INSTITUTE FOR SCIENCE AND INTERNATIONAL SECURITY

Analysis of the IAEA Iran Verification and Monitoring Report

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Summary

This report summarizes and assesses information in the International Atomic Energy Agency (IAEA's) quarterly safeguards report for June 5, 2020, *Verification and monitoring in the Islamic Republic of Iran in light of United Nations Security Council resolution 2231 (2015),* including Iran's compliance with the Joint Comprehensive Plan of Action (JCPOA). The IAEA continued its important verification and monitoring mission in light of the COVID-19 pandemic, including chartering jets to fly inspectors to Iran.

Highlights of the report are:

- Iran's violations of nuclear limitations in the JCPOA continued.
- Iran's stock of low enriched uranium (LEU) grew by about 50 percent, to 2324.9 kilograms of low enriched uranium (hexafluoride mass), all enriched below 5 percent, or the equivalent of 1571.6 kilograms (uranium mass).
- Enrichment capacities did not grow at the Natanz and Fordow Fuel Enrichment Plants during this reporting period. Total enrichment capacity increased by only about five percent, reflecting the deployment of more advanced centrifuges at the Natanz Pilot Fuel Enrichment Plant.
- Breakout timelines decreased slightly from the last reporting period to an average of 3.5 months, with a minimum of at least 3.1 months. These values reflect greater certainty that Iran possesses sufficient enriched uranium to make enough weapon-grade uranium (WGU) for a nuclear weapon. Iran does not yet possess enough LEU for a second nuclear weapon, but if it did, it could produce the second one more quickly than the first.
- A companion IAEA Iran safeguards report, *NPT (Nuclear Non-Proliferation Treaty) Safeguards Agreement with the Islamic Republic of Iran*, which will be discussed in a separate Institute report, makes the startling finding: "The Agency notes with serious concern that, for over four months, Iran has denied access to the Agency, under Article 4.b.(i) and Article 5.c of the Additional Protocol, to two locations and, for almost a year, has not engaged in substantive discussions to clarify Agency questions related to the possible undeclared nuclear material and nuclear-related activities in Iran."

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Part 1: Low Enriched Uranium Stocks

The IAEA reports that Iran has continued to exceed the JCPOA's cap of 300 kilograms (kg) of low enriched uranium (hexafluoride mass), or 202.8 kg (uranium mass). On July 1, 2019, the IAEA first reported that Iran had surpassed the JCPOA's LEU stock limit by enriching 205.0 kg of LEU (uranium mass).[2] Iran also continued to enrich to 4.5 percent, in violation of the JCPOA's 3.67 percent enrichment limit. The IAEA first stated on July 8, 2019 that Iran was enriching up to a level of 4.5 percent.[3]

On May 20, 2020, the IAEA's most recent verification date, Iran possessed a total stockpile of about 2324.9 kg of low enriched uranium (hexafluoride mass), all enriched below 5 percent, or the equivalent of 1571.6 kg (uranium mass). Iran added 550.7 kg (uranium mass) to its low enriched uranium stockpile during the reporting period. As seen in Table 1, of the 1571.6 kg quantity, Iran has a stock of 873.4 kg of LEU (uranium mass) enriched above 2 percent and up to 4.5 percent, and 483.1 kg of LEU (uranium mass), enriched up to 2 percent, all in the form of uranium hexafluoride (UF6), enriched in advanced centrifuges at the Natanz Pilot Fuel Enrichment Plant (PFEP). The remainder, 215.1 kg LEU (uranium mass), is uranium enriched up to 3.67 percent before July 8, 2019. In terms of uranium hexafluoride mass, Iran possessed 1292.0 kg of up to 4.5 percent but greater than 2 percent enriched uranium, 714.6 kg of uranium enriched up to 2 percent, and 318.2 kg of uranium enriched to about 3.5 percent and produced before July 8, 2019.

Not all of the LEU enriched between 2 and 4.5 percent was produced at the Natanz and Fordow Fuel Enrichment Plants; an unstated amount was produced in advanced centrifuges at the Pilot Fuel Enrichment Plant at Natanz.

In Table 1 below, a stockpile comparison from May 2019 to May 2020 shows how Iran has increased its production of LEU throughout the year, as measured only in uranium mass. The net increase in the total stock of LEU in Iran from May 20, 2019 to May 20, 2020, was 1397.5 kilograms LEU (uranium mass), at an overall average rate of about 108.7 kilograms (uranium mass) per month. Alternatively, these values convert to 2067.3 kg LEU (hexafluoride mass), or an average of about 160.8 kg LEU (hexafluoride mass) per month.

During this reporting period, covering February 2020 to May 2020, the average production rate was about 181.4 kg per month of enriched uranium (uranium mass) and 268.3 kg per month of enriched uranium (hexafluoride mass). Average monthly production of enriched uranium is only slightly up from the last reporting period, where it was 179.6 kg per month.

Ignoring the LEU enriched less than 2 percent, the monthly rate of production during this reporting period is 111 kg per month (uranium mass) or 164 kg per month (uranium

[2] IAEA Director General, *Verification and monitoring in the Islamic Republic of Iran in light of United Nations Security Council resolution 2231 (2015)*, GOV/INF/2019/8, July 1, 2019, https://isis-online.org/uploads/iaea-reports/documents/IAEA_Iran_report_1Jul2019.pdf

[3] IAEA Director General, *Verification and monitoring in the Islamic Republic of Iran in light of United Nations Security Council resolution 2231 (2015),* GOV/INF/2019/9, July 8, 2019, https://isis-online.org/uploads/iaea-reports/documents/IAEA_Iran_report_8Jul2019.pdf

hexafluoride mass). As discussed above, a fraction of this LEU was produced in advanced centrifuges at the pilot plant.

Table 1. Enriched Uranium Quantities, less than 5 % enriched, all quantities in uranium mass*

	May 2019	**August 2019**	**November 2019**	**February 2020**	**May 2020**
Chemical Form					
UF6 (kg)	153.2	218.9	349.9	996.5	1546.7
Uranium oxides and their intermediate products (kg)	10.4	11.1	10.4	9.7	9.7
Uranium in fuel assemblies and rods (kg)	4.3	4.6	4.6	7.7	7.7
Uranium in liquid and solid scrap (kg)	6.2	7.0	7.4	7	7.5
Enrichment Level Subtotals					
Uranium enriched to 3.67 percent (kg)**	174.1	216.5	212.6	214.6	215.1
Uranium enriched up to 4.5 percent (kg) but >2%	0.0	25.1	129.2	537.8	873.4
Uranium enriched up to 2 percent (kg)	0.0	0.0	30.5	268.5	483.1
Totals of Enriched Uranium, <5% (kg)	**174.1**	**241.6**	**372.3**	**1020.9**	**1571.6**

*These totals do not include undisclosed stocks of enriched uranium exempted by the Joint Commission.
**This value has shifted slightly in the last few IAEA quarterly reports. In the two most recent reports, the IAEA attributes the difference to further processing of some of it. The reason for the discrepancy from August to November 2019 was not explained.

Part 2: Enrichment capacity

IR-1 Centrifuge Deployments at Natanz Fuel Enrichment Plant (FEP)

At the Natanz Fuel Enrichment Plant, the IAEA reported that Iran operated no more than 5060 IR-1 centrifuges in 30 cascades. Iran withdrew 96 IR-1 centrifuges from storage to replace broken ones in these cascades. During the previous reporting period, it withdrew 92 IR-1 centrifuges, and during the prior one, it withdrew 48 IR-1 centrifuges.

Fordow Fuel Enrichment Plant (FFEP)

The IAEA reported that since January 22, 2020, the Fordow plant was enriching uranium in six cascades, containing 1044 IR-1 centrifuges, in one wing of the plant, called Unit 2. An additional

13 IR-1 centrifuges were installed in Unit 2, all of them involved in initial research and development activities related to stable isotope production. In total, as of late May 2020, 1057 IR-1 centrifuges were installed in Unit 2 of the FFEP.

Advanced Centrifuges

Iran continued to take steps during the IAEA reporting period to violate the JCPOA's limitations on advanced centrifuges. The following summarizes the deployment of advanced centrifuges in the six lines at the Natanz Pilot Fuel Enrichment Plant, or PFEP, their enrichment status, and their enrichment capacity, if known, as of the last reporting period.

Iran was no longer remixing the product and tails (waste), but collecting it separately, meaning that Iran accumulated enriched uranium at the PFEP. As of May 20, 2020, 483.1 kilograms (uranium mass) of uranium enriched up to two percent had been collected from lines 2 and 3 of the six lines at the PFEP. The IAEA does not provide the average enrichment of this material, although it can be safely assumed that it varies from just above natural uranium (0.71% uranium 235) up to 2% uranium 235. (This average value matters because the amount of separative work to make, for example, a quantity of two percent enriched uranium, is several times the amount needed to make that same quantity of one percent enriched uranium.) The IAEA did not reveal how much enriched uranium was collected in lines 4, 5, and 6 of the PFEP.

Lines 2 and 3 contained a variety of centrifuge types and numbers, many accumulating enriched uranium. The following is a summary, as of the end of the last reporting period, of all the centrifuges installed in lines 2 and 3, or about 90 in total, that were accumulating enriched uranium (so far about 483.1 kg, as mentioned above):

1. Up to 20 IR-4 centrifuges in a cascade;
2. Up to 10 IR-5 centrifuges in a cascade;
3. Up to 30 IR-6 centrifuges, in a centrifuge cascade of 10 IR-6 centrifuges and another of 20 IR-6 centrifuges;
4. Up to 20 IR-6s centrifuges; and
5. Up to 10 IR-s centrifuges.

According to the IAEA report, as of June 1, Iran was testing the following single centrifuges with uranium hexafluoride in lines 2 and 3, but not accumulating enriched uranium:

1. one IR-2m centrifuge;
2. one IR-3 centrifuge;
3. two IR-4 centrifuges;
4. one IR-5 centrifuge;
5. three IR-6 centrifuges;
6. one IR-6m centrifuge;
7. one IR-6s centrifuges;
8. one IR-6sm centrifuge;
9. one IR-7 centrifuge;
10. two IR-8 centrifuges;

11. two IR-8s centrifuges;
12. one IR-8B centrifuge;
13. two IR-s centrifuges; and
14. one IR-9 centrifuge.

Iran was also accumulating enriched uranium in lines 4, 5, and 6, in redeployed IR-2m and IR-4 centrifuge cascades (164 centrifuges each) and an IR-6 cascade (135 centrifuges). The IAEA did not specify how much enriched uranium had been produced so far, or its level of enrichment. This enriched uranium is likely included in the IAEA's aggregate, reported amount of enriched uranium enriched up to 4.5 percent.

The redeployed cascades of 164 IR-2m and IR-4 centrifuges in lines 4 and 5 of the PFEP represent Iran's most successful advanced centrifuge types. When previously operated in a production-scale cascade, each IR-2m centrifuge had an enrichment capacity of about 3.7 separative work units (SWU) per year. The total cascade thus has an estimated enrichment capacity of about 607 SWU per year. This is equivalent to about 675 IR-1 centrifuges operating in production cascades, where each IR-1 is assumed to have a capacity of 0.9 SWU per year. The IR-4 has a lower capacity than the IR-2m, estimated here as ten percent lower, or about 3.3 SWU per year per centrifuge. The production cascade would have a total output of about 540 SWU per year, or equivalent to about 600 IR-1 centrifuges. These two cascades represent a total capacity of about 1147 SWU/year, or the equivalent of about 1275 IR-1 centrifuges.

Line 6 at the PFEP held 135 IR-6 centrifuges in a single cascade (up from 72 during the last reporting period). Iran stated earlier that the line will hold 164 IR-6 centrifuges in a cascade. The IR-6 has a single machine estimated capacity of 6.8 SWU per year. No recent data are available publicly on its performance in this cascade. Assuming that the cascade value would be about 90 percent of the capacity achieved by an IR-6 operating by itself, 135 IR-6 centrifuges in cascade would have an output of about 826 SWU per year, and a cascade of 164 IR-6 would have total capacity of about 1000 SWU per year, or the equivalent of about 1115 IR-1 centrifuges.

Line 1 currently holds an inoperable cascade of IR-1 centrifuges. However, Iran reportedly announced planned modifications of line 1 that include removal of the inoperable centrifuges, apparently to clear space for upcoming R&D activities.

In addition, according to the quarterly report, Tehran was violating an additional JCPOA limitation by conducting mechanical testing of centrifuges at the Tehran Research Centre and a workshop at Natanz. According to the IAEA report, "On 27 May 2020, the Agency verified that, for periods of four to ten days, Iran had conducted mechanical testing of up to six IR-4 centrifuges simultaneously, and up to ten IR-6 centrifuges simultaneously" at these two locations.

As can be seen, Iran is developing a large number of centrifuges simultaneously, an unusual practice. The centrifuges at the PFEP include: IR-1, IR-2m, IR-3, IR-4, IR-5, IR-6, IR-6m, IR-6s, IR-6sm, IR-7, IR-8, IR-8s, IR-8B, IR-s, and IR-9. No information was provided in the IAEA report on how well these centrifuges work, their failure rates, or why so many of them are being developed. Typically, a centrifuge program with such characteristics is likely failing at developing a commercially viable centrifuge, although several of these centrifuges could work adequately in a nuclear weapons program, where efficiency, low failure rates, and low cost are not priorities.

Table 2 summarizes the enrichment capacity by facility. Iran's enrichment capacity has grown from an estimated 7429 swu/yr to 7835 swu/yr during this reporting period, representing a growth of about 5.5 percent.

This total enrichment capacity represents the equivalent of 8706 IR-1 centrifuges. However, as will be noted below, this entire capacity cannot be used in a breakout capacity, since many of the advanced centrifuges are not properly organized to contribute meaningfully to a breakout.

Table 2. Number of enriching centrifuges and enrichment capacity

	Number of centrifuges	**Enrichment capacity in swu/yr**	**IR-1 equivalent**
Natanz	5060	4554	5060
Fordow	1044	940	1044
Natanz PFEP (advanced)*	553**	2342**	2602**
Lines 2&3	See text		
Lines 4,5,6	See text		
Total	**6657**	**7835**	**8706**

*The value for lines 2 and 3 of the PFEP is a rough estimate based on the use of estimated and measured values for the separative output of these centrifuges in cascades, drawn from IAEA information. The values for lines 4, 5, and 6 of the PFEP are given in the text. All of the values used to make these estimates reflect historical enrichment output values obtained by Iran prior to the nuclear deal and do not reflect current values, which are not included in the IAEA's quarterly reports.
**Twenty advanced centrifuges in lines 2 and 3 operating as single centrifuges are not included; moreover, the capacity of the ten IR-s centrifuges are not included in the enrichment capacity total due to lack of data about their enrichment output, but their contribution to the overall capacity is negligent.

Part 3: Current Breakout Estimates

The Institute's breakout calculator is used to estimate current breakout times based on Iranian LEU stocks and installed enrichment capacity, using the above values.[4]

[4] David Albright and Sarah Burkhard, "New Estimates of Iran's Breakout Capabilities at Declared Sites Using a New, Simple-to-Use Breakout Calculator," *Institute for Science and International Security,* September 3, 2019, https://isis-online.org/isis-reports/detail/new-estimates-of-irans-breakout-capabilities-at-declared-sites-using-a-new/8

In the breakout estimate, the following conditions are assumed:

- An enrichment capacity at the Natanz and Fordow Fuel Enrichment Plants, as drawn from the latest IAEA report. The enrichment contribution from advanced centrifuges at the Pilot Fuel Enrichment Plant is not included, as their use in a breakout would be complicated and likely not contribute to reducing breakout timelines;
- Only LEU stocks above two percent enriched are used. Stocks of less than two percent enriched uranium are not used, since to do so would require additional modifications of the cascades to handle the lower enrichments, likely significantly slowing or contributing only slightly, rather than speeding up breakout timelines; and
- Iran redeploys its 1000 IR-2m centrifuges, removed from the Natanz FEP prior to the JCPOA's Implementation Day; however, the rest of the centrifuges deployed are IR-1 centrifuges from Iran's existing stock. Iran may in fact deploy additional advanced centrifuges, but this effect is not included in this estimate, as none of the dozen advanced centrifuge types Iran is testing at the PFEP stands out as Iran's clear centrifuge of choice, many assessed as performing poorly.
- This breakout calculator utilizes a modified form of the well-known four-step enrichment process that was developed under A.Q. Khan for Pakistan's centrifuge program and transferred to other countries, such as Iran. Using all four steps, Iran would enrich natural uranium to 3.5 percent in step one, then to 20 percent in step two, 60 percent in step three, and finally to weapon-grade uranium in step four. Currently, Iran can achieve weapon-grade uranium in three steps, starting with its existing LEU stockpiles.

Under these conditions, the breakout calculator gives an estimate of 3.1 months, with no initial set-up time added. Doing so would lengthen the estimate to about 3.5 months. In addition to the IR-2m re-deployment, a major factor is that most of the LEU is already enriched to 4.5 percent instead of 3.5 percent, a significant change from estimates performed before the JCPOA's Implementation Day, since this one percent increase in enrichment can provide up to a 15 to 20 percent reduction in breakout time to produce 25 kilograms of weapon-grade uranium. The greater enrichment level also means that the production of 25 kilograms of weapon-grade uranium requires less LEU than if it were enriched to 3.5 percent: 900 kilograms of 4.5 percent LEU vs. 1250 kilograms of 3.5 percent LEU in hexafluoride mass. This last condition is particularly significant here, since it means that the existing amount of LEU is enough to reach the requisite amount of weapon-grade uranium without the need to also use some natural uranium to make a portion of the needed WGU. As a result, the process is strictly a three-step one instead of a three-step followed by a four-step one. This ability to use only three steps to reach weapon-grade, instead of four, is why the media often discusses a key threshold of about 1000 kg of LEU as significant.[5]

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[5] David E. Sanger and William J. Broad, "Iran Crosses a Key Threshold: It Again Has Sufficient Fuel for a Bomb," *The New York Times,* March 3, 2020, https://www.nytimes.com/2020/03/03/world/middleeast/iran-nuclear-weapon-trump.html

As discussed above, it is possible that the average enrichment level is lower than assumed in the breakout calculation. If the enriched uranium in these two stocks is assumed to have an average uniform enrichment level of 3.5 percent instead of 4.5 percent, then the breakout estimate is 3.4 months, assuming no initial set-up time. Assuming an initial set-up time of two weeks, this value increases to 3.9 months. During this reporting period, Iran's stock of LEU grew in excess of 1250 kilograms, allowing for a three-step process with 3.5 percent enriched uranium and a significantly lower breakout timeline than reported at the end of the last reporting period. If the average of the range of 3.1 to 3.9 months is used, the estimated breakout time as of late May 2020 is 3.5 months, with a lower bound of about three months.

Part 4: Other Information - Undeclared uranium particles, Arak reactor, Heavy water

In January 2019, according to the recent IAEA report, the IAEA detected "natural uranium particles of anthropogenic origin at a location in Iran not declared to the Agency." The media reported in April 2019 that the IAEA had taken the samples at an open-air warehouse in the Tehran neighborhood of Turquz-Abad, a site Israel originally revealed to the IAEA in the summer of 2018 and revealed publicly in September 2018. Over the summer of 2018, Iran removed the contents of the site and sanitized it during the subsequent months, prior to the IAEA visit.[6] Despite the sanitization, the IAEA found the uranium particles, which *Bloomberg* reported included uranium hexafluoride.[7] At least in part due to this environmental sampling result, the IAEA's investigation led it to request access to the two other sites, as described in the IAEA's separate June 5, 2020 NPT safeguards report and one prior from March 2020. As mentioned above, Iran has refused IAEA access to the sites during the last four months, triggering a safeguards crisis.

The IAEA also reports for the first time in this report that it took environmental samples at two declared sites in Iran in January 2020, "pursuant to information provided by Iran related to the possible origin of the detected natural uranium particles." The IAEA reports that its analysis of those samples has been delayed due to the temporary closure of its analytical laboratories during the COVID-19 pandemic.

The IAEA reports that Iran has not pursued construction on the Arak (IR-40) heavy water reactor based on its pre-JCPOA design. Questions remain about how far a JCPOA project with China and the UK has progressed to re-orient the reactor to a configuration producing less plutonium, operating on lower power, and using low-enriched uranium fuel instead of natural uranium fuel. The IAEA has never reported on the project's progress. Iran announced one

[6] David Albright, Olli Heinonen, Frank Pabian, and Andrea Stricker, "Revealed: Emptying of the Iranian "Atomic Warehouse" at Turquz Abad," *Institute for Science and International Security*, November 29, 2018, https://isis-online.org/isis-reports/detail/revealed-emptying-of-the-iranian-atomic-warehouse-at-turquz-abad/8

[7] Jonathan Tirone, "Iran Atomic Inspections Continued at a Record Pace Last Year," *Bloomberg,* May 5, 2020, https://www.bloomberg.com/news/articles/2020-05-05/iran-nuclear-inspections-continued-at-a-record-pace-last-year

development in December 2019, namely the start of a secondary cooling circuit, that may support the original reactor configuration and not the JCPOA design.[8]

The IAEA reports that Iran's heavy water stock was 132.6 metric tonnes as of May 11. Iran shipped out 5.1 metric tonnes of heavy water during the reporting period; the heavy water's destination was not provided in the report. Iran deliberately exceeded the JCPOA's cap on heavy water in November 2019 and the stock has remained over the limit since that time. Iran notified the IAEA that the Heavy Water Production Plant (HWPP) will be "overhauled" for about one month starting in late June.

Finally, the IAEA reports that Iran continued to use carbon fiber for centrifuge rotor tube production "that was not subject to continuous Agency [IAEA] containment and surveillance measures," as required by the JCPOA and a decision of the Joint Commission of January 14, 2016 (see INFCIRC/907).[9]

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[8] Iran Unveils Development at Arak Reactor in Face of U.S. Pressure," Reuters, December 23, 2019, https://www.reuters.com/article/us-iran-nuclear-arak/iran-unveils-development-at-arak-reactor-in-face-of-us-pressure-idUSKBN1YR0KA#:~:text=Iranian%20state%20media%20said%20technicians,the%20core%20of%20nuclear%20reactors.

[9] Relevant clauses from INFCIRC/907: "Template for Describing Centrifuge Types: Explanatory Note," II(3)(e)(v). The IAEA would verify that Iran only engages in manufacturing of centrifuge rotor tubes using the material that are drawn from the above referenced dedicated monitored storage locations for as long as Paragraph 61 of the Annex 1 of the JCPOA remains in effect, subject to the exception specified below.
II(3)(e)(v). Despite the readiness of supply, Iran may decide, consistent with the JCPOA, to manufacture centrifuge rotor tubes using its own materials of construction, provided that the IAEA has verified the technical specifications of these materials through sampling and maintained them under monitoring until their use in the manufacture of rotor tubes.