

If Time Runs Out Again: Implications of Iran's Nuclear Escalation



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Executive Summary

Time may again start running out to address the Iranian nuclear problem. In response to the U.S. withdrawal from the Joint Comprehensive Plan of Action (JCPOA) last year, Tehran declared on May 8 it would initiate certain violations of the deal, with further violations beginning July 7 and every sixty days thereafter, unless the remaining parties offset U.S. sanctions. On July 1, Iran officially began the process of violating the agreement by exceeding the limit on its low enriched uranium (LEU) stockpile.¹

These steps could begin reducing the “breakout time” Iran needs to produce enough fissile material for a nuclear weapon. These actions not only demonstrate just how reversible the JCPOA’s constraints are, but also indicate where Iran could apply additional pressure by moving even closer to nuclear weapons capability – most effectively and worryingly by expanding its uranium enrichment capacity.

Building on years of analysis of Iran’s nuclear program and diplomatic, economic and military options to address it, including what we considered to be an untenable agreement in the form of the JCPOA, our task force has assessed the potential effects of Iran’s stated moves on its progress toward a bomb, as well as the likelihood, impact and indications of further escalatory steps it could take.²

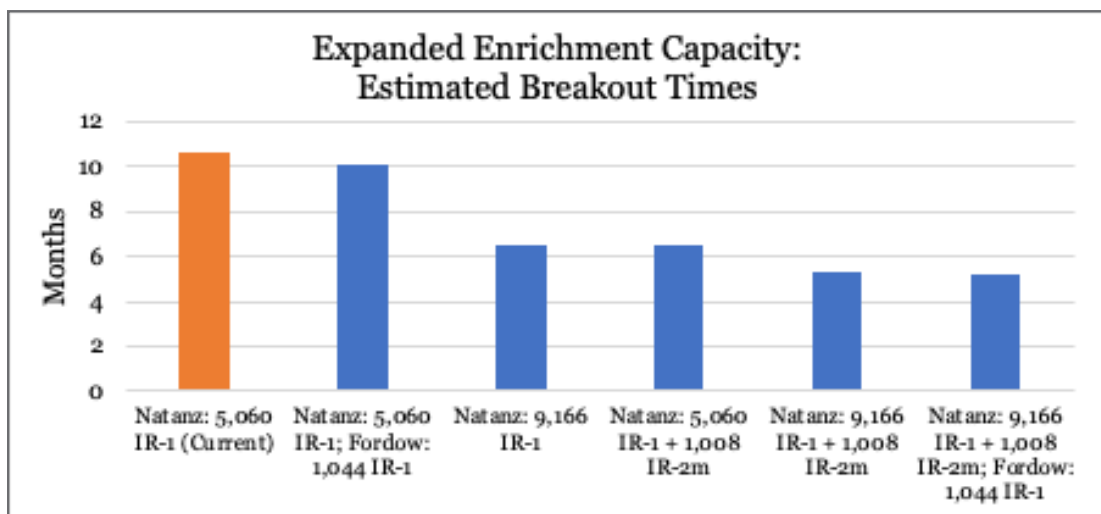
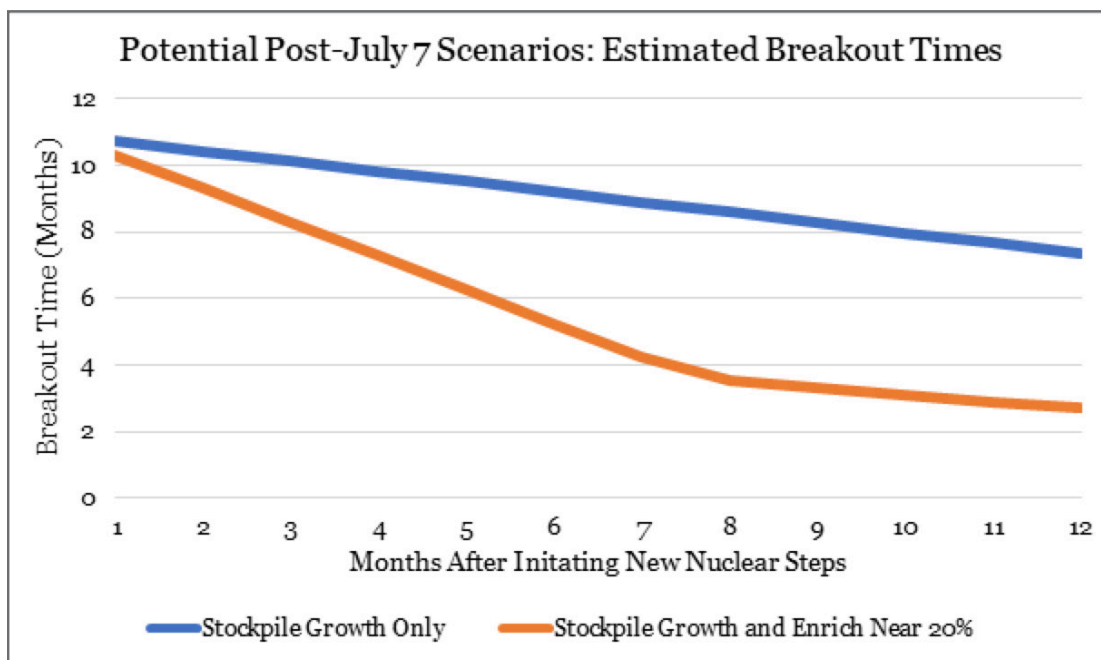
Of the steps already taken or threatened by Iran, we assess:

- By itself, Iran’s May 8 decision to grow its 3.67 percent LEU stockpile could shrink its breakout time steadily and significantly, but not precipitously.
 - Breakout time will shrink more rapidly as Iran also fulfills its July 7 threat to enrich beyond 3.67 percent LEU, to the point where inspectors might struggle to detect a breakout attempt less than one year from when Iran would start enriching near-20 percent LEU, if it chooses to do so.
- By itself, Iran’s May 8 decision to grow its heavy water stockpile will not advance its ability to produce a nuclear weapon via plutonium.
 - However, this stockpile likely would suffice to restart the plutonium path to a bomb, if Iran also fulfills its ongoing threats to abandon the JCPOA-approved heavy water reactor project at Arak and revert to the initial design.
 - While highly problematic, Iran likely would still need considerably longer to produce fissile material via plutonium compared to uranium, given common estimates that Iran would need several years to bring the reactor online.³

Of prospective steps Iran could take in addition to those above, we assess:

- On the uranium path, Iran could exert the most pressure by cutting its breakout time immediately and markedly through expanded enrichment capacity.
 - The likeliest and most feasible options would be reinstalling centrifuges removed under the JCPOA, including more advanced IR-2m machines than it currently operates, and restarting uranium enrichment at its deeply-buried Fordow facility.

- Though less likely to cut breakout time quickly, Iran could also attempt to deploy even more advanced IR-6 and IR-8 centrifuges currently confined to research and development (R&D).
- On the plutonium path, Iran could pursue two primary pressure points in parallel, though they would impact far less quickly than if it expands enrichment capacity.
 - Iran would have to make the original reactor operational, including by inserting a duplicate of the original part of the reactor that holds nuclear fuel (calandria) and by producing natural uranium reactor fuel.
 - It also would need to conduct R&D to reprocess spent reactor fuel into weapon-grade plutonium.



Given its track record of undeclared nuclear facilities, the possibility that Iran also is currently, or would start, engaging in covert nuclear activities cannot be ignored. Nor can the prospect of secret collaboration with North Korea, especially given the two countries' shared history on this score. Such activities could shorten Tehran's path to nuclear weapons capability significantly, including possibly helping it achieve an undetectable breakout (or "sneakout") capability.⁴

Unless Iran's breakout time shrinks to something near 3-4 months, or it conducts covert activities, inspectors from the International Atomic Energy Agency (IAEA) conceivably would detect and report these actions. Therefore, Iran could also exert pressure through actions to reduce the transparency of its nuclear program, and by extension the outside world's ability to detect any breakout attempt:

- Initial steps could include ending implementation of the Additional Protocol and/or Modified Code 3.1 to its IAEA Safeguards Agreement, adherence to both of which is required by the JCPOA.
- A more egregious step would be to eject inspectors or otherwise end compliance with its IAEA Safeguards Agreement, adherence to which is stipulated by its being party to the Non-Proliferation Treaty (NPT).

Finally, as its leading officials have threatened, Iran could also leave the JCPOA and potentially the NPT altogether. By itself, the former would not put Iran any closer to a bomb, but rather signal the resumption of many activities that placed it on a clear path to nuclear weapons capability before the interim Joint Plan of Action in 2013, while at the same time reducing transparency. The very fact Iranian officials are threatening to withdraw from the NPT gives the lie to frequent statements by Iranian leadership and their supporters that there is a fatwa against developing nuclear weapons and that Iran's nuclear activities are for peaceful purposes. Formally withdrawing from the treaty would strongly suggest an intention to achieve nuclear weapons capability, perhaps imminently.

As Iran takes its preparatory steps, the United States should take its own steps to deter or deny any potential Iranian breakout. American policymakers should make clear they will use whatever tools necessary to prevent Tehran achieving sneakout capability.

Furthermore sanctions, while clearly impacting Iran's economy, are less likely to compel Tehran to change course than when the United States backs up red lines with credible military options. These should include viable contingency plans to neutralize Iran's nuclear facilities and nuclear-capable missiles, increased forward military posture, coordination with regional allies to defend against Iranian retaliation, as well as public declarations and joint exercises in each of these areas to make U.S. intentions and capabilities abundantly clear to Tehran.

Pathway to a Bomb: Uranium

JCPOA Background and Parameters

The time required to enrich enough fissile material for a nuclear weapon (“breakout time”) is a function of multiple factors, and the JCPOA’s advocates argued that it extended Iran’s breakout time from an estimated 2-3 months to closer to one year by reducing or capping each of these factors, albeit temporarily and reversibly.⁵

Factor 1 – uranium enrichment level:

- JCPOA: until October 2030, no enrichment of uranium beyond 3.67 percent.
- Low enriched uranium (below 20 percent), or “LEU,” is suitable for nuclear reactors, while anything above this threshold is considered high enriched uranium (HEU) suitable for weaponization.⁶
 - Most nuclear devices require roughly 90 percent HEU for a critical mass small enough to fit into a warhead.
 - Despite the much greater increase in enrichment level, going from 3.67 percent LEU to 90 percent HEU requires only half as much effort as getting to 3.67 percent LEU from 0.7 percent unenriched uranium hexafluoride (UF₆).

Factor 2 – uranium stockpiles:

- JCPOA: until October 2030, Iran’s stockpile of 3.67 percent LEU cannot exceed 300 kilograms (kg).
 - This reduced Iran’s 3.67 percent LEU stockpile by 97 percent, leaving it well short of enough LEU to enrich into a bomb.
- However, the JCPOA does not restrict Iran’s stockpiles of yellowcake or unenriched uranium, even though these provide the source material for enrichment.
 - Iran’s ability to produce unenriched uranium actually has grown under the JCPOA, since Iran can exchange its excess LEU stockpiles for yellowcake from abroad, which it can then convert into unenriched uranium.
 - June 2018: Iran announces it has resumed production of unenriched uranium.⁷

Factor 3 – centrifuges:

- JCPOA:
 - Until October 2025, Iran can operate no more than 5,060 IR-1 centrifuges in no more than 30 cascades for uranium enrichment at Natanz.
 - Until October 2030, Iran cannot enrich uranium at Fordow, and it can retain no more than 1,044 IR-1 centrifuges at the facility for medical and industrial R&D.
 - Beginning March 2024, Iran can steadily conduct more enrichment R&D on more advanced centrifuges, and eventually can deploy them for enrichment.

Iran's Declared Actions

- May 8, 2019: Iran says it will keep its excess 3.67 percent LEU, rather than export it as agreed under the JCPOA.⁸
 - June 17: Iran declares it has quadrupled its production of 3.67 percent LEU and it will soon exceed the JCPOA's 300 kg limit (which it does by July 1).⁹
 - Based on IAEA reports, even a quadrupling of this rate would leave plenty of operational infrastructure for additional enrichment, including to levels higher than 3.67 percent LEU.
- Iran also says on May 8 it is prepared to enrich above 3.67 percent LEU by July 7.¹⁰
 - Iran's Atomic Energy Organization (AEOI) says it needs to produce 5 percent LEU for its Bushehr nuclear power plant, and near-20 percent LEU for its Tehran research reactor, even though agreements already exist for Iran to receive outside shipments for these fuel supplies.¹¹
 - Iran enriched LEU to near-20 percent in 2010-13.

Implications of Iran's Actions

The two steps announced on May 8 will not drastically reduce Iran's breakout time overnight; instead, they can be expected to cut breakout time steadily and significantly over months, to the point where a breakout attempt could be difficult to detect less than one year from the point it would begin enriching near 20 percent, if it chooses to do so.

- To have enough equivalent material for a bomb, Iran would need to increase its stockpiles of 3.67 percent LEU significantly, and this requires much more time and effort than enriching to higher levels.
- As long as Iran still adheres to JCPOA caps on centrifuges, its limited enrichment capacity will impose tradeoffs between increasing its existing stockpiles and enriching to higher levels.

Taking both steps together will reduce breakout time more quickly than just growing its 3.67 percent LEU stockpile:

- Prior to increasing its production rate of 3.67 percent LEU, Iran's estimated breakout time was roughly 11 months, and very possibly longer.
 - If Iran maintains the new production rate of 3.67 percent claimed by its officials, one year from now its estimated breakout time would be at least 7-8 months.¹²
- By comparison, if Iran maintains this new production rate and devotes the rest of its JCPOA enrichment capacity to producing 19.75 percent LEU, one year later its estimated breakout time could be as little as 2-3 months (though possibly longer).

Possible Next Step: Increase Enrichment Capacity

More, and better, centrifuges – If, in addition to its declared steps, Iran also expanded its enrichment capacity by installing and operating more centrifuges, its breakout time would decrease significantly – and also immediately.

Prior to the JCPOA, Iran had 19,466 total installed centrifuges, of which:

- 9,166 were operational IR-1 machines at its Natanz enrichment facility;
- 1,008 were installed IR-2m machines at Natanz that were not enriching.
 - The IR-2m is estimated to be 4-5 times as efficient as the IR-1.¹³
- Assuming Iran would choose to reconstitute any or all of its pre-JCPOA enrichment capacity, upon completion of these steps its breakout time would shrink at once:

BREAKOUT TIME UNDER EXPANDED ENRICHMENT CAPACITIES	
No change at Natanz, but also enrich at currently-configured Fordow	~10 months
No change in IR-1 at Natanz, but reinstall and enrich with IR-2m	6-7 months
Return to pre-JCPOA output at Natanz	6-7 months
Return to pre-JCPOA output at Natanz, and enrich with IR-2m	5-6 months
Pre-JCPOA output at Natanz, enrich with IR-2m, and Fordow	5-6 months

Accelerated enrichment R&D – Iran could also expand enrichment capacity by using even more advanced IR-6 and/or IR-8 centrifuges, though currently its ability to do so appears limited given small quantities of machines and R&D challenges:

- This would entail violating its enrichment R&D plan – agreed in secret as part of the JCPOA but since made public – which restricts Iran to testing roughly 10 each of the IR-6 and IR-8 until roughly October 2023 and prohibits Iran using these tests to accumulate enriched uranium.¹⁴
 - As of May 2019, Iran has installed only a small number of advanced centrifuges – including 33 IR-6 and 1 IR-8 machine – though the former potentially violates its enrichment R&D plan.¹⁵
- Moreover, while the IR-6 and IR-8 are estimated to be roughly 8 and 16 times as efficient as the IR-1, respectively, recently Iran appears to have faced significant performance problems when testing these advanced models.¹⁶
- Despite the current problems and limited size of its enrichment R&D program, any declaration by Iran or detection by the IAEA of significantly increased testing on advanced centrifuges, including accumulating enriched uranium, could threaten further reductions in breakout time.

New enrichment facilities – Iran could also construct additional enrichment facilities, overtly or covertly, or announce plans to build such a facility. Notably, its enrichment plants at Natanz and Fordow were built secretly in violation of its NPT obligations.

Indicators of Renewed Path to a Bomb

Iran would have to undertake multiple actions to decrease its breakout time in any of the above ways, most but not all of which would entail further JCPOA violations. These steps, most all of which would be subject to IAEA scrutiny, can be pursued in parallel and are not mutually exclusive. The more steps Iran would pursue, and the greater extent to which it would pursue them, the greater the expected reduction in estimated breakout time.

Actions to increase LEU stockpiles, including possibly 19.75 percent LEU:

- Halting or reducing measures stipulated by the JCPOA to maintain Iran's 3.67 percent LEU stockpile under 300 kg, including:
 - Selling excess 3.67 percent LEU abroad, and/or
 - Down-blending 3.67 percent LEU to unenriched uranium.
- Reinstalling interconnectors between cascades at Natanz and/or Fordow:
 - Though not absolutely necessary for higher enrichment levels, this would strongly indicate Iran is preparing to enrich near 20 percent and possibly to weapon-grade.¹⁷
 - Iran used such "tandem cascade" configurations, which help enrich uranium to higher levels more efficiently than in separate cascades, when it enriched LEU to near-20 percent in 2010-13.
- Increasing conversion of yellowcake to unenriched uranium:
 - June 2018: Iran resumes production of this feedstock for uranium enrichment, for the first time since August 2009.¹⁸
 - While the deal requires Iran to report and allow the IAEA to verify yellowcake production and stockpiles, under the JCPOA the IAEA has stopped providing specific quantities in its quarterly reports.
 - Nevertheless, Iran is commonly estimated to possess multiple bombs' worth of yellowcake already.
 - The more rapidly Iran would seek to cut its breakout time using possible combinations of the above steps, the greater its need for yellowcake conversion.
 - The increase in unenriched uranium production that is needed to quadruple Iran's output of 3.67 percent LEU is at least an order of magnitude smaller than if it were preparing to enrich enough fuel for a weapon.
 - Iran could also claim it is increasing unenriched uranium production for the initial fuel load for the previously-designed Arak reactor (see below).
- Accumulating, rather than down-blending, LEU produced by enrichment R&D on advanced centrifuges.
- Reconverting fuel plates or scrap into UF₆.

Actions to increase enrichment capacity:

- Removing IR-1 and/or IR-2m centrifuges from IAEA-surveilled storage at Natanz and reinstalling them at Natanz or Fordow.
- Producing IR-1 centrifuges in excess of the average monthly crash rate, and/or accumulating more than 500 functional IR-1 machines as excess stock.
 - The JCPOA permits Iran to produce and possess IR-1 machines in small enough quantities to replace broken machines one-for-one in its operational cascades.
 - June 2018: Iran announces a new facility at Natanz would soon begin producing IR-1 centrifuges.¹⁹
- Reintroducing uranium to Fordow and reconfiguring cascades at the facility, both of which would be necessary to use the facility to increase Iran's enrichment capacity.
 - AEOI head, in May 2019: "We have 1,044 centrifuges in Fordow, and if the establishment wants, we will restart 20-percent uranium enrichment."²⁰
- Violating R&D restrictions on advanced centrifuges, including but not limited to:
 - Producing new advanced centrifuges with or without rotors, and/or building capacity to produce advanced centrifuges.
 - June 2018: Iran announces it will begin manufacturing and assembling centrifuge rotors and begin building a plant specifically for this purpose.²¹
 - That same month, Iran also claims it will begin using an advanced centrifuge assembly center at Natanz, which it had not disclosed previously.²²
 - Removing IR-2m and/or IR-4 centrifuges from storage;
 - Installing infrastructure for advanced centrifuges anywhere other than Natanz Pilot Fuel Enrichment Plant (PFEP);
 - Replacing operational IR-1 centrifuges with advanced centrifuges;
 - Testing IR-6 and IR-8 centrifuges in cascades of each greater than 10.
 - Iran is already testing 33 IR-6 centrifuges in a single cascade.

Pathway to a Bomb: Plutonium

JCPOA Background and Parameters

Based on the original IR-40 design, once completed the reactor at Arak could allow Iran to produce enough fissile material for a nuclear weapon by reprocessing spent fuel to extract weapon-grade plutonium. The JCPOA's restrictions on each element of this process would limit, but not eliminate, Iran's ability to produce fissile material.

Element 1 – produce heavy water:

- The Arak reactor would use heavy water, which is created from ordinary light water through chemical processes, to moderate the reactor core.
- JCPOA:
 - Iran needs an estimated 130 metric tons of heavy water before commissioning the reactor, and 90 metric tons thereafter.
 - Iran will make excess stockpiles available for export, and will inform and allow the IAEA to monitor its heavy water production and stockpile.

Element 2 – design and construct a heavy water reactor:

- Prior to the JCPOA, the Arak reactor was designed and in the process of being built as a heavy water reactor fueled by unenriched uranium.
 - This was a greater proliferation risk than a light water reactor, given the higher amounts of plutonium that could be extracted from the reactor's spent fuel.
 - Once operational, the initially-designed reactor was widely estimated to be capable of producing 1-2 bombs' worth of plutonium annually.²³
 - The Joint Plan of Action (JPA) interim agreement on Iran's nuclear program paused construction before the reactor was planned to go critical in 2014.
- JCPOA:
 - IR-40 will remain a heavy water reactor, but the old core will be destroyed and the reactor redesigned with a new core so "as to minimize the production of plutonium and not to produce weapon-grade plutonium in normal operation."
 - The IAEA verified Iran rendered the old core unusable by filling with cement the specialized tubing that holds nuclear fuel, known as the calandria.
 - The redesigned reactor would be fueled by approximately 3.67 percent LEU, which Iran would produce after the initial fuel load.
 - Until October 2030, no construction of new heavy water reactors.

Element 3 – reprocess spent reactor fuel into weapon-grade plutonium:

- JCPOA:
 - Until October 2030, no spent fuel reprocessing, though reprocessing R&D is permitted in the meantime for medical and industrial purposes.
 - All spent fuel will be shipped out for the lifetime of the redesigned reactor, and for all present and future nuclear power and research reactors.

Iran's Declared Actions

- On May 8, 2019, Iran announced it will no longer export heavy water stockpiles in excess of 130 metric tons (as of May 2019, Iran's stockpile was 125.2 metric tons).²⁴
- Since May 8, Iran also has threatened repeatedly to “end our cooperation with JCPOA participants on the Arak heavy water reactor project.”²⁵

Implications of Iran's Actions

The decision to stockpile excess heavy water does not pose an immediate proliferation risk, since Iran has not completed a reactor in which to use the heavy water (or at least it has not declared any such facility). The announcement that Iran could end its cooperation on redesigning the reactor raises much greater concerns about its ability to reconstitute the original reactor core:

- If Iran resumes building the originally-designed reactor, it would again be on the path to producing multiple bombs' worth of weapon-grade plutonium annually, though not until construction would be completed (possibly a matter of years).
- Multiple Iranian officials in 2019 suggested that, even though the country had verifiably rendered the old calandria unusable, prior to JCPOA implementation it also had furtively secured a replacement set of tubes:
 - AEOI head, in January: “We had bought similar tubes, but I could not declare this at the time... We had bought the same quantity of similar tubes. When they told us to pour cement into the tubes... we said: ‘Fine. We will pour.’ But we did not tell them that we had other tubes. Otherwise, they would have told us to pour cement into those tubes as well. Now we have the same tubes.”²⁶
 - AEOI spokesman, in June: “We have the old design as well as the new design of the Arak reactor in front of us. In case of disloyalty by the Europeans, Iran – which is in possession of the calandria tubes – can revive the former reactor.”²⁷
 - Even if the purported acquisition was not technically a violation of the JCPOA, given that it was said to have occurred prior to implementation, it certainly would be inconsistent with the deal's intent and it reinforces pre-existing concerns about the JCPOA's procurement channel for monitoring or denying Iran's illicit acquisition of dual-use materials.²⁸

Possible Next Steps

On the plutonium path, the most worrisome next step Iran could undertake would be to halt construction of the redesigned reactor and resume construction based on the initial design. Until it has an operational heavy water reactor, presumably Iran would face near-insuperable hurdles to producing sufficient weapon-grade plutonium for a bomb.

Nevertheless, in parallel with any reversion to the old design, reprocessing R&D would reinforce concerns about Iran's intent to pursue nuclear weapons capability. Though permitted by the JCPOA for medical and industrial purposes, these activities can also produce weapon-grade plutonium. This could indicate intentions to produce fissile material once the Arak reactor becomes operational and irradiates sufficient fuel to reprocess into enough weapon-grade plutonium for a bomb – commonly assumed to be a matter of several months.

Indicators of Renewed Path to a Bomb

As with uranium enrichment, Iran would have to undertake multiple actions to progress toward producing weapon-grade plutonium. Several of these steps could be pursued in parallel, and most all would be subject to IAEA monitoring and detection. Given the greater effort needed to build the reactor compared to expanding enrichment capacity, Iran's plutonium path to a bomb could be expected to take significantly longer than a concerted dash down the uranium path.

Actions to bring the originally-designed IR-40 online:

- Inserting the purported duplicate of the original calandria into the reactor core.
- Transferring natural uranium produced at Iran's uranium conversion facility to the nearby Fuel Manufacturing Plant (FMP), and/or increasing production of natural uranium for subsequent fabrication at FMP.
- Testing or producing new natural uranium pellets, fuel pins or fuel assemblies which are specifically designed for the original reactor, and/or removing natural uranium pellets and fuel assemblies from IAEA-monitored storage.
 - If Iran builds the reactor according to the original design, it would have to produce its own fuel for the initial load.

Actions to conduct reprocessing R&D:

- Irradiating uranium targets or any other activities related to reprocessing in the Tehran Research Reactor and/or at the Molybdenum, Iodine and Xenon Radioisotope Production (MIX) Facility.
 - Iran conducted similar tests in the past which it failed to report to the IAEA, in violation of its Safeguards Agreement.
- Acquiring, testing or operating hot cells larger than six cubic meters – and in greater numbers – since these could be used to separate plutonium from spent fuel.
 - Though the JCPOA prohibited hot cells in excess of six cubic meters, previously Iran received an exemption for operating larger hot cells than permitted.

Possible Other Steps by Iran

Further Reducing Transparency

The more of the above activities Iran undertakes, the easier it would be for IAEA inspectors to detect. Accordingly, Iran could suspend or cease implementation of any number of its IAEA safeguards to limit detection and timely response.

As part of the JCPOA, Iran agreed to implement both the Additional Protocol and the Modified Code 3.1 to its existing IAEA Safeguards Agreement. On top of Iran's obligations under its basic Safeguards Agreement to declare nuclear materials at its declared facilities, the Additional Protocol requires Iran to declare related activities and allow inspectors to visit facilities where these would occur. It also permits inspectors to request to visit suspected undeclared nuclear facilities, though other provisions in the JCPOA severely hamstringing this authority. The Modified Code 3.1 would require Iran to provide advanced notice of any new or updated designs to its nuclear facilities.

Among other things, without the Modified Code 3.1, inspectors likely would be prevented from or limited in detecting in advance:

- Certain reconfigurations of centrifuge cascades to boost uranium enrichment;
- Progress on reconvert the Arak reactor to its original, pre-JCPOA design;
- New facilities to fabricate or convert uranium for enrichment or fuel assemblies.

Among other things, without the Additional Protocol, inspectors likely would be prevented from or limited in detecting:

- Centrifuge manufacturing activities, including efforts to significantly bolster enrichment capacity by producing more advanced machines;
- Reprocessing spent reactor fuel into weapon-grade plutonium;
- Potential covert enrichment facilities, or diversion of nuclear material to such sites.

As troubling and alarming as these moves would be, an even more escalatory move would be simply kicking out IAEA inspectors or denying them access to declared facilities, in violation of Iran's baseline Safeguards Agreement. This would largely blind the outside world to Iran's progress down both the uranium and plutonium paths to a bomb, likely signaling a concerted effort to attain nuclear weapons capability.

Leaving International Agreements

Rather than violate the JCPOA piecemeal, Iran could publicly declare its withdrawal from the deal altogether – especially if it continues viewing European efforts to counteract U.S. sanctions as grossly insufficient. Supreme Leader Khamenei and President Rouhani have declared Iran would leave the agreement if the United States withdrew and the remaining parties could not counteract renewed U.S. sanctions.²⁹

By itself, this would not immediately put Iran closer to nuclear weapons capability. However, it likely would strongly suggest Tehran's intent to undertake many, if not all, of the possible actions listed above to expand its nuclear program and begin eating into breakout time significantly.

Even if it leaves the JCPOA, as a signatory to the Non-Proliferation Treaty (NPT) Iran would still be subject to its IAEA Safeguards Agreement. Among other functions, this agreement permits regular inspections of and reporting on Iran's nuclear program – including its activities at Natanz, Fordow, Esfahan and Arak. Though Iran has a lengthy history of NPT violations, formally withdrawing from the treaty, as Foreign Minister Zarif publicly mooted earlier this year, would effectively confirm Iran's nuclear activities are not for peaceful purposes and would likely indicate an intention to achieve nuclear weapons capability, perhaps imminently. Indeed, only one country – North Korea – has ever gone to the extreme of leaving the NPT, and then only after it detonated a nuclear weapon.³⁰

Recommendations

At this point, as Iran takes its preparatory steps, the United States should take its own steps to bolster readiness to deter or deny any potential Iranian breakout. Sanctions are clearly impacting Iran’s economy, yet they are less likely to compel Tehran to back down than when the United States backs up its red lines with credible military options. Because the JCPOA weakened legally-binding U.N. prohibitions on Iran’s nuclear delivery vehicles, U.S. policy options must address Tehran’s ballistic missile capabilities in addition to its production of fissile material.

Specific actions should include:

- American policymakers declaring the United States will use whatever tools necessary to prevent Tehran achieving undetectable nuclear breakout capability (“sneakout”).
- Announcement by the Pentagon of viable contingency plans for operations to neutralize Iran’s nuclear facilities, if the United States or IAEA detects an Iranian approach to sneakout capability or if Iran denies IAEA inspectors’ access to declared or suspected undeclared nuclear-related facilities.
- Coordination with Israel and other regional allies to ensure adequate defensive preparations, to include increased forward military posture, against retaliation by Iran for military operations against its nuclear program.
- Serious steps to arrest further progress by Iran on nuclear-capable delivery vehicles, chiefly ballistic missiles, including:
 - Unequivocal threats to shoot down future ballistic missile tests if necessary;
 - Visible demonstrations of new U.S. missile defense interceptors;
 - Rotating additional U.S. Navy missile defense ships to the Middle East area of responsibility (AOR).
- Public announcements by American leadership of every step above, as well as joint exercises in each of these areas, to make U.S. intentions and capabilities abundantly clear to Tehran.

Endnotes

1. Loveday Morris and Michael Birnbaum, "U.N. watchdog confirms Iran has breached nuclear deal stockpile limit," *Washington Post*, July 1, 2019.
2. All breakout scenarios are intended to estimate the minimum time Iran would need to produce enough 90 percent HEU for one nuclear weapon (27.8 kg of uranium hexafluoride, as per the IAEA's standard for a significant quantity, or "SQ," of 90 percent HEU). Estimates of breakout time are by nature approximations and involve multiple assumptions about the choices Iran would make in seeking to produce enough fissile material for a nuclear weapon. All breakout estimates contained herein entail a set of assumptions, several of which are based on Iranian official statements since May 8, 2019 – even if these statements suggest different enrichment scenarios than Iran pursued prior to the JCPOA and the interim Joint Plan of Action (JPA).

Each estimate assumes Iran uses a batch recycling method to produce one SQ of 90 percent HEU. Based on statements from Iranian officials that they are growing their 3.67 percent stockpile while also making preparations to enrich to near-20 percent LEU, it is assumed that Iran begins only with a stockpile of 300 kg 3.67 percent LEU. It is also assumed Iran would devote its entire enrichment capacity to accumulating both stockpiles (3.67 and 19.75 percent) simultaneously in such a way as to: 1) produce the combined equivalent of one SQ in 3.67 and 19.75 percent LEU forms as quickly as possible, then 2) devote all capacity to enriching its 3.67 percent stockpile to 19.75 percent, and finally 3) switching all capacity over to enriching to 90 percent HEU. Previously Iran enriched to near-20 percent LEU only at its Fordow facility, while certain scenarios in this report assume Iran would also devote capacity at Natanz to enrichment above 3.67 percent LEU. Scenarios involving expansion of enrichment capacity assume the same numbers of centrifuge cascades as when they were previously operating or installed prior to the JPA/JCPOA.

Each scenario also factors in three weeks' total additional time to retire the centrifuges between processes. In each scenario, a tails assay of 0.6 percent is assumed for enrichment from 0.7 percent unenriched uranium to 3.67 percent LEU, a tails assay of 0.711 percent for enrichment from 3.67 to 19.75 percent LEU, and a tails assay of 4 percent for enrichment from 19.75 percent LEU to 90 percent HEU. Tails assays are calculated to minimize SWU requirements, even at the cost of maximizing requirements for 0.7 percent unenriched uranium feedstock. Furthermore, in each scenario an average of 0.82 SWU/year is assumed for all operational IR-1 machines and 3.75 SWU/year for all operational IR-2m machines. The 0.82 SWU/year rate is based on IAEA safeguards reporting data for IR-1 machines enriching to 19.75 percent LEU prior to the JPA, though both higher (1.0-1.1 SWU/year) and lower (~0.75 SWU/year) rates for various IR-1 enrichment processes have been recorded by the IAEA. The 3.75 SWU/year rate is based on a conservative estimate by the Institute for Science and International Security for what Iran could achieve if it ever operated IR-2m machines in production cascades.

There are plausible choices Iran could make to extend these timeframes, including using a three- or four-step enrichment process that would entail less waste and feedstock than the batch recycling process, and which would entail the added step of reconnecting cascades in tandem. As in the past, Iran could also choose not to enrich to 3.67 percent and 19.75 percent LEU simultaneously, it could encounter inefficiencies operating these machines in production cascades and/or it could experience delays bringing any expanded enrichment capacity online.

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