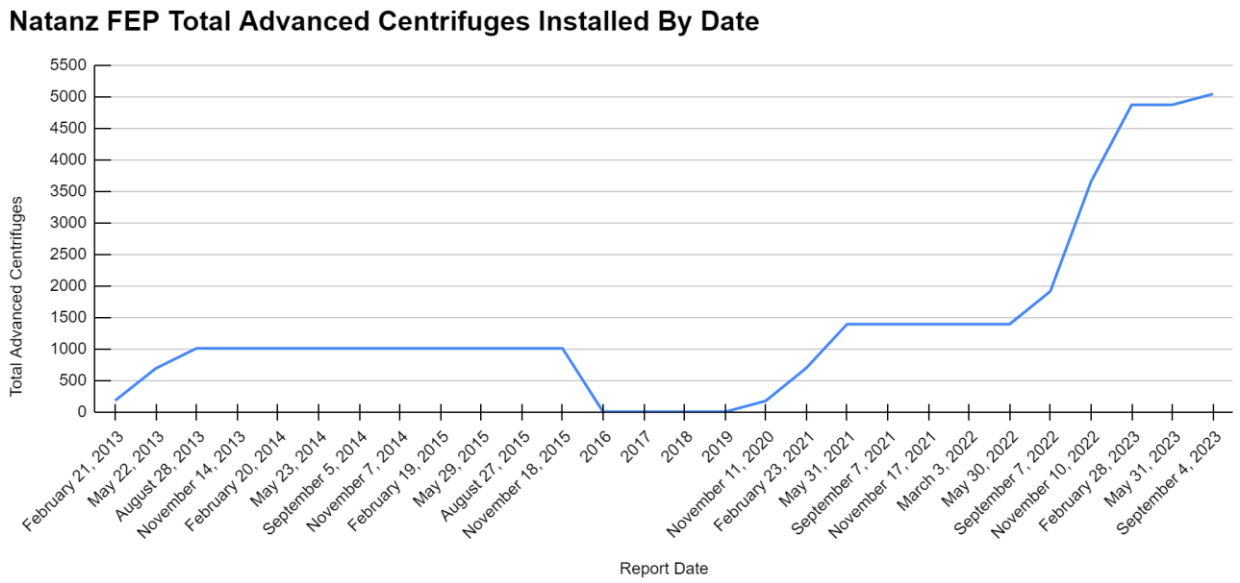

Figure 2. The total number of advanced centrifuges deployed at the Natanz Fuel Enrichment Plant. The deployment rate remained flat between February and May 2023 quarterly reports, with only a single cascade of IR-4 centrifuges deployed during the most recent reporting period. These numbers demonstrate that Iran has made no tangible concession and, on the contrary, continued to deploy advanced centrifuges, albeit at a much slower rate than in 2022.

Part 1: Enriched Uranium Stocks

At the Natanz FEP, Iran produced approximately 1746.3 kg of UF_6 enriched up to 5 percent U-235 during the reporting period, which spanned 97 days from May 13, 2023 to August 18, 2023.[2] 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, ignoring the fluorine elements, is 1180.5 kilograms, for a monthly average production rate of 365 kg U mass and a daily average production rate of 12 kg U mass. These average production rates increased from 278 kg U mass per month, or 9.3 kg U mass per day, during the previous reporting period, consistent with the fact that both natural uranium and 2 percent LEU were used as feed, which allows for the quicker production of 5 percent LEU.

At the FFEP, during the last reporting period, which spanned May 13, 2023 to August 18, 2023, Iran produced 13.2 kg (hex mass) of near 60 percent enriched uranium, or 8.9 kg U mass. The daily average production rate was 0.097 kg (U mass), resulting in a monthly average of 2.8 kg (U mass), about half the average production during the last reporting period, when it was 5.2 kg (U mass). Annually, at this rate, Iran could produce 49.7 kg (hex mass) or 33.6 kg (U mass).

[2] That production values are reported in uranium hexafluoride mass can be discerned only 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 is in uranium hexafluoride mass.

Iran also produced 63.3 kg of UF_6 (hex mass) enriched up to 20 percent enriched uranium, or 42.8 kg U mass. Average production of 20 percent enriched uranium at the FFEP was slightly higher compared to the last reporting period, at 0.65 kg (hex mass) or 0.4 kg (U mass) per day. At this rate, Iran could produce 19.6 kg of near 20 percent enriched uranium per month (hex mass) or 12.2 kg (U mass). Annually, Iran could produce 238 kg (hex mass) or 161 kg (U mass).

From its production of 60 and 20 percent enriched uranium at the FFEP, Iran accumulated 697.9 kg (hex mass) or 496.5 kg (U mass) of up to 2 percent enriched uranium in tails.

At the PFEP, Iran continued to produce 2 percent enriched uranium, 5 percent enriched uranium, and up to 60 percent enriched uranium stock during the reporting period. Between May 13, 2023 and August 18, 2023, the PFEP produced 7.4 kg (hex mass) of near 60 percent enriched uranium (equivalent to 5 kg in U mass); 166.2 kg (hex mass) of up to 5 percent LEU (112.4 kg U mass); and 208.9 kg (hex mass) of uranium enriched up to 2 percent U-235 (141.2 kg U mass).

The 60 percent enriched uranium production rate at the PFEP during this reporting period was 7.4 kg (hex mass) or 5 kg (U mass) over 97 days, resulting in a monthly average production rate of 2.3 kg (hex mass) or 1.5 kg (U mass) per month, or a daily average production rate of 0.08 kg (hex mass) or 0.05 kg (U mass) per day. This rate is a bit less than half the previous reporting period's monthly average production rate, which was 5.6 kg (hex mass) or 3.8 kg (U mass) per month. Annually, using only the two advanced production-scale centrifuge cascades at the PFEP, Iran could produce 28 kg (hex mass) or 19 kg (U mass) of 60 percent enriched uranium. Together with production at the FFEP, Iran is producing 4.3 kg (Uranium mass) or 6.4 kg (hex mass) per month on average and could produce 52 kg (U mass) or 78 kg (hex mass) of near 60 percent enriched uranium per year.

Iran's overall near 60 percent enriched uranium stock grew by less than the amount it produced in its gas centrifuge cascades, while its overall 20 percent enriched uranium stock grew by more than the amount it produced in the cascades. This is because Iran mixed 6.4 kg (U mass) near 60 percent enriched uranium with 15.8 kg (U mass) near 5 percent LEU and produced 22.2 kg (U mass) of near 20 percent enriched uranium. The blending stock, based on a material balance, was enriched to about 3.5 percent.

Estimates of additional amounts of LEU in oxides and intermediate products, fuel assemblies and rods, and scrap, add up to 354.3 kg (U mass), an amount only slightly lower than during the previous reporting period. The report specifies that of the 354.3 kg enriched to unspecified levels (U mass), 33 kg are up to 20 percent enriched uranium and 2 kg are up to 60 percent HEU. Of the 33 kg (U mass) near 20 percent enriched uranium, 27.2 kg (U mass) are specified to be in the form of fuel assemblies.

Of its near 5 percent LEU stock, Iran fed 643.7 kg hex mass (or 435.1 kg U mass) into the cascades at Fordow, for an average feed rate of about 6.6 kg per day hex mass, or 4.5 kg U mass, less than during the previous reporting period, where the rate was 5.9 kg U mass per day. Iran dumped 4.97 kg of near 5 percent LEU feed at the FFEP (hex mass), or about 3.3 kg in uranium mass, less than

one percent of the feed. Iran also fed 345.6 kg of near 5 percent hex mass (233.6 kg U mass) into PFEP R&D lines 4, 5, and 6, for a daily average feed rate of 3.6 kg (hex mass) or 2.4 kg U mass per day, about 75 percent that of the previous reporting period.

Based on this information, Iran's new stockpile of near 5 percent LEU in uranium mass should be the sum of 1340.2 kg U mass from the last reporting period, 1180.5 kg from the FEP, and 112.4 kg from the PFEP, with the feed of 668.7 kg subtracted. Adding back the 3.3 kg (U mass) feed dumped at the FFEP, this total becomes 1967.7 kg (after rounding of addends). Subtracting also the 15.8 kg near 5 percent LEU used to down blend near 60 percent HEU to near 20 percent enriched uranium, this becomes 1951.9, close to the 1950.9 kg U mass of near 5 percent LEU in UF_6 form that the IAEA reported.

The net overall enriched uranium stock, including all levels of enrichment and all chemical forms, decreased by 949 kg from 4744.5 kg to 3795.5 kg (U mass) (see Table 1). This decrease stems largely from a decrease in less than 2 percent enriched uranium, of which a large amount was used as feedstock at the FFEP (the report specifies that 3358.5 kg hex mass, or 2270.3 kg U mass, were fed into the cascades at Fordow). The near 5 percent LEU stock in the form of UF_6 increased by 610.7 kg, a significant increase. The near 20 percent enriched uranium stock increased by 64.9 kg from 470.9 kg to 535.8 kg (U mass), and the near 60 percent enriched uranium stock increased by 7.5 kg from 114.1 kg to 121.6 kg (U mass).

At the PFEP, Iran continued to use a combination of R&D lines 4, 5, and 6 to feed 5 percent LEU into the interconnected cascades in lines 4 and 6 and produce 60 percent enriched uranium. During this reporting period, spanning May 13, 2023 to August 18, 2023, of the 345.6 kg (hex mass) of 5 percent LEU fed into lines 4 and 6, Iran turned 7.5 kg (hex mass) (2.2 percent) into 60 percent enriched uranium and 166.2 kg (hex mass) back into 5 percent enriched uranium (48 percent). 172 kg (hex mass) (49.8 percent) remained as tails enriched up to 2 percent.

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	August 21, 2022	October 22, 2022	February 12, 2023	May 13, 2023	August 18, 2023
UF6 (kg)	3621.3	3323.1	3402	4384.8	3441.3
Uranium oxides and their intermediate products (kg)	252.3	241.6	215.3	207.5	206.9
Uranium in fuel assemblies and rods (kg)	48.2	49.3	58.4	59.5	54
Uranium in liquid and solid scrap (kg)	19.1	59.7	85.1	92.7	93.37
Enrichment Level Subtotals					
Uranium enriched up to 5 percent (kg) but more than 2 percent	713.9	1029.9	1324.5	1340.2	1950.9
Uranium enriched up to 2 percent (kg)	2519.9	1844.5	1555.3	2459.6	833
Uranium enriched up to 20 percent (kg)	331.9	386.4	434.7	470.9	535.8
Uranium enriched up to 60 percent (kg)	55.6	62.3	87.5	114.1	121.6
Uranium in chemical forms other than UF6 with unspecified enrichment level (kg) (including 33 kg up to 20% LEU and 2 kg up to 60% HEU)	319.6	350.6	358.8	359.7	354.3
Totals of Enriched Uranium in UF6, <5 % (kg)	3233.8	2874.4	2879.8	3799.8	2783.9
Totals of Enriched Uranium in UF6, including near 20% and near 60% (kg)	3621.3	3323.1	3402	4384.8	3441.3
Totals of Enriched Uranium in all chemical forms , <5% <20% and <60% enriched	**3940.9**	**3673.7**	**3760.8**	**4744.5**	**3795.6**

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

Part 2: Enrichment Capacity

Natanz Fuel Enrichment Plant

Installed Centrifuges. As of August 22, 2023, Iran had installed at the Natanz FEP 36 cascades of IR-1 centrifuges,[3] 21 cascades of IR-2m centrifuges, five cascades of IR-4 centrifuges, and three cascades of IR-6 centrifuges. Iran has plans to install an additional seven cascades of IR-4 centrifuges, and the installation of one IR-4 cascade was on-going. Iran now has an estimated total of 5046 advanced centrifuges installed at the FEP, of which 3654 are IR-2m centrifuges.

Enriching Centrifuges. As of August 22, 2023, the IAEA reports that at the FEP, in total, 36 cascades of IR-1 centrifuges, eight cascades of IR-2m centrifuges, three cascades of IR-4 centrifuges, and three cascades of IR-6 centrifuges were being fed with natural UF_6 or uranium enriched up to 2 percent to produce UF_6 enriched up to 5 percent. During the previous reporting period, 36 IR-1 cascades, nine IR-2m cascades, two IR-4 cascades, and three IR-6 cascades were being fed, also with natural UF_6 or with uranium enriched up to 2 percent. Overall, the enrichment capacity in enriching centrifuges remains significantly below that of installed centrifuges, as a total of 13 IR-2m cascades and two IR-4 cascades are installed but not enriching at the FEP.

The quantity of IR-1 centrifuges Iran withdrew from JCPOA-mandated storage continues to be unavailable for this reporting period because of Iran's refusal since February 2021 to provide the IAEA with access to data and recordings collected by agency equipment, and since June 2022, to continue collecting such data. In general, these centrifuges are believed to be coming from stocks of IR-1 centrifuges dismantled before JCPOA Implementation Day in January 2016 rather than representing newly built machines.

No new cascades of IR-2m centrifuges have been installed since February 2023, but for those installed prior to February — specifically the approximately 2600 installed over a short period of time between September 2022 and February 2023 — it is unclear whether they are newly produced machines or were drawn from a secret storage site. The total number of IR-2m centrifuges installed is now three times the quantity Iran had installed prior to the JCPOA and even exceeds the quantity Iran declared prior to the JCPOA that it planned to install at the FEP. Iran may have built the machines while declaring falsely that it had not done so.

Planned Expansion. Iran is planning to commission up to eight enrichment units in Building B1000 at Natanz. The IAEA reports that the installation has yet to start. Each of the eight enrichment units can hold 18 cascades (same general design as Building A1000), but Iran has not specified how many centrifuges and what type it plans to install there.

Fordow Fuel Enrichment Plant

[3] In August 2022, Iran had announced its intention to reconfigure some of the IR-1 cascades to include additional centrifuges, and in December 2022, this process was completed with 120 total IR-1 centrifuges added.

Overall, no changes in centrifuge deployment have occurred at Fordow. At the FFEP, Iran currently has 1044 IR-1 centrifuges installed in three sets of two interconnected cascades, and two interconnected cascades of 166 IR-6 centrifuges. Iran has not installed any additional IR-6 or IR-1 centrifuges toward its plans of installing up to 14 additional cascades to the FFEP (where the six currently installed IR-1 cascades would be replaced for a total of 16 cascades) but the installation of necessary infrastructure for eight new cascades was ongoing.

Iran continues to use the three sets of two interconnected IR-1 cascades to produce 20 percent enriched uranium from up to 5 percent LEU. Two interconnected IR-6 cascades have produced 60 percent HEU from 5 percent LEU feed. In late January 2023, the IAEA detected near-84 percent enriched HEU at the product sampling point, suggesting that the enrichment level temporarily rose above 60 percent (see below).

60 Percent Production at the FFEP. The IAEA confirmed that on November 22, 2022, Iran started using the two cascades of IR-6 centrifuges to produce UF_6 enriched up to 60 percent from near 5 percent LEU feed "by operating the two IR-6 cascades as one set of two interconnected cascades." In a footnote, the IAEA specified that the declared mode of interconnection used the IR-6 cascade without modified sub-headers for the last stage of enrichment to 60 percent, and this mode appears to have been used through January 16, 2023.

At some point after an unannounced inspection (UI) on January 16, 2023, Iran made an undeclared change to the operation, where the IR-6 cascade with modified sub-headers was used for the last stage of enrichment. This change was detected by the IAEA during another unannounced inspection on January 21, 2023. The IAEA reported the undeclared change of operation as a breach of Iran's safeguards obligations. Further, inspectors decided to collect environmental samples at the product sampling point during the monthly interim verification (IIV) the next day.

The most recent IAEA report specified that as of June 6, 2023, Iran reverted the mode of operation to the IR-6 without modified sub-headers enriching at the higher stage. The report also states that the rate of production of 60 percent HEU was reduced from mid-June onwards (see production levels above).

Near-84 Percent Production at the FFEP. On January 22, 2023, the IAEA detected uranium particles enriched to 83.7 percent from environmental sampling taken during a monthly IIV on January 22. Iran's answers about this anomaly did not satisfy the IAEA, and it asked Iran for more credible answers. One month later, the IAEA took destructive analysis samples from the cylinder Iran had been using to collect the 60 percent HEU product, but did not identify an anomaly in the overall enrichment level of the product collected in that cylinder. In its earlier reporting, the IAEA tied the detection of near-84 percent enriched uranium particles directly to its closer examination of the area following the change in the IR-6 cascade configuration discussed above.

On February 20, 2023, Iran informed the Agency that "unintended fluctuations in enrichment levels may have occurred during the transition period at the time of commissioning the process of [60 percent] product (November 2022) or while replacing the feed cylinder." In February and

March, the IAEA and Iran held several meetings at the facility and in Tehran, where Iran provided additional information, including supporting operational data, with regards to the particles enriched up to 83.7 percent. The IAEA checked the consistency of the new information.

On March 30, 2023, the IAEA indicated in a letter to Iran that, based on its evaluation, it "assessed that the information provided was not inconsistent with Iran's explanation for the origin of these particles and that the Agency had no further questions on the matter at that stage." The IAEA reports in its latest report that it found "no indication of the accumulation and collection of nuclear material enriched above 60 percent" and "no indication of the diversion of declared material," and was able to confirm this during the most recent annual physical inventory verification (PIV) in April to May 2023.

It is apparent from the IAEA's description that Iran's production of the 83.7 percent HEU was probably a one-off occurrence, but the episode has left an indelible impression that Iran can produce 90 percent enriched uranium quickly and perhaps secretly if it chooses to do so.

Pilot Fuel Enrichment Plant

New Underground PFEP. Since the previous report, Iran has made progress with plans to transfer its enrichment research and development activities to "a segregated area of Building A1000 at the FEP, to create a new area of the PFEP." On April 24, 2023, Iran provided the IAEA with an updated design information questionnaire (DIQ) for Building A1000, stating it intends to commission there six of the 18 R&D lines (A-F), consisting of "up to 174 IR-4 or IR-6 centrifuges, or various configurations of smaller cascades and single machines." It further declared that it may accumulate enriched uranium product of up to 5 percent LEU from enrichment activities in that area. Iran had begun installing centrifuges in two of the lines, lines A and B, where line A consists of five IR-4 centrifuges, and line B consists of 20 IR-6s centrifuges. On August 27, 2023, the IAEA verified that the installation of infrastructure for the overall 18 cascades was progressing and the installation of feed and withdrawal infrastructure had begun.

The report does not provide an anticipated start date for this new area. Given that this new R&D area represents a three-fold increase from the six lines in the above-ground PFEP, and each could hold a full production-scale cascade of Iran's advanced centrifuges, 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 4, 5, and 6. The IAEA reported no changes to the deployment of centrifuges in production lines 4 and 6 which are used for production of 60 percent enriched uranium. Since 60 percent enriched uranium production started on April 17, 2021, Iran has changed the mode of production several times, described in previous IAEA reports.

On August 27, 2023, the IAEA verified that Iran was continuing to feed up to 5 percent LEU into the two interconnected cascades in lines 4 and 6, comprising up to 164 IR-4 and up to 164 IR-6 centrifuges, respectively, and producing up to 60 percent enriched uranium. Line 5 is used to re-

enrich tails from lines 4 and 6 to near 5 percent LEU. The assay of the tails is likely about 2-3 percent. In a footnote in a previous report, the IAEA confirms that the tails from lines 4 and 6 that were not re-enriched in line 5 were accounted for as part of the stockpile enriched up to 5 percent, rather than the stockpile enriched up to 2 percent. As of August 27, line 5 was enriching tails from lines 4 and 6 in a cascade of 164 IR-4 and three IR-6 centrifuges.

The IR-4 cascade in line 4 and the IR-6 cascade in line 6 have similar estimated production-scale enrichment outputs of about 600 SWU per year each, where the enrichment outputs for these two centrifuge types in a production-scale cascade are taken from separate Institute reports.[4] The IR-6 centrifuge cascade has a production-scale enrichment output that is lower than expected. The two lines together have an estimated output of 1200 SWU per year, or the equivalent of about 1330 IR-1 centrifuges.

The IAEA reports that from mid-June 2023 onwards, the production rate of 60 percent HEU was reduced by "approximately two-thirds" (also see 60 percent HEU production discussed in Part 1).

Line 1. Iran was feeding natural UF_6 into an intermediate cascade of 18 IR-1 centrifuges and an intermediate cascade of 872 IR-2m centrifuges in line 1 to produce uranium enriched up to 2 percent U-235.

Lines 2 and 3. On August 27, 2023, the IAEA verified that lines 2 and 3 continued to accumulate uranium enriched up to 2 percent through feeding of natural UF_6. The IAEA verified that Iran had been using for this purpose small and intermediate cascades of up to: 20 IR-4 centrifuges; six IR-5 centrifuges and 18 IR-5 centrifuges; ten IR-6 centrifuges and 19 IR-6 centrifuges; and 20 IR-6s centrifuges. Iran has not redeployed any IR-s centrifuges, which had previously been installed in lines 2 and 3.[5] The following single centrifuges were being tested with natural UF_6 but were not accumulating enriched uranium: six IR-2m centrifuges, six IR-4 centrifuges; one IR-5 centrifuge; two IR-6 centrifuges; one IR-7 centrifuge; one IR-8 centrifuge; one IR-8B centrifuge; and one IR-9 centrifuge.

In 2021, Iran implemented a new mode of operation in line 2, feeding either near 5 or 20 percent enriched uranium into single advanced centrifuges, intermediate cascades of 10 advanced centrifuges, and intermediate cascades of 20 advanced centrifuges. For part of the fall in 2021, only near 20 percent enriched uranium was used as feed, marking the first time Iran started

[4] 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://isis-online.org/isis-reports/detail/a-comprehensive-survey-of-irans-advanced-centrifuges. The enrichment output for the IR-6 is further adjusted based on: David Albright and Sarah Burkhard, "The IR-6 Centrifuge Needs Further Development," *Institute for Science and International Security,* September 9, 2022, https://isis-online.org/isis-reports/detail/the-ir-6-centrifuge-needs-further-development/.

[5] The IR-s is a shorter centrifuge with a relatively high theoretical enrichment output, suggesting that it uses a carbon fiber rotor tube and is designed to operate at higher speeds than other Iranian advanced centrifuges, as discussed in an earlier Institute report. Perhaps, Iran acquired enough information from a multi-year testing period, or just as likely, encountered a problem. Iran has had difficulty operating centrifuges at high speeds and the centrifuges may have broken and were not replaced.

feeding a cascade with uranium enriched higher than 5 percent at any of its enrichment plants. Although the product and tails streams were re-combined, with no product collected, the experience gained from this procedure was likely important, particularly in the production of HEU in key advanced centrifuges when using near 20 percent enriched uranium feedstock. It is possible, and perhaps the objective, that Iran achieved an enrichment level of 90 percent and measured it, prior to remixing with the tails, a measurement likely unavailable to the IAEA. In any case, Iran gained irreversible knowledge in the setup and use of feed equipment designed for smaller quantities and higher enriched uranium levels.

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 feed and withdrawal setup, a setup likely required because of the smaller quantities of enriched uranium and concerns about criticality of HEU product. The IAEA did not state where this setup is stored or how many such setups exist. These setups 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.

Capacity of Centrifuges Enriching Uranium

Table 2 lists the estimated enrichment capacity by facility for those centrifuges that are currently enriching (not including machines installed but not yet enriching), leading to a total of 19,150 SWU per year, or the equivalent of 21,280 IR-1 centrifuges. This total enrichment capacity of enriching centrifuges remained close to the previous reporting period, because as Iran started to enrich uranium in a cascade of IR-4 centrifuges at the FEP, it stopped to enrich uranium in one cascade of IR-2m.

By contrast, including the installed but not yet enriching centrifuges results in an increase of enrichment capacity by 50 percent, for 30,185 SWU per year. This difference is especially significant at the moment, because Iran has 15 additional advanced centrifuge cascades installed, which it was not using to enrich during the latest reporting period.

Of note, the total enrichment capacity used in breakout calculations is different. It includes currently installed centrifuges but excludes many of the advanced centrifuges in the PFEP, except production-scale advanced cascades, as they would likely not contribute meaningfully to the quick production of enough WGU for a nuclear explosive when starting with up to five percent or near 20 percent enriched uranium.

Table 2. Quantity of enriching centrifuges and enrichment capacity

	Number of enriching centrifuges	Enrichment capacity in SWU/yr	IR-1 equivalent
Natanz FEP	8606	14,465	16,073
Fordow	1376	2135	2372
Natanz Above-Ground PFEP*	693	2548	2831
Lines 1, 2 & 3	See text		
Lines 4, 5 & 6	See text		
Natanz Below-Ground PFEP	N/A (not enriching yet)	–	–
Total	10,675	19,148	21,275

* The values for lines 1, 2 and 3 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, and its stock now exceeds three significant quantities of HEU.[6] Thus, Iran continues to have enough nuclear explosive material to have assurance it can directly fashion a nuclear explosive device. Its recent production of an unspecified amount of 84 percent enriched uranium supports that Iran can reach even higher enrichments.

Sixty percent enrichment is a level associated with a key step in the traditional A.Q. Khan stepwise process of climbing from natural uranium to 90 percent enriched uranium. As indicated, however, 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 25 kg (U mass) of 90 percent enriched uranium the Institute uses as a sufficient quantity for Iran to manufacture a nuclear explosive.

Moreover, the way Iran has enriched to 60 percent in one step, starting from near 5 percent enriched material, is innovative, suggesting Iran gained valuable experience in producing HEU, and

[6] A significant quantity of 60 percent enriched uranium is 41.7 kg, and it contains 25 kilograms of uranium-235, all in uranium mass.

by extension, even WGU. Iran 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.

Iran may have applied this one-step process to the production of small quantities of WGU from near 20 percent enriched uranium, despite not collecting this product, as discussed above. In November 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 levels reached may include 90 percent, or weapon-grade.

Although Iran's process of creating 60 percent enriched uranium is far from ideal, the Iranian process has demonstrated certain advantages, 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 that are 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, if the leadership orders production of WGU 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.

Transfer of 20 Percent Enriched Uranium and 60 Percent HEU from Natanz to Esfahan

Iran transferred additional 20 percent enriched uranium and 60 percent HEU in hexafluoride form from the Natanz site to the FPFP, which it declared to be for the production of HEU targets for the TRR. However, almost none of this enriched uranium has been turned into targets. Iran's storage of so much proliferation-sensitive material at the FPFP requires enhanced IAEA monitoring to detect and prevent diversion to a secret enrichment plant. It is unclear if such monitoring has been applied, such as stepped-up inspector presence or camera surveillance.

In January 2022, Iran transferred 23.3 kg (U mass) of 60 percent material to the FPFP. On April 19, 2022, the IAEA verified the receipt of an additional quantity of 15.3 kg (U mass) 60 percent HEU, bringing the total to 38.6 kg (U mass). On September 11, 2022, the IAEA verified the receipt of 16.5 kg (U mass) of 60 percent enriched uranium, bringing the total to 55.1 kg. On October 24, 2022, the IAEA verified the presence of a total of 53 kg (U mass) 60 percent HEU at the "storage area" of FPFP. The difference of about 2 kg matches the amount of 60 percent HEU reported to be in forms other than uranium hexafluoride, specified to contain 1.6 kg (U mass) in mini-plates. As of August 19, 2023, this 1.6 kg of HEU in 264 targets had been irradiated in the TRR and these targets were being stored in the TRR reactor pool. Another 0.4 kg (U mass) is in liquid and solid scrap.

On February 15, 2023, the IAEA verified the receipt at the FPFP of 16.55 kg (U mass) of 60 percent enriched uranium in the form of uranium hexafluoride. On July 19, 2023, the IAEA verified receipt at the FPFP of 30.92 kg of 60 percent enriched uranium, and on August 20, 2023, it verified an overall total of 100.52 kg of 60 percent enriched uranium at the FPFP.

On May 30, 2023, the IAEA verified receipt from the PFEP of 64.5 kg (U mass) of 20 percent enriched uranium in the form of uranium hexafluoride, bringing the total of 20 percent enriched uranium to 454.64 kg. No additional transfer or production of mini-plates (targets) has been reported since the previous reporting period.

Of Iran's total stock of 121.6 kg (U mass) of 60 percent HEU, about 83 percent of this stock was in storage at the FPFP as of August 2023. This represents an increase from the total of 60 percent of this material stored at the FPFP at the end of the previous reporting period. Of Iran's total stock of 20 percent enriched uranium, nearly 85 percent of this stock was in storage at the FPFP. Given that Esfahan holds Iran's capabilities to turn enriched uranium hexafluoride into metal, the IAEA should carefully monitor these stocks, as well as guard against diversion to a secret enrichment facility.[7]

Part 3: Current Breakout Estimates

During this reporting period, as during the previous reporting period, Iran's installed centrifuge capacity used for breakout calculations grew only slightly. The reason for the halt to what had been a rapid growth in deployed advanced centrifuges is not explained. However, since Iran no longer allows the IAEA to monitor its manufacture and assembly of advanced centrifuges, it could be stockpiling such machines without the IAEA's knowledge.

Iran's breakout timeline remains at zero. It has enough 60 percent enriched uranium, or HEU, to be assured it could directly fashion almost three nuclear explosives.[8]

If Iran wanted to further enrich all its 60 percent HEU up to weapon-grade, obtaining 75 kg of weapon-grade uranium, it could do so in about 1.3 months, utilizing only three or four of its advanced IR-6 centrifuge cascades, all of which are already configured to make HEU.[9] It could produce enough WGU for its first nuclear explosive in about 12 days after starting a breakout, where a weapon is assigned 25 kg of weapon-grade uranium (U mass) (see below for a brief

[7] David Albright, Sarah Burkhard, and Andrea Stricker, "Analysis of IAEA Iran Verification and Monitoring Report - May 2022," *Institute for Science and International Security*, June 6, 2022, https://isis-online.org/isis-reports/detail/analysis-of-iaea-iran-verification-and-monitoring-report-may-2022/8.

[8] According to the IAEA, Iran has 121.6 kg of 60 percent enriched uranium (uranium mass) in the form of uranium hexafluoride, almost three significant quantities, where the IAEA defines a significant quantity as the "approximate amount of nuclear material for which the possibility of manufacturing a nuclear explosive cannot be excluded." By definition, it is the amount of HEU containing 25 kg of uranium 235, or 41.7 kg of 60 percent enriched uranium.

[9] For background, see David Albright and Sarah Burkhard: "Entering Dangerous, Uncharted Waters: Iran's 60 Percent Highly Enriched Uranium," *Institute for Science and International Security,* April 11, 2022, https://isis-online.org/isis-reports/detail/entering-uncharted-waters-irans-60-percent-highly-enriched-uranium.

explanation for this choice). It could produce more than enough WGU from this 60 percent stock for two nuclear weapons in the first month.

In parallel to further enriching 60 percent material, Iran could enrich its near 20 percent enriched uranium stock to weapon-grade uranium in its production-scale cascades at the FEP and FFEP. Using the Institute's breakout calculator, and assuming a set-up time of two weeks, Iran is estimated to be able to accumulate, in one month, enough weapon-grade uranium for almost four nuclear weapons from its total stock of near 20 percent enriched uranium.

Looking at the issue differently, in one month, using 20 and 60 percent stocks, with a set-up time applied to the 20 percent enriched uranium, Iran could produce enough weapon-grade uranium for six nuclear weapons. Smaller amounts may be sufficient for each nuclear weapon, indicating that the breakout calculation is conservative.

In the second month, Iran could continue enriching to weapon-grade using its remaining feedstock of 60 and start enriching to weapon-grade its less than five and above two percent (taken as 4.5 percent) enriched uranium stock, producing enough weapon-grade uranium for two more nuclear weapons, or a cumulative total of eight nuclear weapons.

During the third and fourth month, there would be enough of the less than 5 but greater than 2 percent enriched uranium to produce enough WGU for one more nuclear weapon during each month.

Thus, Iran's enriched uranium stocks are sufficient to make enough weapon-grade uranium for six nuclear weapons in one month, eight nuclear weapons in two months, nine in three months, and ten in four months.

When Iran ended its crash nuclear weapons program in 2003, called the Amad Plan, its biggest bottleneck was the lack of WGU; it still needed at least a few more years to accumulate enough WGU for a nuclear weapon.[10] Under intense international pressure, Iran decided in 2003 to downsize and better camouflage its nuclear weapons effort, while pushing to establish a robust capability to enrich uranium. Today, that decision has borne fruit. While it could only aim for enough nuclear explosive material for five nuclear weapons in 2003, today it can have enough for those five weapons in less than one month. With its residual and covert nuclear weaponization capabilities, Iran could test a nuclear explosive underground or deploy a crude nuclear weapon in six months, or reestablish and complete its Amad Plan infrastructure in two years, before serially producing nuclear weapons for ballistic missiles.[11]

Breakout Calculator. The Institute's breakout calculator is used to estimate the breakout time, as in previous reports. The methodology is described in earlier Institute reports. The production of

[10] David Albright with Sarah Burkhard and the Good ISIS Team, *Iran's Perilous Pursuit of Nuclear Weapons* (Washington, DC: Institute for Science and International Security Press, 2021).
[11] David Albright, "Iran Building Nuclear Weapons," *Institute for Science and International Security,* December 5, 2022, https://isis-online.org/isis-reports/detail/iran-building-nuclear-weapons/8.

WGU from the 4.5, 20, and 60 percent enriched uranium stocks significantly reduces the timeline for the production of multiple quantities of 25 kg of WGU (U mass). The authors' benchmark reflects a reasonable, assured quantity of WGU for a variety of nuclear weapon designs available to Iran and the creation of a pipeline for production of multiple WGU cores. As before, the total enrichment contribution from small, non-production-scale 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 significantly to reducing breakout timelines. Stocks of less than 2 percent enriched uranium are also not used, since to do so would require additional modifications of the cascades to handle lower enrichments, likely significantly slowing or contributing only slightly, rather than speeding up, breakout timelines. Lastly, only enriched uranium hexafluoride stocks are used; Iran's chemical conversion of other stocks is assessed as too time consuming, and involving too little material, to significantly affect the breakout estimate.

The breakout timelines are credible, worst-case estimates, likely representing the shortest timelines 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, although the calculations use a significantly lower estimated enrichment output for the IR-6 cascades than expected.

Part 4: Enriched Uranium Metal Production Remains Halted, Nuclear Material Discrepancy at Uranium Conversion Facility

During the last seven reporting periods, Iran has not produced any uranium metal at the Fuel Plate Fabrication Plant (FPFP). On February 28, 2022, the IAEA verified that Iran had converted the remaining 900 grams of uranium in the form of uranium tetrafluoride (UF_4) enriched up to 20 percent, previously intended for production of uranium metal, into U_3O_8. However, Iran's capability to produce uranium metal remains intact.

In December 2020, Iran informed the IAEA that it would begin producing uranium metal, including uranium metal enriched up to 20 percent, a step that alarmed many. Iran is using the uranium metal in civil applications, including to produce experimental fuel rods for the 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 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.[12]

[12] *Iran's Perilous Pursuit of Nuclear Weapons*; 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.

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.

Iran stated this enriched uranium metal was for use in silicide fuel for the TRR. 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). As of May 20, 2023, three irradiated silicide fuel elements, containing 70 grams of 20 percent enriched uranium, were in the TRR spent fuel pond. As of that date, another two such fuel elements were being irradiated in the TRR. As of August 19, 2023, the situation remained the same, with these three fuel elements still in the TRR reactor pond and another two still being irradiated in the TRR.

On February 21, 2022, the IAEA verified that the installation of equipment for the first of three stages for the production of enriched UF_4 from enriched UF_6 at the FPFP, while almost complete, had progressed only slightly. Uranium tetrafluoride can be the intermediate product of uranium metal. The IAEA noted that on May 17, 2022, installation had been completed but Iran had not yet tested it with nuclear material, and the IAEA observed the same in May 2023 and likewise on August 14, 2023. The IAEA observed no progress, as of August 14, 2023, on the remaining two stages of this conversion process.

At the nearby Uranium Conversion Facility (or UCF) at Esfahan, in November 2021, Iran had finished installing equipment for producing uranium metal, and the facility was ready to operate with depleted or natural uranium. As of May 17, 2023, the IAEA verified that no nuclear material had been introduced into the production area. As of August 28, the situation was the same, with no nuclear material introduced.

Discrepancy at the Uranium Conversion Facility

The IAEA continued to report on a discrepancy in the inventory of natural uranium at the UCF, adding in the most recent NPT safeguards report Iran's lack of adequate cooperation to resolve the issue, despite an earlier promise to do so. On March 9, 2022, the IAEA verified the receipt at the UCF of 302.7 kg of natural uranium, as declared by Iran, in the form of solid waste and items of uranium metal from Jabar Ibn Hayan Multipurpose Laboratory (JHL). Later that same month, inspectors verified at the UCF Iran's dissolution of this nuclear material. The IAEA identified a discrepancy in the amount of nuclear material it had verified compared to the amount declared by Iran.

JHL has figured prominently in past IAEA efforts to understand the fate of undeclared uranium metal discs dating to Amad Plan activities undertaken at the secret Lavisan-Shian site in Tehran. There, Iran used uranium shavings taken from at least one metal disc in the production of uranium deuteride for neutron initiators, which were being developed for use to start the chain reaction in the weapon-grade uranium core of a nuclear weapon. *The Wall Street Journal*, citing two senior

diplomats familiar with Iran's activities, reported that the discrepancy was "connected to Iran's dissolution of a natural uranium metal disc the IAEA has been looking for as part of a probe into undeclared nuclear material found in Iran."[13]

Unlike the previous IAEA report, which did not report whether the discrepancy meant a surplus or a shortfall in Iran's declaration, the latest IAEA report specifies that there was a shortfall in Iran's declaration. This indicates that the IAEA did indeed verify the presence of more material than declared by Iran, and while not evidence, this is consistent with the media reporting that Iran may have mixed in undeclared nuclear material it used at Lavisan-Shian.

The original discrepancy was acknowledged by Iran during a technical meeting between senior IAEA and Iranian officials in Tehran on February 23, 2023. Iran agreed to work with the IAEA to address this discrepancy. In April 2023, however, Iran provided the IAEA with revised nuclear material accountancy information for the UCF, but the IAEA stated these revisions "neither addressed the discrepancy nor satisfied the requirements stipulated under' its comprehensive safeguards report. The IAEA concluded that revisions are "not based on scientific grounds, and, therefore [are] not acceptable."

Following this standoff,[14] in a letter to the IAEA dated July 5, 2023, Iran stated that "there is no need for any correction on the nuclear material accounting records and reports" and that Iran expected the Agency to "correct this inaccurate assessment on baseless discrepancy." The IAEA rejected this claim. Iran added in an August 9 reply that the discrepancy had "emerged due to the irregular process of recovering uranium from the waste material," that "such differences in this recovery process is predictable, and it is logically expected that the matter is considered as resolved." Again, in late August 2023, the IAEA informed Iran that it did not agree with Iran's statement regarding how the discrepancy emerged or that "such differences in this recovery process is predictable." Therefore, the IAEA regards the discrepancy as still requiring resolution.

Part 5: Heavy Water and Arak Reactor

The IAEA reports that since February 2021, due to Iran's reductions in agency monitoring, it has not been able to ascertain the status of Iran's Heavy Water Production Plant (HWPP) nor the production and inventory of heavy water. Since June 11, 2022, when Iran removed Flow-rate Unattended Monitoring (FLUM) equipment at the HWPP, the IAEA has had no monitoring capabilities. Based on commercial satellite imagery, the IAEA included in its August 2023 report its assessment that the HWPP continued to operate during the reporting period.

The IAEA reports that as of August 19, 2023, Iran had not resorted to the original, pre-JCPOA design of the Arak heavy water research reactor (IR-40 reactor), now called the Khondab Heavy

[13] Laurence Norman, "U.N. Agency Confirms Iran Produced Enriched Uranium Close to Weapons Grade," *The Wall Street Journal*, February 28, 2023.
[14] This paragraph draws from the September 4, 2023 IAEA report, *NPT Safeguards Agreement with the Islamic Republic of Iran*.

Water Research Reactor (KHRR), or IR-20. Iran also had not produced or tested natural uranium pellets, fuel pins, or fuel assemblies for the reactor as originally designed. In May 2023, the IAEA reported that Iran provided an updated DIQ for the Arak reactor, indicating "that the reactor power of 20 MW(th), the fuel enrichment and the preliminary core design are consistent with the 'Fundamental Principles' and 'Preliminary Characteristics' for the re-design of the research reactor" were consistent with the Arak conceptual design set out in Annex I of the JCPOA.

Previously, Iran informed the IAEA that it expected to commission the reactor and the primary circuit in August 2023 using dummy IR-20 fuel assemblies, and the reactor would start operations in 2024. The IAEA reports, however, that it "did not observe any indication that the primary circuit had been commissioned," yet Iran did not inform the IAEA of any change to timing for commissioning of the reactor. A wide range of "civil construction work was ongoing at all floors of the reactor building." Iran appears to have fallen behind schedule on the reactor's commissioning.

Part 6: Additional Protocol, Monitoring, and Transparency

Iran stopped implementing the Additional Protocol (AP) to its comprehensive safeguards agreement (CSA) and the JCPOA's additional monitoring arrangements on February 23, 2021. It also stopped implementing modified Code 3.1 to the CSA, a non-voluntary provision of the CSA that requires Iran to provide notification and design information as soon as it decides to build a new nuclear facility, such as an enrichment plant. Iran has also consistently refused to cooperate with the inspectors as they try to determine the correctness and completeness of Iran's nuclear declaration.

Iran's actions and its refusal to cooperate with the IAEA across a wide range of safeguards and monitoring issues helps explain why the IAEA cannot certify that Iran's nuclear program is peaceful and increasingly expresses doubt about understanding key aspects of Iran's nuclear activities. Without monitoring in place for more than two years, for example, the IAEA cannot determine the number of centrifuges Iran has manufactured.

Although the IAEA can ascertain the number of centrifuges deployed at Fordow and Natanz, it cannot know how many more Iran has made and stored or deployed at an undeclared site. A risk is that Iran will accumulate a secret stock of advanced centrifuges, deployable in the future at a clandestine enrichment plant. At the least, this situation complicates any future verification effort and contributes to uncertainty about the status of Iran's nuclear activities and facilities.

Monitoring and Surveillance Equipment

Iran previously agreed to continue operating IAEA monitoring and surveillance equipment installed for JCPOA monitoring purposes, but would keep footage and data in its custody until it received sanctions relief. Iran would continue to collect and store these data "with the aim of enabling the Agency to recover and re-establish the necessary continuity of knowledge" at the affected nuclear sites. On June 8, 2022, following IAEA board censure over its failure to cooperate on the IAEA's separate safeguards probe, Iran notified the IAEA that it would remove the IAEA's JCPOA-related

monitoring and surveillance equipment. From June 9 to 11, 2022, the IAEA removed, in total, 27 surveillance cameras, the on-line enrichment monitor (OLEM) at the FEP, and the FLUM equipment installed at the HWPP. The equipment was placed in storage under IAEA seal. The IAEA notes, "This seriously affected the Agency's JCPOA-related verification and monitoring."

The IAEA reports in its separate September 4, 2023 NPT report that Iran and the IAEA had made "no progress" during the reporting period on implementing a subsequent March 2023 Joint Statement, in which Iran agreed to cooperate on restoring some monitoring and on resolving safeguards issues.[15] The IAEA reports that no exchanges "in relation to implementation of the Joint Statement [occurred] until 9 August 2023 when meetings took place in Vienna and then on 28 August 2023 [when] a technical meeting took place in Tehran." The IAEA notes, "At the technical meeting, the Agency and Iran discussed matters related to the implementation of the Joint Statement and other safeguards implementation issues." Despite lengthy discussions, the two made no progress. Iran typically makes a pretense of cooperating with the IAEA just before IAEA board meetings, the next which is scheduled for September 11, 2023.

Cameras and Surveillance at the Esfahan Centrifuge Manufacturing Plant. The IAEA reported in May 2023 that in line with an IAEA/Iran Joint Statement from March 2023, in May, "the Agency installed surveillance cameras at workshops in Esfahan where centrifuge rotor tubes and bellows are manufactured," although Iran does not turn over the video footage to the IAEA.

In a new development, Iran delayed the IAEA from servicing these cameras at Esfahan. Under standard safeguards practice, these cameras should not be left for more than three months without being serviced by the inspectors, including replacing the storage medium. When the IAEA asked for access to service these cameras in early August, Iran delayed responding. It subsequently agreed to allow the inspectors to service the cameras on September 2, 2023 – four months after they had been installed.

Enrichment Monitoring at FFEP and PFEP, Lack of OLEM at FEP. The IAEA reported in May 2023 in a separate NPT report that Iran permitted the installation of enrichment monitoring devices (EMDs) at the FFEP and PFEP. The IAEA reported in its September 4th NPT report, "The evaluation of the data collected confirmed the general good functioning of the systems. Technical adjustments and changes to operational procedures required to enable their commissioning have been identified and are being discussed with Iran." Iran has not reinstalled the OLEM at the FEP.

Iran Denies IAEA Access to Another Centrifuge Manufacturing Site

There remains at least one other Iranian centrifuge manufacturing and assembly facility where Iran has still not permitted the IAEA to install cameras. During a technical meeting on 28 August 2023, according to the September 4, 2023 NPT report, "Iran did not agree to the Agency's request

[15] "Joint Statement by the Atomic Energy Organization of Iran (AEOI) and the International Atomic Energy Agency (IAEA)," March 4, 2023, https://www.iaea.org/newscenter/pressreleases/joint-statement-by-the-atomic-energy-organization-of-iran-aeoi-and-the-international-atomic-energy-agency-iaea

to install cameras at another location in Iran where centrifuge rotor tubes and bellows are manufactured."

Denying Visas to Experienced Inspectors

Moreover, the IAEA reports that during the reporting period, Iran had de-designated experienced IAEA inspectors and denied them visas. The IAEA stressed that this runs "counter to the co-operative relationship that should prevail between the Agency and Iran, and, more specifically, for the renewed positive approach expressed in the first paragraph of the Joint Statement of 4 March 2023."

Lack of Updated Declarations and Complementary Access

Due to Iran's refusal to implement the AP, the IAEA reports that "for more than two and a half years Iran has not provided updated declarations and the Agency has not been able to conduct any complementary access under the Additional Protocol to any sites and locations in Iran." The IAEA can no longer carry out daily visits to Iran's enrichment facilities. It has not "had access to data from its on-line enrichment monitors and electronic seals, or access to measurement recordings registered by its installed measurement devices." The IAEA also no longer receives data and recordings of test stands engaged in quality control tests of advanced centrifuge rotor assemblies, prior to their installation at Natanz and Fordow enrichment plants. It 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:

> *In the event of a full resumption of implementation by Iran of its nuclear-related commitments under the JCPOA, the Agency would not be able to re-establish continuity of knowledge in relation to the production and inventory of centrifuges, rotors and bellows, heavy water and uranium ore concentrate (UOC). Instead, the Agency would need to establish a new baseline in relation to such production and inventories. The Agency is aware that it would face major challenges in doing so, including the difficulty in confirming the accuracy of any declaration by Iran of its production of centrifuges, rotors and bellows, heavy water and UOC for the period when no verification and monitoring equipment had been in operation. In order to try to fill the gaps in its knowledge and minimize the margin of error, the development of specific arrangements with Iran would be indispensable.*

Iran has augmented centrifuge manufacturing, assembly, and mechanical testing activities in violation of the JCPOA, while halting IAEA monitoring. Without any monitoring in place, for more than two years, the IAEA cannot ascertain the total quantities of centrifuges Iran has manufactured.

Construction of a New, Large Underground Centrifuge Manufacturing Facility

Iran continues building a large, advanced centrifuge assembly facility under a nearby mountain to the south of the Natanz enrichment plants.[16] The facility will replace the above-ground Iran Centrifuge Assembly Center (ICAC), destroyed in an explosion in July 2020. The Institute assesses that this new tunnel facility is likely to be more deeply buried than the enrichment halls of the Fordow enrichment plant, and its working areas would be buried from 80 to 145 meters below the mountain peak.[17] Moreover, its working areas are expected to contain a significant amount of floor space, significantly more than the floor space of the facility it replaces.

The potential size of the underground halls and their depth suggests that, in addition to a centrifuge assembly facility, this facility could also house a small, advanced centrifuge enrichment facility.[18] However, construction progress has been slower than planned, and the facility may not open this year or possibly even next year. Since Iran refuses to implement the non-voluntary Modified Code 3.1 of its CSA, Iran may not inform the IAEA about such a facility until the facility is nearly complete, if it informs the IAEA at all. In addition, the IAEA has yet to visit the site.

Miscellaneous

The IAEA reports that it cannot verify Iran's JCPOA commitments under Sections D, E, S, and T. 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 evidence of illicit procurements.[19]

Part 7: Iran's Compliance with the NPT and Undeclared Nuclear Material and Activities

Iran remains in non-compliance with the NPT regarding its failure to resolve outstanding IAEA questions about Iran's undeclared nuclear weapons work and use of equipment at two sites. The IAEA reports in its separate report on Iran's compliance with the NPT that "no progress was made in the current reporting period" on commitments Iran made in the March 2023 IAEA/Iran Joint

[16] David Albright, Sarah Burkhard, and John Hannah, "Iran's Natanz Tunnel Complex: Deeper, Larger than Expected," *Institute for Science and International Security*, January 13, 2022, https://isis-online.org/isis-reports/detail/irans-natanz-tunnel-complex-deeper-larger-than-expected/8.

[17] David Albright and Sarah Burkhard, "Imagery Update: Iran Continues to Harden its New Natanz Tunnel Complex," *Institute for Science and International Security,* May 5, 2022, https://isis-online.org/isis-reports/detail/imagery-update-iran-continues-to-harden-its-new-natanz-tunnel-complex-2022.

[18] "Imagery Update: Iran Continues to Harden its New Natanz Tunnel Complex."

[19] Benjamin Weinthal, "Iran moves toward possible atom bomb test in defiance of Western sanctions: intel report," *Fox News,* July 9, 2023, https://www.foxnews.com/world/european-intel-report-warns-iran-moves-toward-possible-testing-nuclear-bomb

Statement. The two sites at issue are Varamin, a suspected former pilot-scale uranium conversion plant, and Turquz-Abad, an open-air warehouse site in Tehran where Iran stored equipment related to undeclared efforts (see earlier Institute report).[20]

The IAEA reports that "no exchanges between the Agency and Iran took place in relation to the implementation of the Joint Statement until 9 August 2023 when meetings took place in Vienna and then on 28 August 2023 a technical meeting took place in Tehran." At that technical meeting, the two "discussed matters related to the implementation of the Joint Statement and other safeguards implementation issues." However, "despite lengthy discussions, no progress was made in relation either to the implementation of the Joint Statement or on other safeguards implementation issues."

On June 7, 2023, Iran told the IAEA regarding "the nuclear material particles identified at Varamin and Turquzabad, "it had 'exhausted all its efforts so as to discover the origin of such particles'." The IAEA notes that, "according to Iran, it had 'explained its assumptions about the probable causes of the presence of uranium particles' and, given that it 'could not yet find any technical reasons for the presence of uranium particles, it would reasonably imply that possibly external elements, such as sabotage and malicious acts, have been involved in the contamination'". The IAEA reports that "Iran also stated that 'based on our intensive investigations into the background of activities carried out in two remaining locations has not yet been found. There has not been any nuclear activity or storage in these locations.'"

The IAEA reports that during the technical meeting in Tehran on August 28, 2023, "Iran informed the Agency that it has no additional information on Varamin but stated that it would continue to investigate the matter. Regarding Turquzabad, Iran stated that it had collected additional information regarding containers that were present at this location." The IAEA notes, "According to Iran, none of the containers were transferred intact from Turquzabad; they were all dismantled at the location. Iran informed the Agency that it would provide this information to the Agency for its review, together with other information related to the whereabouts of the dismantled containers."

The IAEA "requested Iran to provide this additional information to the Agency as soon as possible for its review and assessment at Agency Headquarters." The IAEA "stresses, however, that at the technical meeting Iran did not address the presence of uranium particles of anthropogenic origin found by the Agency at these two locations."

The IAEA concludes, "Unless and until Iran provides technically credible explanations and informs the Agency of the current location(s) of the nuclear material and/or of the contaminated equipment, the Agency will not be able to confirm the correctness and completeness of Iran's declarations under its Safeguards Agreement and therefore these issues remain outstanding."

[20] David Albright, Sarah Burkhard, and Andrea Stricker, "Analysis of the IAEA's Iran NPT Safeguards Report – May 2023," *Institute for Science and International Security,* June 1, 2023, https://isis-online.org/isis-reports/detail/analysis-of-the-iaeas-iran-npt-safeguards-report-may-2023