INSTITUTE FOR SCIENCE AND INTERNATIONAL SECURITY

Analysis of IAEA Iran Verification and Monitoring Report — November 2023

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Background

- This report summarizes and assesses information in the International Atomic Energy Agency's (IAEA's) quarterly report, dated November 13, 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 includes findings from a separate IAEA report, *NPT Safeguards Agreement with the Islamic Republic of Iran,* dated November 15, 2023, referred to alternatively as *NPT Report* or *NPT Safeguards Report*.

Findings

- Iran's stocks of enriched uranium and its centrifuge capacity combined are sufficient to make enough weapon-grade uranium (WGU), taken as 25 kilograms (kg) of WGU, for six nuclear weapons in one month, eight in two months, ten in three months, eleven in four months, and twelve in five months. This represents a growth in Iran's breakout capabilities in months three through five, resulting from the continued growth of enriched uranium stocks. Centrifuge capacity has remained relatively constant.
- With Iran's growing experience and using only a portion of its stock of 60 percent enriched uranium, Iran could choose to produce its first quantity of 25 kg of WGU in as little as seven days, down from the Institute's previous estimate of 12 days. The shorter timeframe results from a scenario in which Iran dedicates four advanced centrifuge cascades to the task and uses a higher tails assay, causing faster production of WGU but requiring more 60 percent feed to do so. This breakout could be difficult for the IAEA to detect promptly, if Iran delayed inspectors' access.
- According to the IAEA's NPT safeguards report, after almost five years since the IAEA first detected undeclared uranium at the first site relevant to its investigation, and after many chances for Iran to provide explanations, the IAEA continues to conclude that undeclared nuclear-related activities or undeclared nuclear material were present at all four sites

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under investigation. The IAEA reports, "The Agency has not changed its assessment either of the undeclared nuclear-related activities at the four locations [...] or of the origin of the uranium particles [...] found at three of these four undeclared locations in Iran."

- The NPT safeguards report language makes clear that not only was there little Iranian cooperation over the last two and a half months, but also that Iran shows no real willingness to cooperate in the future. In a further demonstration of Iran's strategy to reduce transparency over its sensitive nuclear programs, for political reasons, Iran withdrew the designation of European inspectors with experience in enrichment technology. *The Wall Street Journal* reports that eight inspectors had to leave Iran.[2] The IAEA called this move "extreme and unjustified" and underscored that this "seriously affected the agency's work." Iran responded that the IAEA's complaint "is not compelling and lacks any legal basis," and said only that it was exploring possibilities to address the issue.
- The net overall enriched uranium stock, including all levels of enrichment and all chemical forms, increased by 691.2 kg from 3795.5 kg to 4486.8 kg (Uranium mass or U mass).
- Iran's stockpile of 60 percent highly enriched uranium (HEU) was 128.3 kg (U mass) or 189.8 kg uranium hexafluoride mass (hex mass) as of October 28, 2023.
- The average production rate of 60 percent HEU dropped from 4.3 kg (U mass) per month to 2.9 kg. At this rate, Iran can produce about 35 kg (U mass) annually.
- However, Iran did not downblend any 60 percent HEU during this reporting period. Thus, the 60 percent HEU stock grew at a faster average rate than during the previous period. It grew by 94 grams (U mass) per day (6.7 kg over 71 days), compared to the previous 77 grams per day (7.5 kg over 97 days).
- Of note, Iran 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 might still have been able to hit its annual production target even if it had stopped producing 60 percent altogether for the subsequent six months.
- Iran continued to produce 60 percent HEU from 5 percent low enriched uranium (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.
- In its May 2023 report on Iran's compliance with the Nuclear Non-Proliferation Treaty (NPT), the IAEA reported that the agency 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

[2] Laurence Norman, "Iran Maintains Steady Expansion of Nuclear Program," *The Wall Street Journal,* November 15, 2023, https://www.wsj.com/world/middle-east/iran-maintains-steady-expansion-of-nuclear-program-46df894a.

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 reported previously that, "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." The IAEA provides no update on the status of the EMDs in the most recent report.

- The IAEA's technical report is shorter in length and omits previously reported details, including how much of the 20 percent enriched uranium and 60 percent HEU stocks Iran keeps at the Esfahan Fuel Plate Fabrication Plant (FPFP), where Iran maintains a capability to make enriched uranium metal. According to previous reports, Iran was storing the majority of those stocks at Esfahan. 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 October 28, 2023, Iran had an IAEA-estimated stock of 567.1 kg of 20 percent enriched uranium (U mass and in the form of UF_6), equivalent to 838.9 kg (hex mass), representing an increase of 31.3 kg from 535.8 kg (U mass). Iran also had a stock of 32.7 kg (U mass) of 20 percent uranium in other chemical forms.
- The average production rate of 20 percent enriched uranium at the FFEP remained steady at about 13.4 kg (U mass) or 19.9 kg (hex mass) per month.
- Iran's deployment of advanced centrifuges has remained fairly steady since February 2023, with about one new advanced centrifuge cascade installed during each of the three subsequent reporting periods. Iran now has almost 6300 advanced centrifuges at Natanz and Fordow, where most are deployed at the Natanz Fuel Enrichment Plant (FEP) (see Figure 1).
- Including the installed IR-1 centrifuges at the FEP and FFEP brings the total number of installed centrifuges to about 13,500. It should be noted that many of the advanced centrifuges are deployed but not enriching uranium, and the IR-1 centrifuges have a far lesser ability to enrich uranium than the advanced ones.
- During this reporting period, Iran installed one additional cascade of IR-4 centrifuges at the FEP, where Iran now has a total of 36 cascades of IR-1 centrifuges, 21 cascades of IR-2m centrifuges, six cascades of IR-4 centrifuges, and three cascades of IR-6 centrifuges installed. An additional six 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 producing 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 be about 19,800 separative work units (SWU) per year, where only cascades enriching uranium during this reporting period are included in the estimate. As of this reporting period, Iran was not yet using its fully installed enrichment capacity at the FEP, which, if operational, would total about 31,000 SWU/yr.
- Iran's stockpile of near 5 percent LEU increased by 267.2 kg (U mass) to 2218.1 kg (U mass) or 3281.2 kg (hex mass). Average production of near 5 percent LEU at the FEP decreased, consistent with the reporting that Iran used natural uranium as feedstock instead of up to 2 percent LEU.
- 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. For example, it has not made planned progress on the Enriched Uranium Powder Plant, a key civil facility to convert less than 5 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 states in the NPT safeguards report that Iran provided new data the IAEA needs to assess to see whether the agency can resolve 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 and Iran has provided no update.
- The IAEA underscores that it has been "two years and nine months since Iran stopped provisionally applying its Additional Protocol and, therefore, since it provided updated declarations and the Agency was able to conduct complementary access 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. The IAEA proposed installing cameras at the Natanz centrifuge workshops, but Iran refused. The IAEA also proposed conducting consistency checks on cameras installed at the Esfahan centrifuge facility, and Iran refused. 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 secretly move manufacturing equipment to new, undeclared sites, further complicating any future verification effort and contributing to uncertainty about where Iran manufactures centrifuges.

- During the reporting period, the IAEA pressed Iran on obtaining its commitment to implement the non-voluntary Modified Code 3.1 to its CSA. Iran's ongoing refusal raises doubts about whether Iran will report the construction of a new nuclear facility, such as an enrichment plant, or provide design information to the IAEA as soon as it decides to construct such a facility. The IAEA is concerned since Iran has mentioned a desire to build new nuclear facilities. 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. Iran told the IAEA that "design information for any new facilities…will be provided in due time." The IAEA acknowledged that Iran "was no longer prepared to work with the Agency to find a mutually acceptable solution" regarding implementation of Modified Code 3.1.
- 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 the 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.
- The IAEA reports in its NPT report that the Director General "is seriously concerned that Iran appears to have 'frozen' the implementation of the Joint Statement of 4 March 2023 for the past two reporting periods, and questions Iran's continued commitment to its implementation." Atomic Energy Organization of Iran (AEOI) chief, Mohammad Eslami, told the IAEA not to expect any new cooperation, particularly on JCPOA-related measures, while sanctions on Iran remain in effect.
- 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.

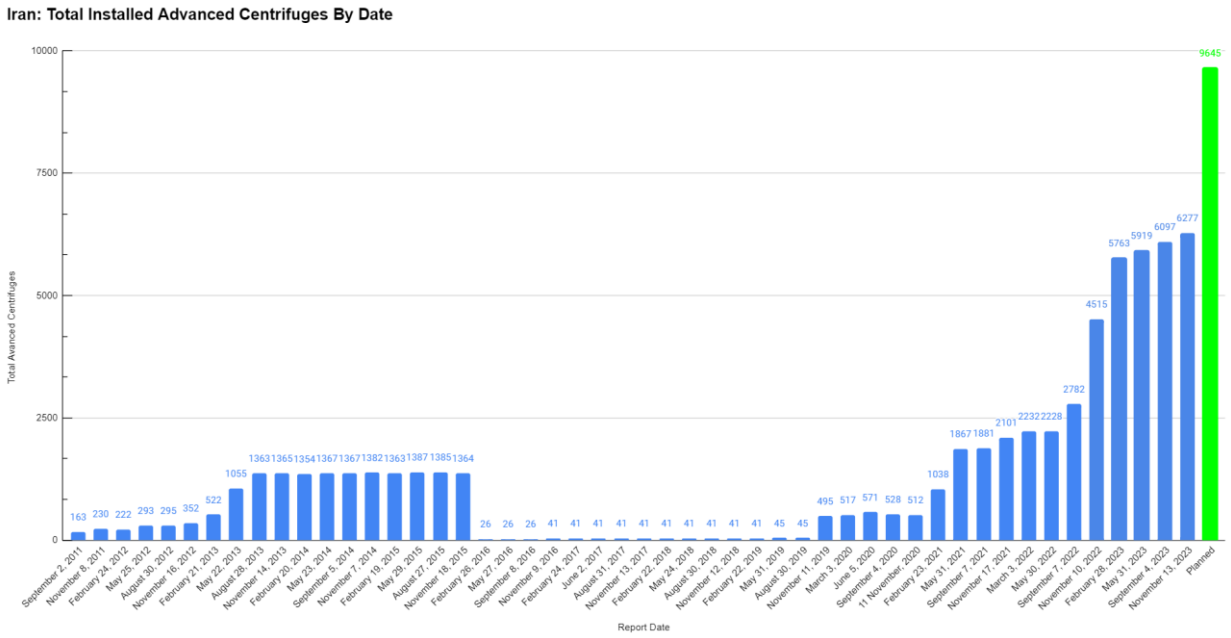

Figure 1. The total number of advanced centrifuges installed at all three enrichment facilities. One cascade of IR-4 centrifuges was reportedly added during this quarterly report. As can be seen, centrifuge installation has been relatively minimal, although steady, since February 2023.

Part 1: Enriched Uranium Stocks

At the Natanz FEP, Iran produced approximately 926.8 kg of UF_6 enriched up to 5 percent U-235 during the reporting period, which spanned 70 days from August 18, 2023 to October 27, 2023.[3] 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 626.6 kilograms, for a monthly average production rate of 268.5 kg U mass and a daily average production rate of 9 kg U mass. These average production rates decreased from 365 kg U mass per month, or 12 kg U mass per day, during the previous reporting period, consistent with the fact that only natural uranium was used as feed, instead of 2 percent LEU, which allows for the quicker production of 5 percent LEU.

At the FFEP, during the last reporting period, which spanned August 18, 2023 to October 27, 2023, Iran produced 6.9 kg (hex mass) of near 60 percent enriched uranium, or 4.7 kg U mass. The daily average production rate was 66 grams (U mass), resulting in a monthly average production rate of 2 kg (U mass), less than the average production during the last reporting period, when it was 2.8 kg (U mass). Annually, at this rate, Iran could produce 36 kg (hex mass) or 24.3 kg (U mass).

[3] 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 46.4 kg of UF_6 (hex mass) enriched up to 20 percent enriched uranium, or 31.4 kg U mass. Average production of 20 percent enriched uranium at the FFEP remained steady compared to the last reporting period, at 0.66 kg (hex mass) or 0.4 kg (U mass) per day. At this rate, Iran could produce 19.9 kg of near 20 percent enriched uranium per month (hex mass) or 13.4 kg (U mass). Annually, Iran could produce 242 kg (hex mass) or 163.6 kg (U mass).

From its production of 60 and 20 percent enriched uranium at the FFEP, Iran accumulated 398 kg (hex mass) or 269 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 August 18, 2023, and October 27, 2023, the PFEP produced 3 kg (hex mass) of near 60 percent enriched uranium (equivalent to 2 kg in U mass); 166 kg (hex mass) of up to 5 percent LEU (112 kg U mass); and 171 kg (hex mass) of uranium enriched up to 2 percent U-235 (115.6 kg U mass).

The 60 percent enriched uranium production rate at the PFEP during this reporting period was 3 kg (hex mass) or 2 kg (U mass) over 70 days, resulting in a monthly average production rate of 1.29 kg (hex mass) or 0.87 kg (U mass) per month, or a daily average production rate of 43 grams (hex mass) or 29 (U mass) per day. This rate is a bit more than half the previous reporting period's monthly average production rate, which was 2.3 kg (hex mass) or 1.5 kg (U mass) per month. Annually, using only the two advanced production-scale centrifuge cascades at the PFEP, Iran could produce 15.6 kg (hex mass) or 10.6 kg (U mass) of 60 percent enriched uranium. Together with production at the FFEP, Iran is producing 2.9 kg (Uranium mass) or 4.2 kg (hex mass) per month on average and could produce 34.9 kg (U mass) or 51.6 kg (hex mass) of near 60 percent enriched uranium per year.

Despite the reduced production rate, Iran's overall near 60 percent enriched uranium stock grew faster on average per day during this reporting period than during the last reporting period, because Iran did not down-blend any of its 60 percent HEU stock. During the previous reporting period, Iran mixed 6.4 kg (U mass) of 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. Thus, the daily average increase in stock was 94 grams per day, compared to the previous reporting period, where the daily average increase was 77 grams per day.

Estimates of additional amounts of LEU in oxides and intermediate products, fuel assemblies and rods, targets, and scrap, add up to 356.1 kg (U mass), an amount similar to that during the previous reporting period. The report specifies that of the 356.1 kg enriched to unspecified levels (U mass), 32.7 kg are up to 20 percent enriched uranium and 2 kg are up to 60 percent HEU. Of the 32.7 kg (U mass) of near 20 percent enriched uranium, 24.2 kg (U mass) are specified to be in the form of fuel assemblies and 2.8 kg are in targets, a new category the IAEA added for uranium that was previously included under fuel assemblies, plates, and rods. 0.2 kg of uranium were removed from the previous 3 kg in targets as they are irradiated and dissolved.

Of its near 5 percent LEU stock, Iran fed 429.8 kg hex mass (or 290.5 kg U mass) into the cascades at Fordow, for an average feed rate of about 6.1 kg per day hex mass, or 4.2 kg U mass, similar to the amount during the previous reporting period. Iran dumped 7.6 kg of near 5 percent LEU feed at the FFEP (hex mass), or about 5.1 kg in uranium mass, or less than two percent of the feed. Iran also fed 274.7 kg of near 5 percent hex mass (185.7 kg U mass) into PFEP R&D lines 4, 5, and 6, for a daily average feed rate of 3.9 kg (hex mass) or 2.6 kg U mass per day, slightly less than the amount during 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 1950.9 kg U mass from the last reporting period, 626.5 kg from the FEP, and 112.2 kg from the PFEP, with the feed of 476.2 kg subtracted. Adding back the 5.1 kg (U mass) feed dumped at the FFEP, this total becomes 2218.5 kg (after rounding of addends), close to the 2218.1 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, increased by 691.2 kg from 3795.5 kg to 4486.8 kg (U mass) (see Table 1). This increase stems from an increase across all four enriched uranium stocks. The near 2 percent LEU stock in the form of UF_6 increased by 384.2 kg (U mass), the near 5 percent LEU stock in the form of UF_6 increased by 267.2 kg (U mass), the near 20 percent enriched uranium stock increased by 31.3 kg from 535.8 kg to 567.1 kg (U mass), and the near 60 percent enriched uranium stock increased by 6.7 kg from 121.6 kg to 128.3 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, while using centrifuges in line 5 to increase the enrichment level of the tails (see below). During this reporting period, spanning August 18, 2023, to October 27, 2023, of the 274.7 kg (hex mass) of 5 percent LEU fed into lines 4 and 6, Iran turned 3 kg (hex mass) (1.1 percent) into 60 percent enriched uranium and 166 kg (hex mass) back into 5 percent enriched uranium (60 percent). 105.7 kg (hex mass) (38.5 percent) remained as tails enriched up to 2 percent.

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

Chemical Form	October 22, 2022	February12, 2023	May 13, 2023	August18, 2023	October 28, 2023
UF6 (kg)	3323.1	3402	4384.8	3441.3	4130.7
Uranium oxides and their intermediate products (kg)	241.6	215.3	207.5	206.9	205.6
Uranium in fuel assemblies, rods, and targets (kg)	49.3	58.4	59.5	54	54.1
Uranium in liquid and solid scrap (kg)	59.7	85.1	92.7	93.37	96.4
Enrichment Level Subtotals					
Uranium enriched up to 5 percent (kg) but more than 2 percent	1029.9	1324.5	1340.2	1950.9	2218.1
Uranium enriched up to 2 percent (kg)	1844.5	1555.3	2459.6	833	1217.2
Uranium enriched up to 20 percent (kg)	386.4	434.7	470.9	535.8	567.1
Uranium enriched up to 60 percent (kg)	62.3	87.5	114.1	121.6	128.3
Uranium in chemical forms other than UF6 with unspecified enrichment level (kg) (including 32.7 kg up to 20% LEU and 2 kg up to 60% HEU)	350.6	358.8	359.7	354.4	356.1
Totals of Enriched Uranium in UF6, <5 % (kg)	2874.4	2879.8	3799.8	2783.9	3435.3
Totals of Enriched Uranium in UF6, including near 20% and near 60% (kg)	3323.1	3402	4384.8	3441.3	4130.7
Totals of Enriched Uranium in all chemical forms, <5% <20% and <60% enriched	**3673.7**	**3760.8**	**4744.5**	**3795.6**	**4486.8**

* 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 October 21, 2023, the IAEA reports that Iran had installed at the Natanz FEP 36 cascades of IR-1 centrifuges,[4] 21 cascades of IR-2m centrifuges, six cascades of IR-4 centrifuges (up from five during the previous reporting period), and three cascades of IR-6 centrifuges. Iran has plans to install an additional six cascades of IR-4 centrifuges, and the installation of one IR-4 cascade was on-going. The installation of sub-headers for the remaining five IR-4 cascades was also on-going. Iran now has an estimated total of 5220 advanced centrifuges installed at the FEP, of which 3654 are IR-2m centrifuges.

Enriching Centrifuges. As of October 21, 2023, the IAEA reports that at the FEP, in total, 36 cascades of IR-1 centrifuges, nine cascades of IR-2m centrifuges (up from eight cascades during the previous reporting period), three cascades of IR-4 centrifuges, and three cascades of IR-6 centrifuges were being fed with natural UF_6. Overall, the enrichment capacity in enriching centrifuges remains significantly below that of installed centrifuges, as a total of 12 IR-2m cascades and three 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 many of these machines prior to the JCPOA's Implementation Day in early 2016 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, based on previous IAEA reports. 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. The current report provides no update on this planned commissioning.

[4] 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.

Fordow Fuel Enrichment Plant

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).

60 Percent Production at the FFEP. 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. The IAEA reported 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.

Pilot Fuel Enrichment Plant

New Underground PFEP. Iran 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 November 8, 2023, the IAEA verified that no additional centrifuges had been installed, but that the installation of infrastructure for the overall 18 cascades and the installation of feed and withdrawal infrastructure was on-going.

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 November 8, 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 November 8, 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.[5] 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.

Line 1. Iran was feeding natural UF_6 into an intermediate cascade of 18 IR-1 centrifuges and an intermediate cascade of 93 IR-2m centrifuges in line 1 to produce uranium enriched up to 2 percent U-235.

Lines 2 and 3. On November 8, 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 19 IR-5 centrifuges; ten IR-6 centrifuges and 19 IR-6 centrifuges; and 19 IR-6s centrifuges. Iran has not redeployed any IR-s centrifuges, which had previously been installed in lines 2 and 3.[6] The following single centrifuges were being tested with

[5] 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/.

[6] 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.

natural UF_6 but were not accumulating enriched uranium: two IR-2m centrifuges, seven IR-4 centrifuges; one IR-5 centrifuge; three IR-6 centrifuges; one IR-7 centrifuge; one IR-8 centrifuge; one IR-8B centrifuge; and one IR-9 centrifuge.

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 19,840 SWU per year, or the equivalent of 22,050 IR-1 centrifuges.

By contrast, including the installed but not yet enriching centrifuges results in an increase of enrichment capacity by 50 percent, for roughly 30,800 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 5 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	8780	15,100	16,790
Fordow	1376	2140	2370
Natanz Above-Ground PFEP*	699	2570	2860
Lines 1, 2 & 3	See text		
Lines 4, 5 & 6	See text		
Natanz Below-Ground PFEP	N/A (not enriching yet)	–	–
Total	10,855	19,810	22,020

* 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.[7] Thus, Iran continues to have enough nuclear explosive material to have assurance it can directly fashion a nuclear explosive device. 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 by extension, even WGU. Iran is practicing breakout under a civilian cover and is 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. 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.

On January 22, 2023, the IAEA detected uranium particles enriched to 83.7 percent from environmental sampling taken during a monthly Interim Inventory Verification (IIV). Iran claimed that the 84 percent level resulted from “unintended fluctuations in enrichment levels” during the transition period at the time of commissioning the process of 60 percent HEU production (November 2022) or while replacing the feed cylinder. On March 30, 2023, the IAEA indicated in a letter to Iran that, based on its evaluation, the information provided by Iran was “not inconsistent” with Iran’s explanation for the origin of these particles and that the IAEA had no further questions on the matter at that stage. The IAEA also reported 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.

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

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

The new IAEA report does not discuss additional transfers or existing stocks of near 20 and 60 percent enriched uranium at the Esfahan FPFP. The reason for the omission is not provided.

Past reports discussed Iran's transfer of 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 safeguards to detect and prevent diversion to a secret enrichment plant. It is unclear if such safeguards have been applied, such as stepped-up inspector visits, more frequent inventory verification, or camera surveillance.

Based on past reports, 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.

As of August 2023, of Iran's total stock of 121.6 kg (U mass) of 60 percent HEU at that time, about 83 percent of this stock was in storage at the FPFP. This represented an increase from the total of 60 percent of this material stored at the FPFP at the end of the prior reporting period in May 2023. Of Iran's total stock of 20 percent enriched uranium, nearly 85 percent of this stock was in storage at the FPFP at that time. The November 2023 report provides no information about the size of these stocks 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. It also should be noted that the presence of these stocks of 20 and 60 percent stocks violates the JCPOA and the amounts should be available in the IAEA report.

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 three nuclear explosives.[8]

If Iran wanted to further enrich all its 60 percent HEU up to weapon-grade, it could do so quickly, using only three to four advanced centrifuge cascades that are already installed at the PFEP and FFEP. The length of time needed to further enrich the 60 percent HEU to WGU also depends on its choice of tails assay, or the enrichment level of the "waste" material. The two most expected enrichment levels of the tails assay would be 5 percent or 20 percent enriched uranium, which would allow Iran to reuse the tails as feed in cascades making 20 percent or 60 percent enriched uranium. The penalty of using a higher tails assay is that less WGU is produced. With Iran's existing stock of 60 percent enriched uranium, and using four IR-6 and IR-4 cascades, Iran could produce about 73 kg of WGU in three weeks, if it used a tails assay of 20 percent, and 83 kg of WGU in 1.17 months, or about five weeks, using a tails assay of 5 percent. If Iran emphasized speed to obtain its first 25 kg of WGU, where a weapon is assigned 25 kg of weapon-grade uranium (U mass) (see below for a brief explanation for this choice), then it would likely prefer choosing a 20 percent tails assay, allowing Iran to have its first such quantity of WGU in about 7

[8] According to the IAEA, Iran has 128.3 kg of 60 percent enriched uranium (uranium mass) in the form of uranium hexafluoride, more than 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.

days. If Iran wanted more WGU, and chose a tails assay of 5 percent enriched uranium, then it would need about 12 days. In both cases, within the first month after breakout starts, Iran could produce almost enough WGU for three quantities of 25 kg of WGU.

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 feedstocks of enriched uranium, in particular 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 month, there would be enough of the less than 5 but greater than 2 percent enriched uranium to produce enough WGU for two more nuclear weapons, bringing the cumulative total to enough WGU for 10 weapons.

During the fourth and fifth months, there would be still enough of the less than 5 but greater than 2 percent enriched uranium to produce enough WGU for one more nuclear weapon each month, bringing the total to 11 after four months and 12 after five months.

In summary, Iran can use a fraction of its 60 percent enriched uranium to rush to its first quantity of 25 kg of WGU in as little as seven days. Its enriched uranium stocks are sufficient to make enough weapon-grade uranium for six nuclear weapons in one month, eight nuclear weapons in two months, ten in three months, eleven in four months, and twelve in five 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.[9] 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

[9] 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).

six months after it decides to build nuclear weapons, or reestablish and complete its Amad Plan infrastructure in two years, before serially producing nuclear weapons for ballistic missiles.[10]

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 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 included, 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 eight reporting periods, Iran has not produced any uranium metal at the Fuel Plate Fabrication Plant (FPFP). 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

[10] 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.

both pilot and large-scale uranium metallurgy facilities to make nuclear cores and was practicing with surrogate materials for WGU.[11]

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. The November 2023 report does not update this information, although the report implies that no new silicide fuel elements were introduced into 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 through October 9, 2023.

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 October 30, 2023, the IAEA verified that no nuclear material had been introduced into the production area.

Discrepancy at the Uranium Conversion Facility

The IAEA continued to report on a discrepancy in the inventory of natural uranium at the UCF. In the most recent NPT safeguards report, the IAEA stated that Iran provided additional information, but the IAEA needed time to assess the new information.

Background. 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

[11] *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.

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."[12]

Based on a previous IAEA report, this discrepancy represented 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,[13] 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 and mid-September 2023, the IAEA informed Iran that it did not agree with Iran's statement regarding how the discrepancy emerged. On November 8, 2023, Iran provided "updated information" that the IAEA is currently assessing, and the IAEA and Iran agreed on additional verification activities at the UCF "in the near future." Therefore, the IAEA regards the discrepancy as still requiring an urgent resolution.

[12] Laurence Norman, "U.N. Agency Confirms Iran Produced Enriched Uranium Close to Weapons Grade," *The Wall Street Journal*, February 28, 2023.

[13] This paragraph draws from the September 4, 2023 IAEA report, *NPT Safeguards Agreement with the Islamic Republic of Iran*.

Part 5: Heavy Water and Khondab (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 November 2023 report its assessment that the HWPP continued to operate during the reporting period.

The IAEA reports that as of November 7, 2023, civil construction work was ongoing on all floors of the Khondab Heavy Water Research Reactor (KHRR), or IR-20, formerly known as the Arak reactor or IR-40. Iran agreed to re-orient the reactor's design under the JCPOA. In May 2023, the IAEA reported that Iran provided an updated DIQ for the 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 conceptual design set out in Annex I of the JCPOA.

The IAEA reports observing no significant changes to the project since the previous report. 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. Iran has not communicated any formal update to the agency regarding these plans.

Part 6: Additional Protocol, Safeguards, JCPOA 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 consistently expresses doubt about understanding key aspects of Iran's nuclear activities. Without monitoring in place for two years and nine months, 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.

De-designation of Inspectors

In its NPT safeguards report, the IAEA condemns Iran's disbarring on September 16 of around one-third of the agency's key enrichment-related inspectors, calling the move "extreme and unjustified" and underscoring that this "seriously affected the agency's work." The IAEA reports, "Iran's stance is not only unprecedented, but unambiguously contrary to the cooperation that is required and expected in order to facilitate the effective implementation of its NPT safeguards agreement."

Iran reportedly disbarred experienced French and German enrichment inspectors, and perhaps inspectors from one other country (*The Wall Street Journal* reports eight inspectors were de-designated in total).[14] Iran took this action after several dozen states, led by the U.S. and Europe, signed a joint statement at the September IAEA board meeting demanding Iran's cooperation with the IAEA's five-year investigation into undeclared nuclear weapons work.

The IAEA writes, "The Director General regards the linking by Iran of statements by IAEA Member States to the withdrawal by Iran of designations of Agency inspectors with the same nationality as extreme and unjustified: it effectively makes the independent technical work subject to political interpretation of other Member States' views about Iran's nuclear activities."

Director General Grossi reports that he wrote in an October 31 letter to AEOI head Eslami that "Iran's sudden withdrawal of previously agreed designations for several Agency inspectors adversely affects the Agency's ability to conduct inspections and risks impeding the conduct of inspections…" It appears that Iran delayed addressing the matter, replying only on November 15 to the IAEA's overtures that Iran was "within its rights to de-designate agency inspectors." Eslami stated that the IAEA's assertion about impeding inspections "is not compelling and lacks any legal basis." Eslami said only that he was exploring possibilities to address the issue.

In a previous IAEA report on the matter, Grossi called upon Iran to "reconsider its decision and to return to a path of cooperation with the Agency" and in this report "expresses his hope that this matter will be resolved quickly."

Modified Code 3.1

Since February 2021, the IAEA has been seeking Iran's pledge that it will adhere to a non-voluntary provision of the subsidiary arrangements to Iran's CSA, Modified Code 3.1. The code requires Iran to provide notification and early design information when it has taken a decision to build a new nuclear facility, such as an enrichment plant. Iran illegally reverting to the original Code 3.1 means Iran believes it must provide notification to the IAEA only six months before it introduces nuclear material into a facility, which experience has taught could be when the plant is essentially operational. Iran could outfit a clandestine enrichment facility, for example and not notify the

[14] Laurence Norman, "Iran Maintains Steady Expansion of Nuclear Program," *The Wall Street Journal,* November 15, 2023, https://www.wsj.com/world/middle-east/iran-maintains-steady-expansion-of-nuclear-program-46df894a.

IAEA of the plant's existence until right before it begins operating, or not at all, if no nuclear material is introduced.

The IAEA emphasizes Iran's non-compliance with Modified Code 3.1 in its latest report, writing, "The Director General has reminded Iran on many occasions that implementation of modified Code 3.1 is a legal obligation" which Iran may not modify or suspend. The IAEA reports its concern that "Iran has made reference to having decided the locations for new nuclear facilities, for which it has not provided the Agency with preliminary design information despite having been requested to do so."

Iran had in the past expressed a readiness to work with the agency, but in a letter dated November 1, Iran informed the IAEA that "implementation of modified code 3.1 is suspended. Therefore, currently the implementation of the initial Code 3.1 is the legal obligation…and it should be noted that design information for any new facilities…will be provided in due time." The IAEA replied on November 3 acknowledging that Iran's responses indicated it "was no longer prepared to work with the Agency to find a mutually acceptable solution."

Monitoring and Surveillance Equipment

After halting implementation of the AP and JCPOA monitoring measures in February 2021, Iran agreed to continue operating IAEA monitoring and surveillance equipment installed for JCPOA monitoring purposes, but keep footage and data in its custody until it received sanctions relief. Iran pledged to continue collecting and storing 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 Natanz FEP, and the FLUM equipment installed at the HWPP. The equipment was placed in storage under IAEA seal. The IAEA noted, "This seriously affected the Agency's JCPOA-related verification and monitoring."

Cameras and Surveillance at the Natanz Centrifuge Workshops. During the September 25 meeting with Eslami, the IAEA proposed to Iran the voluntary measure of installing agency cameras in the centrifuge component workshops at Natanz and "a limited number of consistency checks" of the data stored in those cameras. Iran dismissed the request as "not acceptable."

Cameras and Surveillance at the Esfahan Centrifuge Manufacturing Plant. The IAEA reported in May 2023 that in line with the joint statement, "the Agency installed surveillance cameras at workshops in Esfahan where centrifuge rotor tubes and bellows are manufactured," although Iran has not turned over the video footage to the IAEA.

In its previous report, the IAEA reported that 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. In the latest report, the IAEA proposed to conduct consistency checks on the data stored in the Esfahan cameras, but Iran refused.

Enrichment Monitoring at FFEP and PFEP. The IAEA reported in May 2023 in the NPT report that Iran permitted the installation of enrichment monitoring devices (EMDs) at the FFEP and PFEP. The IAEA reported in its September 4 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." The IAEA reported no new information about the status of the EMDs in its latest report.

Lack of Updated AP Declarations, Complementary Access, and Enhanced JCPOA Monitoring

Due to Iran's refusal to implement the AP, the IAEA reports that it has been "two years and nine months since Iran stopped provisionally applying its Additional Protocol and, therefore, since it provided updated declarations and the Agency was able to conduct complementary access to any sites and locations in Iran."

The IAEA can no longer carry out daily visits to Iran's enrichment facilities or measure in-process low enriched nuclear material. It has not had access to data from on-line enrichment monitors and electronic seals, or access to measurement recordings registered by 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. Table B.1 in the IAEA report describes these and other reduced provisions under JCPOA enhanced monitoring.

The IAEA also reports, as it has in the past several 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 UOC. Instead, the Agency would need to establish a new baseline in relation to such production and inventories. 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 nearly three years, the IAEA cannot ascertain the total quantities of centrifuges Iran has manufactured.

Joint Statement

In a March 2023 Joint Statement, Iran and the IAEA agreed to cooperate on restoring some monitoring and on resolving safeguards issues.[15] Despite some progress on installing cameras, the IAEA reports in its November 15, 2023 NPT report that the Director General "is seriously concerned that Iran appears to have 'frozen' the implementation of the Joint Statement of 4 March 2023 for the past two reporting periods, and questions Iran's continued commitment to its implementation." During a meeting in Vienna held during the IAEA General Conference on September 25, the Director General "expressed his serious concern to Vice-President Eslami that there had been no progress in the implementation of any of the three agreed elements of the Joint Statement for several months" and that this was against the "spirit of cooperation" agreed in the joint statement. Eslami indicated that he expected "no significant progress towards implementing the Joint Statement, particularly with regard to JCPOA nuclear-related commitments, while sanctions remained in place."

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

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. For additional two sites discussed in earlier safeguards reports, the IAEA does not have outstanding questions but it concluded that undeclared nuclear materials were present or activities with nuclear weapons relevance did take place.

The IAEA states in its NPT report that "during this reporting period, Iran has not provided the Agency with any information on the outstanding safeguards issues relevant to either of the two undeclared locations." The IAEA underscores that "despite numerous resolutions of the Board and many opportunities provided by the Director General over a number of years, Iran has neither provided the Agency with technically credible explanations for the presence of uranium particles of anthropogenic origin at two undeclared locations in Iran nor informed the Agency of the current location(s) of nuclear material and/or of contaminated equipment." In an apparent call for support from the board, the IAEA notes that one year has passed since the board's November 2022 resolution demanding Iran's cooperation and Iran still "has not clarified all outstanding issues."

[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.

The two sites that remain 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 reporting).[16]

The IAEA reports that at the September 25 meeting between the IAEA and Iran, the agency requested additional information regarding the containers at Turquz-Abad "but Iran did not provide the information during the discussions, or subsequently."

In its previous report, the IAEA noted that 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 reported, "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 reported 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 previously reported that during a 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 noted, "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." During the reporting period, the IAEA requested additional information regarding the containers, but Iran refused to meet its previous pledge.

The IAEA reiterates, "The outstanding safeguards issues stem from Iran's obligations under its NPT Safeguards Agreement and need to be resolved for the Agency to be in a position to provide assurance that Iran's nuclear programme is exclusively peaceful."

[16] 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.