

The Road Back to the JCOPA: Analyzing Iran's Compliance and IAEA's Verification Capabilities

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1. Introduction

After the US's withdrawal from the Joint Comprehensive Plan of Action(JCPOA) in May 2018, Iran responded by gradually increasing its enrichment capacity [1][2]. Bloomberg recently published an article in February 2023 stating that IAEA inspectors had found uranium particles enriched up to 84% [3]. While IAEA has not published a statement to clarify this situation, Iran still has outstanding issues with uranium particles discovered at 3 undeclared locations since 2020 [4]. This paper seeks to examine the current state of Iran's compliance with the JCPOA by (1) chronologically analyzing Iran's nuclear activity and (2) identifying the issues around the undeclared locations (Turquzabad, Varamin, Marivan). Finally, this paper will conclude with implications for restoring the JCPOA.

2. IAEA and the Verification of the JCPOA

Verification is "the process of gathering and analyzing information to make a judgment about parties' compliance or non-compliance with an agreement [5]." Verification is achieved through 1) detection, 2) deterrence, and 3) confidence-building [5]. Monitoring is crucial in detecting non-compliance, although the effectiveness and intrusiveness may vary. Deterrence relies on parties' willingness to comply with the agreement and detection measures for violation. Finally, parties can demonstrate their compliance in an "open, official, systematic and continuing way" or may choose to include specific confidence-building measures [5].

As a member of the NPT, Iran is subject to IAEA activities regarding its safeguards agreement. When brokering the JCPOA, the IAEA was charged with monitoring Iran's compliance with nuclear-related measures for the duration of the deal. As part of the JCPOA, Iran and IAEA agreed on measures to monitor Iran's compliance by 1) agreeing to implement the Additional Protocol, which enhanced IAEA's ability to gather information, 2) allowing inspectors to investigate clandestine activities, and 3) providing the IAEA with information on the possible military dimensions(PMD) specified in the "Roadmap for Clarification of Past and Present Outstanding Issues." In return, parties of the JCPOA would gradually lift economic sanctions on Iran.

Iran also had to agree on measures that curbed its breakout time(time needed to enrich enough uranium for 1 nuclear weapon). Iran had to 1) reduce its capacity to

5,060 IR-1 centrifuges, keep enrichment levels to 3.67 percent and keep the uranium stockpile to 300kg, 2) cease enrichment activity at Fordow, and 3) reduce its supply of heavy water to 130 metric tons as well as halt construction of the Arak reactor. After US's withdrawal from the JCPOA, the IAEA continued activities in Iran and found that Iran was implementing its nuclear commitments. In 2019 however, Iran began to pursue nuclear activity that went beyond the JCPOA limitations.

3. Iran's Compliance with the JCPOA

2.1. Iran's Enrichment Capabilities

Iran has three enrichment plants: Natanz Fuel Enrichment Plant(FEP), Natanz Pilot Fuel Enrichment Plant(PFEP), and Fordow Fuel Enrichment Plant. Iran first revealed the Natanz underground Fuel Enrichment Plant in 2003 when it announced the facility was used for producing low-enriched uranium. FEP is described as being 8 meters deep in the earth with a thick concrete roof. Natanz Pilot Fuel Enrichment Plant is an aboveground building(2,800m²) for testing models of centrifuges and cascade configurations. Fordow is also an underground site and was revealed to the IAEA in 2009. Iran declared the site was designed to hold 3,000 IR-1 centrifuges and more advanced machines could be added later [5]. Iran is known to have at least 9 different models of machines(IR-1, IR-2m, IR-2, IR-3, IR-5, IR-6, IR-9), with each new model tested in the PFEP and introduced into service at FEP and Fordow [5].

2.2. Iran's Nuclear Activities Pertaining to JCPOA

Since 2019 Iran has steadily increased the quantity as well as enrichment level of its uranium stockpile [Table I]. In March 2020, Iran denied IAEA inspectors to 3 undeclared sites suspected of being part of Iran's nuclear program in the early 2000s. IAEA announced it needs to receive more information to reach a satisfactory conclusion on these sites, while Iran argues it has provided adequate information.

In December 2020, Iran passed the "Strategic Action Plan to Lift Sanctions and Protect Iranian Nation's Interests." Under this law, Iran could 1) produce and store at least 120 kg of enriched uranium of 20 percent purity level every year for peaceful purposes, 2) increase the country's monthly enriched uranium output and enrichment capacity with different purity levels for peaceful purposes by at least 500 kg, 3) start the installation, injecting uranium gas, and stockpiling

materials using at least 1,000 2m centrifuges, 4) start enrichment R&D with at least 164 IR-6 centrifuges and increase the number to 1,000 after a year [1].

In February 2021, Iran and IAEA agreed that IAEA could not access cameras installed at declared nuclear sites, but Iran would be required to save all surveillance footage for 3 months. Iran also suspended compliance with Additional Protocol but stated it would reverse these steps if the Biden administration lifted sanctions. Although IAEA and Iran extended the deadline to another month, it expired on June 24th, 2021.

On April 11th, 2021, the Natanz FEP experienced an electrical blackout one day after unveiling Iran's new uranium enrichment equipment. Iran attributed this cyber-attack as sabotage and announced its intention to enrich uranium to 60 percent. In July 2021, Iran started the process to produce uranium metal which caused the US, UK, France, and Germany to express concerns that this would be a severe violation of the JCPOA. The JCPOA prohibited the production of uranium metal as uranium metal could be used to make a nuclear weapon core.

Table I: Iran's Nuclear Activity Timeline[2]

Timeline	IAEA findings	
2019	May	Iran in compliance with the JCPOA, but stockpiles of low-enriched uranium and heavy water are increasing
	Aug	Iran began to enrich uranium to 4.5 percent (limited to 3.67 percent), and its stockpile of low-enriched uranium exceeded the JCPOA limit (limited to UF ₆ 300kg or 202 kg by weight)
	Sept	Iran used advanced centrifuges to enrich uranium with cascades installed in R&D lines 2&3 (limited to only 5,060 IR-1 centrifuges)
	Nov	Iran increased its stockpile of enriched uranium, exceeded heavy water limit of 130 metric tons, and inspectors found traces of uranium at an undeclared location
2020	Mar	Iran refused to grant inspectors access to 3 sites (suspected of being part of Iran's nuclear program in the early 2000s)
	Jun	Iran's stockpile of low-enriched uranium was 1,571.6 kg; its heavy water stockpile still exceeded JCPOA limits and blocked IAEA inspectors from accessing 2 sites (suspected of being used for storage and explosive testing of undeclared nuclear materials in the early 2000s)
	Sept	Iran's stockpile of low-enriched uranium reached 2,105 kg, and inspectors visited 1 undeclared nuclear site to take environmental samples
	Nov	Iran's stockpile of low-enriched uranium reached 2,443 kg, installed & began feeding uranium gas into 174 IR-2m centrifuges at Natanz, conducted tests of 3 IR-4 centrifuges
	Dec	Iran informed IAEA that it would install 3 new cascades of advanced centrifuges (more than 150 centrifuges per cascade)
2021	Jan	Iran began enriching uranium up to 20 percent at Fordow
	Feb	Iran enriched uranium with 5,060 IR-1 and 348 IR-2m centrifuges at Natanz; Iran informed IAEA it would install 2 new cascades of advanced centrifuges at Natanz; IAEA detected uranium particles at 2 sites (suspected of being used for storage and explosive testing of undeclared nuclear materials in the early 2000s)
	Mar	IAEA confirmed Iran began feeding uranium gas into the 3 rd cascade of advanced centrifuge at Natanz while the 4 th cascade of 174 IR-2m centrifuge was installed and the 5 th cascade of 174 IR-2m installation continued, began enriching uranium at Natanz with IR-4 centrifuges
	Apr	Iran began enriching with the 4 th cascade of 174 IR-2m centrifuges, began testing IR-9 at Natanz, and announced to IAEA that it would begin enriching uranium up to 60

		percent (total of 1,044 IR-2m and 348 IR-4 centrifuges at Natanz)
	May	Iran has enriched uranium to 63 percent; Iran and IAEA extended deal to retain surveillance footage at declared nuclear sites by one month (~June 24 th); IAEA stated Iran failed to provide the necessary explanation for the presence of uranium particles at 3 undeclared sites, IAEA estimated Iran's stockpile of enriched uranium to be 3,241 kg
	Jun	Iran announced it had produced 6.5 kg of 60 percent enriched uranium; Iran-IAEA monitoring agreement expired
	Jul	Iran started the process to produce uranium metal to enriched to 20 percent for fueling the Tehran Research Reactor
	Aug	Iran produced 200 grams of uranium metal enriched up to 20 percent, Iran added 153 IR-4 centrifuges to enrich uranium up to 60 percent
	Sept	Iran and IAEA reached a monitoring agreement that allowed IAEA to service monitoring equipment at declared nuclear facilities; Iran denied inspectors access to the centrifuge manufacturing plant at Karaj facility
	Nov	Iran denied inspectors access to Karaj facility, 170 IR-6 centrifuges were installed at Fordow
	Dec	Iran and IAEA reached a monitoring agreement that allowed IAEA to replace surveillance cameras at the Karaj facility
2022	Jan	Iran moved its centrifuge manufacturing workshop from Karaj to Isfahan
	Apr	Iran provided written explanations on IAEA questions regarding outstanding issues (undeclared locations)
	Jun	IAEA Board of Governors passed a resolution on the unexplained uranium particles to which Iran retaliated by removing 27 cameras, installed 2 cascades of IR-6 centrifuges in Natanz
	Jul	Iran announced IAEA monitoring cameras would stay off until 2015 JCPOA deal was restored
	Aug	Iran installed 3 cascades of IR-6 centrifuges at Natanz; Iran announced it would agree to the 2015 JCPOA deal if IAEA closed investigations on the uranium particles discovered at the undeclared sites
	Oct	Iran installed 1 cascade of IR-4 centrifuges and 6 cascades of IR-2m centrifuges at Natanz, had a stockpile of 3,260.8 kg of up to 20 percent (low-enriched) uranium and 62.3 kg of up to 60% enriched uranium

3. Outstanding Issues on Iran's Undeclared Sites

The 3 undeclared locations are a source of contention between the IAEA and Iran [2]. IAEA conducted complementary access, took location-specific environmental samples in each location, and found uranium particles of anthropogenic origin.

3.1. Turqz Abad

Prime Minister Benjamin Netanyahu of Israel claimed at a UN General Assembly (September 2018) that a secret Iranian warehouse in Turqz Abad held equipment and material related to Iran's past or ongoing nuclear weapon efforts. Iran denied these claims stating the site was a carpet cleaning facility. Through satellite imagery analysis and complementary access conducted in February 2019, IAEA found multiple natural uranium particles of anthropogenic origin and isotopically altered particles (including low-enriched uranium particles and slightly depleted uranium). IAEA reports concluded that containers stored in Turqz Abad either contained 1) nuclear material or 2) equipment heavily contaminated with nuclear material, 3) or both [4].

3.2. Varamin

From 1999 to 2003, Varamin was an undeclared pilot-scale plant for 1) processing and milling uranium ore, 2) conversion into uranium oxide, 3) conversion into UF₄ and UF₆ at a laboratory scale. In 2020 the IAEA took location-specific environmental samples during a complementary access. Results showed the presence of anthropogenic uranium particles consistent with uranium conversion activities. There were also indications that containers removed from Varamin were transferred to Turquz Abad. However, these activities do not explain the presence of multiple types of isotopically altered particles in Turquz Abad [4].

3.3. Marivan

In the early 2000s, Marivan was used as a high explosive testing site for Iran's nuclear weapons program (Amad Plan). Marivan was mentioned as a high explosive testing location of a prototype nuclear bomb in a 2011 IAEA report but IAEA inspectors did not have access to it [6]. In September 2019, Israel's Prime Minister revealed this location at a press conference. Sources claim Marivan was designated for testing assembled nuclear explosive devices without weapon-grade uranium (cold test) [7]. During the complementary access conducted in August 2020, IAEA took location-specific environmental samples indicating anthropogenic uranium particles in a single area of Marivan [4].

4. Restoring the JCPOA?

Compliance with the JCPOA can be determined by how effective the JCPOA was in achieving verification; through 1) detection, 2) deterrence, and 3) confidence-building measures. Detection of non-compliance was conducted by 1) on-site inspections by IAEA inspectors and 2) information revealed by other countries. As such, IAEA was able to conduct inspections of undeclared facilities and procured environmental samples to investigate these claims of non-compliance in a relatively timely manner.

The willingness to continue confidence-building measures is interlinked with the strength of deterrence. The fact that Iran's compliance with the JCPOA continued after the US's withdrawal for over a year shows that political will and resolve are crucial for an agreement's continued success. The fact that the temporary monitoring agreement between Iran and the IAEA expired due to a lack of negotiations also highlights the importance of the parties' commitment to the agreement.

Deterrence is difficult even when an agreement goes smoothly. When the US withdrew from the JCPOA, it signaled that parties no longer shared the same resolve nor will to comply with/enforce the agreement. This is shown by the fact that while Iran publically announced its increasing enrichment plans from 20 to 40 to 60

percent, concrete negotiations for the restorations of JCPOA have yet to occur.

For the new JCPOA deal to succeed, parties should also determine whether 1) Iran is more interested in demonstrating its capability as a bargaining chip for future negotiations or 2) if it is actually on the path to nuclear proliferation through higher levels of enriched uranium [8]. If it is the former, measures to enforce the continuity of the deal (confidence-building measures) must be strengthened. If it is the latter, additional measures that can delay Iran's breakout time should be considered (deterrence measures). In the JCPOA's case, it is clear that monitoring activities are effective in holding states accountable for detecting non-compliance (be it in the form of on-site inspections, national technical means, or other means). Ensuring those states do not continue towards proliferation will require a balance of detection, deterrence, and confidence-building measures.

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