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REPORT

Iran's Recent, Irreversible Nuclear Advances

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Over the last several months, Iran has continued to advance its sensitive nuclear programs, largely unhindered by weeks of Joint Comprehensive Plan of Action (JCPOA) negotiations, Iranian presidential elections, criticism from the G7, Britain, France, the United States, and the European Union (EU), and unresolved International Atomic Energy Agency (IAEA) safeguards probes.

In many ways, Iran's nuclear capabilities now greatly exceed their status in early 2016, when the JCPOA was implemented. Its breakout time, namely the time needed to produce enough weapon-grade uranium for a single nuclear weapon or explosive device, is on order of one month, rivaling breakout timelines prior to the Joint Plan of Action (JPA) in late 2014.[2] Although Iran would need more time to build a nuclear explosive devise or even longer to build a deliverable nuclear weapon, it has extensive experience in developing and manufacturing nuclear weapons and is ready to build its first one on short order.[3]

With its multiple violations of the JCPOA, Iran has reached previously uncharted territory, accumulating important new knowledge, experience, and practice, representing a significant block of nuclear capability banned to Iran by this point in time under the JCPOA. These advances not only violate the JCPOA limits, but many are irreversible, threatening to collapse the JCPOA's overall purpose of keeping Iran a certain timeframe away from being able to produce enough weapon grade uranium (WGU) for a nuclear weapon and assemble a nuclear weapon. The irreversible advances, which accelerate both Iran's WGU production and weaponization capability, have occurred mainly in three areas: (1) advanced gas centrifuge production and operation, (2) highly enriched uranium (HEU) production, and (3) uranium metal production.

Another possibly irreversible set of actions concerns Iran's illicit procurements for its nuclear programs, some of which appear to have violated the JCPOA's procurement channel provisions.

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[1] We thank Andrea Stricker, research fellow at the Foundation for the Defense of Democracies (FDD), for her thoughtful review and valuable insights.

[2] David Albright, Sarah Burkhard, and Andrea Stricker, "Analysis of IAEA Iran Verification and Monitoring Report – September 2021," September 13, 2021, *Institute for Science and International Security,* https://isis-online.org/isis-reports/detail/analysis-of-iaea-iran-verification-and-monitoring-report-september-2021.

[3] David Albright with Sarah Burkhard and the Good ISIS Team, *Iran's Perilous Pursuit of Nuclear Weapons* (Washington, DC: Institute for Science and International Security, 2021).

Iran is well known to have procured illicitly for its nuclear program, in particular perishable items for its gas centrifuge programs, namely goods that require routine replacement.[4] Recently, a German prosecution revealed that Iran has been importing goods in violation of the JCPOA's procurement channel regulations.[5]

While excess stocks of enriched uranium can be eliminated during a return to the JCPOA, these irreversible gains cannot. These gains pose a challenge to the viability of a renewed JCPOA absent additional conditions, some fiercely opposed by Iran. Collectively, these irreversible gains mean that a simple return to the JCPOA will likely yield a situation where it is no longer possible to achieve a "12-month" breakout timeline and delay progress in sensitive nuclear programs, as the accord originally promised. This leads naturally to the question of what is being negotiated as a return to the JCPOA.

Regardless of one's views of the JCPOA, any restored deal should at a minimum match what the original deal achieved and not be considerably weaker. This report is the first public assessment to provide a basis for determining whether the costs of rejoining the JCPOA outweigh the benefits. If Iran refuses necessary changes, it may be time to move beyond seeking to restore the JCPOA and move to negotiate a stronger, longer, more robust deal.

Advanced Gas Centrifuge Operation and Production

Operation of Banned Advanced Centrifuges. In addition to operating more IR-1 centrifuge cascades than permitted, with many of them in tandem to make near 20 percent enriched uranium, Iran has also been enriching uranium in full or near-full cascades of IR 2-m, IR-6, and IR-4 centrifuges, smaller cascades of IR-5 and IR-6s centrifuges, and in a variety of other individual advanced centrifuges.[6]

Since April 17, 2021, Iran has been using advanced centrifuges to produce 60 percent enriched uranium, starting with an IR-6 cascade at the Pilot Fuel Enrichment Plant (PFEP) at Natanz.[7] Since August 15, 2021, Iran has also been using an IR-4 cascade to enrich uranium from up to 5 percent U-235 to up to 60 percent U-235.

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[4] Examples include carbon fiber, pressure transducers or their subcomponents, vacuum valve subcomponents, measuring equipment, metals, vacuum pumps, helium leak detectors, and electronic equipment.

[5] "Arrest for alleged violations of the Foreign Trade Act" [Google Translation], German Federal Public Prosecutors Office, September 14, 2021, https://www.generalbundesanwalt.de/SharedDocs/Pressemitteilungen/DE/aktuelle/Pressemitteilung-vom-14-09-2021.html?nn=677796; and Spencer Faragasso and Sarah Burkhard, "Iranian Illicit Procurement Scheme to Acquire Controlled Spectrometry Systems Busted," *Institute for Science and International Security,* September 16, 2021, https://isis-online.org/isis-reports/detail/iranian-illicit-procurement-scheme-to-acquire-controlled-spectrometers.

[6] For a list of the centrifuges, see for example: IAEA, Report by the Director General, *Verification and monitoring in the Islamic Republic of Iran in light of United Nations Security Council resolution 2231 (2015)*, GOV/2021/39, September 7, 2021.

[7] Report by the IAEA Director General, *Verification and Monitoring in the Islamic Republic of Iran in light of United Nations Security Council resolution 2231 (2015),* GOV/INF/2021/40, August 17, 2021.

Iran is also implementing the ability to use IR-6 cascades more flexibly at the Fordow Fuel Enrichment Plant (FFEP), permitting them to switch more quickly between production of five and twenty percent enriched uranium. Two IR-6 cascades are being configured to accept either natural uranium or uranium enriched up to five percent, producing five percent or near 20 percent enriched uranium respectively.[8] The IAEA judged that this new configuration would enable Iran to change the "configuration of the cascades more easily."[9]

Typically, Iran's advanced centrifuges have achieved speeds less than optimal, based on the possibilities created by using carbon fiber rotor tubes. However, one of Iran's centrifuges under development, the IR-s, may be testing operation at these higher speeds.[10] Achieving these higher speeds is difficult but would allow significant increases in the enrichment output of an Iranian centrifuge.

These experiences are contributing significantly to Iran's mastery of the operation of advanced centrifuges and their use in stepwise enrichment to highly enriched uranium (see also below)

Production. Significant advanced centrifuge manufacturing has occurred, based on Iran's deployment of new advanced centrifuges, almost all in violation of the JCPOA. The exact amount remains a mystery, absent IAEA access to Iran's centrifuge manufacturing and assembly facilities. Since February 2021 Iran has refused the IAEA access to surveillance footage of centrifuge manufacturing, testing, and assembly facilities, coverage mandated by the JCPOA.[11] It is unknown when the IAEA will receive the seized camera footage Iran is keeping in custody and the extent of gaps that have developed over time in that coverage. In addition, the IAEA has reported that centrifuge assembly has occurred at sites not subject to camera surveillance. Iran started using an existing workshop at Natanz, not listed under the JCPOA, to conduct mechanical testing of centrifuges, a key step in centrifuge assembly. This likely means that this work is not subject to IAEA video surveillance and suggests that any work being done at this workshop will not be included in the set of data and recordings being held by Iran. With a degraded ability to monitor Iran's sensitive centrifuge manufacturing in 2021, arriving at a verified, credible count of the number of advanced centrifuge rotor tubes and bellows produced since February 2021 is a priority, albeit a difficult one to achieve without extensive

[8] *Verification and monitoring in the Islamic Republic of Iran in light of United Nations Security Council resolution 2231 (2015)*, GOV/2021/39, September 7, 2021, Paragraph 37.
[9] Ibid.
[10] Iranian publications list the IR-s as a subcritical centrifuge with a single machine theoretical output of about 8 SWU/yr. This compares to the theoretical output of about 4 SWU/yr for the subcritical IR-6s centrifuge. If these reports about the IR-s's output are correct, this doubling of output suggests an increase due to faster tangential speeds, an increase which scales as velocity squared. See also forthcoming Institute report surveying Iran's centrifuges.
[11] Report by the IAEA Director General, *Verification and Monitoring in the Islamic Republic of Iran in light of United Nations Security Council resolution 2231 (2015),* GOV/2021/39, September 7, 2021; and David Albright, Sarah Burkhard, and Andrea Stricker, "Analysis of IAEA Iran Verification and Monitoring Report - September 2021," *Institute for Science and International Security*, September 13, 2021, https://isis-online.org/isis-reports/detail/analysis-of-iaea-iran-verification-and-monitoring-report-september-2021.

Iranian cooperation. Without that cooperation, an independent, accurate count may no longer be possible.

Two recent incidents have diminished Iran's current ability to make advanced centrifuges. Sabotage in July 2020 destroyed Iran's production-scale advanced centrifuge assembly facility at Natanz, a facility designed to assemble thousands of advanced centrifuges each year. Iran has since begun the construction of a replacement facility in a large tunnel complex south of the Natanz enrichment complex, although commercial satellite imagery indicates that the facility is not yet operational. There was another event on June 23, 2021, targeting Iran's centrifuge manufacturing capability at a site called TABA (also known as TESA), situated near Karaj, and hosting three main workshops.[12] Commercial satellite imagery suggests that damage to one of the three warehouses was substantial. The IAEA reported in September 2021 that one of its cameras at the site was destroyed and another one was heavily damaged, confirming greater damage than Iran has admitted.[13] It is unknown whether Iran has put the Karaj facility back into operation or moved key equipment elsewhere. As a result, with unspecified damage and recovery, the impact of the attack on overall centrifuge production remains difficult to assess. IAEA Director General Rafael Grossi stated that pursuant to an agreement reached between the IAEA and Iran on September 12, 2021, Iran will permit the IAEA to service the cameras and replace the broken ones that were at the TESA/TABA centrifuge manufacturing facility, but it remains unclear when the IAEA will gain access to the camera data or how complete the video coverage is since the sabotage event.[14]

Despite these two attacks, however, Iran has continued to make, test, and assemble advanced centrifuges at smaller, preexisting or recently constructed facilities.

Iran has completed the installation of many advanced centrifuges, particularly in production-scale cascades, where each such cascade typically has about 164 centrifuges, although sometimes there are somewhat fewer and other times, there are up to 174 centrifuges. As of late August 2021, based on the September 2021 IAEA report, Iran had completed the installation of six production-scale cascades of IR-2m centrifuges and two production-scale cascades of IR-4 cascades at the Natanz Fuel Enrichment Plant (FEP), ten IR-6 centrifuges at the Fordow enrichment plant, a production-scale cascade of 153 IR-4 centrifuges and a production-scale cascade of 164 IR-6 centrifuges at the Pilot Fuel Enrichment Plant at Natanz, and a listed total of 102 advanced centrifuges of various types at the PFEP operating singly or in small cascades. Of these 102 centrifuges, 34 are IR-6 centrifuges, 32 are IR-2m centrifuges, and 10

[12] Yonah Jeremy Bob, "Iran nuclear centrifuge facility substantially damaged in attack - sources," *The Jerusalem Post*, June 24, 2021, https://www.jpost.com/middle-east/drone-attack-targets-irans-atomic-energy-organization-671834.

[13] *Verification and Monitoring in the Islamic Republic of Iran in light of United Nations Security Council resolution 2231 (2015),* GOV/2021/39, September 7, 2021.

[14] "Press Conference with IAEA Director General Rafael Mariano Grossi," September 12, 2021, https://www.youtube.com/watch?v=tgcFMzWkGjk.

are IR-4 centrifuges. In addition, there may likely be another 59 or so advanced centrifuges at the PFEP, possibly 30 IR-5 centrifuges and 29 IR-6s centrifuges producing enriched uranium.[15]

In total, the IAEA has verified the installation of approximately 1741-1800 advanced centrifuges in Iran.[16] Almost all of these were installed in violation of the JCPOA.

In addition, Iran has announced its intention to install many more production-scale advanced centrifuge cascades. At the Natanz FEP, Iran has declared to the IAEA that it plans to install four more IR-4 centrifuge production-scale cascades and a single production-scale IR-6 cascade. At the Fordow enrichment plant, Iran plans to install two production-scale IR-6 cascades.

Iran has also told the IAEA that it plans to greatly expand the PFEP at Natanz, increasing the number of cascades from six to 18. However, no details are available on the number or type of centrifuges Iran intends to install there.

Iran's December 2020 nuclear legislation requires the installation of a total of 1000 IR-6 centrifuges by the end of 2021, implying the construction of another one or two IR-6 production-scale cascades. According to a *Mehr News* report, recently appointed Atomic Energy Organization of Iran (AEOI) head Mohammad Eslami told the Iranian parliament that "the Parliament's legislation will act as a base for the future activities of the AEOI."[17] A member of parliament confirmed: "Since the beginning of the implementation of the law, the Article 90 Committee has seriously monitored the implementation of this law and is still determined to pursue it."[18] To meet this legal obligation, Iran has likely been producing IR-6 centrifuge components far in excess of those already contained in the centrifuges installed at Natanz and Fordow.

Ignoring any new centrifuges at the PFEP in the coming months, these plans would add another 1312 to 1476 advanced centrifuges to the number already installed in the coming months. Combining installed and planned centrifuges, the total number of centrifuges is 3053 to 3276.

In addition to the parts needed for planned centrifuges, Iran may have produced a surplus of centrifuge rotors, bellows, and other sensitive parts. Knowing the number produced is further complicated by Iran's secret illicit procurements for its sensitive nuclear programs. With

[15] The September 2021 report omits the number and type of centrifuges operating in line 1 of the PFEP but provides the amount of enriched uranium produced by this line. The February 2021 IAEA report lists the numbers in the text.

[16] This estimate assumes that a production-scale cascade has 164 centrifuges, unless otherwise specified in the IAEA reports or by Iran.

[17] "No one can stop progress of Iran's nuclear program: Eslami," Mehr News Agency, September 15, 2021, https://en.mehrnews.com/news/178704/No-one-can-stop-progress-of-Iran-s-nuclear-program-Eslami.

[18] "Parliament Article 90 Committee reviewing new cooperation agreement with IAEA: MP," The Tehran Times, September 15, 2021, https://www.tehrantimes.com/news/465121/Parliament-Article-90-Committee-reviewing-new-cooperation-agreement.

regards to its centrifuge program, Iran's illicit imports of raw materials such as carbon fiber, high strength aluminum, and maraging steel are not fully known.[19]

The result of Iran's activities is that it is not possible today to know—or more importantly verify—how many sensitive centrifuge components Iran has made and how many centrifuges it has assembled since early this year. Knowing these are critical in verifiably determining the total number of centrifuges that could be used in a potential future breakout, including a clandestine breakout involving production of weapon-grade uranium at undeclared facilities. Given the known enrichment outputs of the IR-6 centrifuges, a covert breakout using hidden centrifuges could occur in a relatively small clandestine facility.

Considering only known advanced centrifuges and ignoring for the moment the real possibility of the existence of large numbers of undeclared advanced centrifuge components, the new advanced centrifuges, whether installed or stored, are adding significantly to Iran's enrichment capacity. Absent their destruction or removal from Iran, they must all be assumed to be usable or deployable during a breakout. A mistake in the original JCPOA implementation period was to assume that Iran's stored IR-2m centrifuges, which numbered about 1000, could not be used in a breakout. Iran proved the fallacy in that assessment by re-deploying these IR-2m centrifuges during the centrifuge program's recent build-back.

Highly Enriched Uranium Production

Stocks of enriched uranium are easily blended down or shipped out of Iran, allowing the reestablishment of the JCPOA's enriched uranium limits. Yet, this is not the case regarding Iran's newly gained experience in making highly enriched uranium.

Iran has been producing 60 percent HEU, the closest in enrichment level it has got so far to 90 percent enriched uranium, or weapon-grade uranium, the most desirable enrichment level for nuclear weapons and a short dash from 60 percent material. Since it started producing at this enrichment level in April 2021 until the end of August, Iran generated a stock of 10 kilograms (uranium mass) or 14.8 kg (uranium hexafluoride (UF_6) mass) of 60 percent enriched uranium, and at the end of August, it was increasing this stock at the rate of 2.3 kg per month (uranium mass).[20]

This amount of HEU could be further enriched to 90 percent in one centrifuge cascade in a few short weeks or even days if two cascades were used. Upgrading to weapon-grade is quick, because in terms of separative work, production of 60 percent enriched uranium represents 99

[19] See, for example, Case 12.1 and 12.2 in David Albright, Sarah Burkhard, Spencer Faragasso, Linda Keenan, and Andrea Stricker, *Illicit Trade Networks - Connecting the Dots*, *Volume 1,* (Washington, DC.: Institute for Science and International Security, 2020). Available at https://isis-online.org/uploads/isis-reports/documents/Illicit_Trade_Networks_Vol1_Connecting_the_Dots_February_2020_FINAL.pdf.

[20] *Verification and monitoring in the Islamic Republic of Iran in light of United Nations Security Council resolution 2231 (2015)*, GOV/2021/39, September 7, 2021; and "Analysis of IAEA Iran Verification and Monitoring Report - September 2021."

percent of the work needed to produce weapon grade uranium. Moreover, this enrichment to weapon-grade could proceed in parallel to other centrifuge cascades further enriching near 20 and five percent enriched uranium up to the level of weapon-grade. In this manner, Iran is further shortening its breakout timelines. The production of ten kilograms of 60 percent in effect allows a 20-25 percent reduction in breakout timelines, compared to a situation of only possessing up to 5 and up to 20 percent enriched uranium.

Often lost in the debate is that 60 percent enriched uranium can be used directly in a nuclear explosive, although 90 percent HEU, or WGU, is preferred, because less material is needed for a given explosive yield. In terms of a simple extrapolation from 25 kg of weapon-grade uranium, Iran now has about one quarter of what it would need to produce one nuclear explosive fashioned from 60 percent HEU, factoring in losses and known Iranian nuclear weapon capabilities. With further design improvements, significantly smaller amounts of 60 percent enriched uranium would suffice, but Iran's past, known nuclear weapons efforts have not demonstrated a capability for such significant reductions in total mass. Adding in expected losses, a reasonable estimate for Iranian capabilities would settle on the 40 kg value, with a recognition that less is possible, as with the case of weapon-grade uranium.

While a new deal would be expected to require the elimination of this dangerous HEU stock, its production has enabled Iran to learn critical information about producing HEU in its cascades. Overall, Iran must be recognized as able to breakout faster and more efficiently than it could do prior to these accomplishments.

For example, Iran has experimented with faster, more efficient production of 60 percent HEU, starting with 5 percent enriched uranium. It has learned how to skip a traditional enrichment step, making the production of HEU more efficient. Iran is learning how to use a cascade declared for production of low enriched uranium to make HEU, without conducting noticeable cascade re-configurations. This advancement may mean that Iran can now make 90 percent enriched uranium directly from 20 percent enriched uranium.

Iran is also practicing re-enriching tails from 60 percent production, resulting in new feedstock that can be more easily and efficiently reused, contributing further to more efficient HEU production and reduced breakout timelines for the production of successive weapon's quantities of weapon-grade uranium.

Moreover, the 60 percent HEU can stand in for weapon-grade uranium hexafluoride during production, handling, and storing. Further, along with 20 percent enriched uranium, the 60 percent enriched uranium could provide an important surrogate material for weapon-grade uranium during conversion experiments, metallurgy, or weaponization tests.

Uranium Metal Production

On August 16, 2021, the IAEA reported that Iran has produced 200 grams of uranium metal enriched to 20 percent enriched uranium. Iran reduced the uranium to its metal form starting

with 257 grams of uranium tetrafluoride (UF_4).[21] Assuming this number is in uranium mass, the uranium recovery rate was 78 percent.

Uranium metal production is significant due to its strong nuclear weapon's application and the lack of a credible civilian application. Following the first IAEA reporting that Iran had started to produce natural uranium metal in February 2021, the United States and European powers released a statement condemning the move.[22]

This new development of using 20 percent uranium instead of natural uranium increases concern about Iran's current trajectory. Twenty percent enriched uranium can stand in for HEU, including weapon-grade uranium, during the production process and the metallurgy that may follow. The same equipment with only minor modifications may be able to process weapon-grade uranium, from conversion of uranium hexafluoride to uranium tetrafluoride and further into metal.

Iran has also added additional uranium conversion steps to its set of established current nuclear weapons capabilities. While Iran could produce natural uranium metal directly from UF_4 produced at Esfahan, the 20 percent enriched uranium had first to be re-converted to UF_4 from the uranium hexafluoride produced at the enrichment plant.

Iran's conversion process involved at least three steps and three intermediate products. On June 23, 2021, Iran had informed the IAEA that it would transfer 20 percent enriched UF_6 from Natanz to the Fuel Plate Fabrication Plant (FPFP) at Esfahan. It converted the UF_4 first to uranyl fluoride (UO_2F_2) and then to ammonium uranyl carbonate (AUC). AUC was converted further to uranium dioxide (UO_2) powder at the R&D laboratory of the Uranium Conversion Facility at Esfahan. Finally, on July 6, 2021, Iran informed the IAEA that it would transfer the 20 percent enriched UO_2 to the R&D laboratory at the FPFP, where fluorination to UF_4 would occur.

While the AEOI has had plans to have a UF_6 to UF_4 conversion capability at Esfahan since at least 2009, when it submitted design information to the IAEA that included intended production of low enriched uranium metal and of depleted uranium metal,[23] Iran is not known to have actually installed or operated an enriched uranium UF_6 to UF_4 conversion line at Esfahan, or elsewhere. Although Iran likely conducted small-scale operations—some likely secret as part of the Amad Plan—Iran did not build a production-scale facility to convert 20 percent enriched uranium hexafluoride to tetrafluoride form or make enriched uranium metal.

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[21] Report by the IAEA Director General, *Verification and Monitoring in the Islamic Republic of Iran in light of United Nations Security Council resolution 2231 (2015),* GOV/INF/2021/39, August 16, 2021.
[22] "Joint Statement by the Secretary of State of the United States of America and the Foreign Ministers of France, Germany, and the United Kingdom," February 18, 2021, https://www.state.gov/joint-statement-by-the-secretary-of-state-of-the-united-states-of-america-and-the-foreign-ministers-of-france-germany-the-united-kingdom/.
[23] Report by the IAEA Director General, *Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions,* GOV/2010/10, February 18, 2010, https://www.iaea.org/sites/default/files/gov2010-10.pdf.

While excess uranium metal can be rendered unusable or removed from Iran, the new knowledge and experience cannot be erased.

Compensating Actions

Some compensating actions are needed, and specifically, compensating nuclear restrictions, if the main goals of the JCPOA are to remain intact in any further negotiations. Keeping certain sanctions to compensate for the irreversible gains is an option, however, it appears to be one that will lead to a significantly weaker nuclear deal, with some economic losses for Iran, but likely not enough to bring Iran back to the negotiating table at a later point.

Several recommended compensating nuclear restrictions follow.

If the goal is to ensure Iran would need twelve months to achieve a breakout, several compensating steps are necessary beyond eliminating stocks of enriched uranium banned by the JCPOA and reimplementing the Additional Protocol. With respect to the advanced centrifuges, a return to the JCPOA should mandate the destruction or removal from Iran of the excess advanced centrifuges and components. The former includes today about 1800 centrifuges; this number could grow to over 3000 in the coming months. Mothballing, i.e., disassembling and storing these centrifuges, would prevent a revived deal from achieving a breakout timeline of twelve months. Assuming the mothballing of 6 IR-2m production-scale cascades, two IR-6 production-scale cascades, and four IR-4 production-scale cascades would reduce breakout timelines to somewhat less than six months, where these cascades would be re-established at both Fordow and Natanz at a rate of two cascades each per month, so four cascades in total per month. If Iran installed only two cascades per month in total at both sites, the breakout timeline would lengthen to about 6.5 months. If Iran deployed a total six IR-6 centrifuge cascades, the breakout timeline would drop to 5.3 months. These calculations ignore Iran's demonstrated capability to rapidly build back its centrifuge production programs, meaning that in latter months of the breakout to a first nuclear weapon, Iran could deploy newly produced advanced centrifuge cascades, speeding up its production of enough WGU for the second, third, and fourth nuclear weapons. Add-on measures, such as supplementing the cascade disassembly with the removal of additional equipment, for example, electronic or power equipment, would be unlikely to significantly shift the breakout timeline, given Iran's capability to duplicate equipment at sites outside the IAEA and JCPOA verification arrangements.

Because of the risk that Iran has accumulated a stock of undeclared sensitive centrifuge components and assembled centrifuges, which could significantly reduce breakout timelines, any sanctions relief should await the IAEA's verification of Iran's declaration of advanced centrifuges, ensuring it is both complete and correct. This verification will inevitably require Iran to provide information about its raw materials and equipment relevant to centrifuge production and assembly.

Iran should be required to declare all procurements for its nuclear programs since May 2018 and any illicit ones prior to that date and after January 2016. The IAEA should be asked to verify that the declaration is complete. This exercise would contribute importantly to determining the completeness of Iran's declaration of advanced centrifuges and their sensitive components.

Additional limitations on centrifuge manufacturing and advanced centrifuge R&D are needed, reflecting irreversible Iranian advances over multiple years. A three-year moratorium on any centrifuge R&D or production would offer partial compensation for Iran's violations of JCPOA limitations in these two areas. Likewise, this moratorium should include a halt to construction of the new pilot enrichment plant at Natanz and all centrifuge manufacturing or assembly facilities or capabilities.

Equipment used to make highly enriched uranium should be destroyed. This could include smaller feed and withdrawal systems, smaller diameter piping, and other equipment to address criticality or low-uranium-flow issues.

Compensating for uranium metal production is difficult to envision, but a removal from Iran or destruction of all major equipment associated with enriched uranium metal production appears appropriate.

Negotiations must ensure that the IAEA is able to determine that Iran's nuclear declaration is complete under its comprehensive safeguards agreement, a declaration the IAEA conclusively views as incomplete today.[24] Without this determination, the IAEA is unable to determine if Iran's nuclear program is peaceful or if it has an on-going nuclear weapons program. Moreover, the current situation, where Iran is succeeding in essentially ignoring its safeguards obligations and the IAEA's rules, is calling the IAEA's credibility into question. While a complete IAEA assessment may not be possible in the next months, Iran needs to demonstrate significant substantive *progress* on this issue rather than mere willingness to meet or negotiate.

Conclusion

Iran's activity this year must be viewed as practicing breakout to make enriched uranium for use in nuclear weapons. It is learning to make such material more quickly and developing valuable experience in doing so. Overall, Iran is able to breakout faster and more efficiently than it could prior to these accomplishments.

In a return to the JCPOA, it is not sufficient to only arrange the removal or down-blending of uranium stocks with enrichment levels above 5 percent low-enriched uranium, the downsizing of Iran's large 5 percent LEU stock, and storage and mothballing of advanced centrifuges. Other steps are necessary.

[24] For background on the Iranian nuclear weapon sites and materials being discussed in the IAEA reports and the significance of the IAEA's findings, see *Iran's Perilous Pursuit of Nuclear Weapons.*

Gained breakout experiences and advances in centrifuge operation and production complicate returning to the JCPOA, since those experiences and advances cannot be destroyed or removed. These gains have been made over multiple years and are not addressed by a simple return to the JCPOA. In essence, a revived JCPOA without compensation for the irreversible gains in nuclear capabilities in the areas discussed above would constitute a new, weaker deal. Without modifications, that deal would be unlikely to achieve a 12-month breakout timeline or maintain the types of delays in Iran's nuclear advancements that the JCPOA promised originally.

The achievement of the compensatory actions discussed above is recognized as difficult, but Iran's recent nuclear gains call for a response beyond trying to reestablish a past that no longer solves the problems posed by the Iranian regime's nuclear program today. If Iran is unwilling to institute necessary changes, the U.S. and European strategy should shift from seeking the restoration of the JCPOA to one striving the negotiation of a stronger, longer, and more comprehensive agreement. The current pause in negotiations offers a welcome reprieve to reconsider a U.S. and European strategy, which so far must be judged in hindsight as a rush to a worse deal.