Centrifuge Cascades and a Final Deal with Iran

JINSA's Gemunder Center Iran Task Force

Co-Chairs Ambassador Eric Edelman and Ambassador Dennis Ross

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Former Under Secretary of Defense for Policy

Ambassador Dennis Ross
Former special assistant to President Obama and NSC Senior Director for the Central Region

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Ashton Kunkle
Research Assistant

Jonathan Ruhe
Associate Director

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Overview

Significant differences remain between Iran and the P5+1 over the parameters of a comprehensive agreement on the Islamic Republic's nuclear program. In particular, Tehran has resisted agreeing to dismantling any of its existing uranium enrichment infrastructure. With the November 24, 2014, deadline for a final deal looming, U.S. negotiators have reportedly considered several workarounds intended to roll back Iran's breakout timing while leaving its existing centrifuges in place.

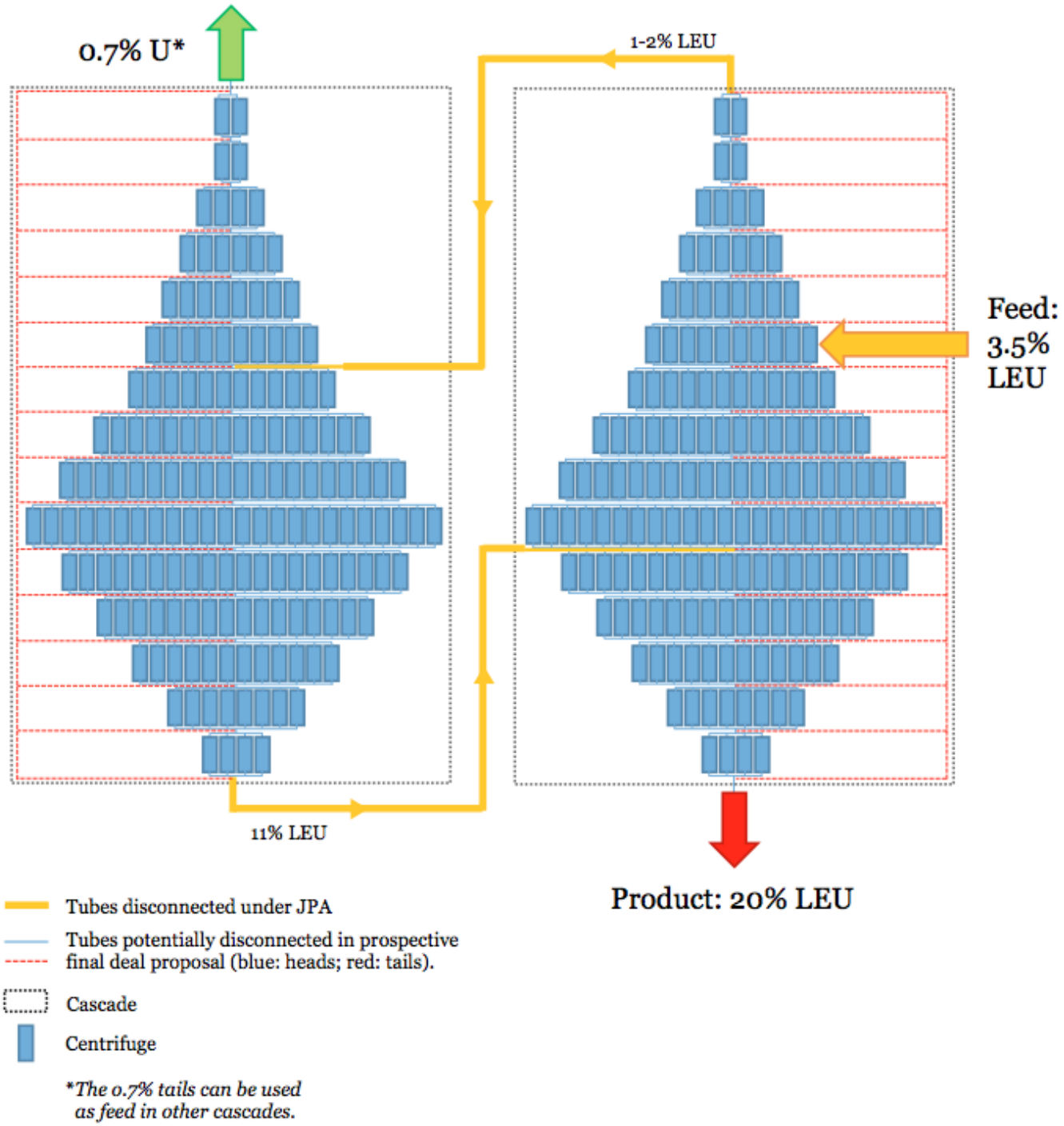
As this Task Force laid out in a September paper, one such possibility would be to limit the total output of Iran's enrichment facilities (as measured in Separative Work Units, or SWU).[1] Since then, U.S. officials reportedly have considered another route, whereby Iran would disconnect the links between some or all of its thousands of installed centrifuges.[2] Depending on the extent of the disconnections, this could potentially increase Iran's breakout timing anywhere from a matter of days to months, were it ever to renege on a final deal and reconnect its centrifuges. Unlike the SWU approach, Iran would not necessarily remain a flip of a switch away from sprinting to a bomb. However, as with the SWU approach, Iran would maintain a latent nuclear weapons capability, and could even expand and upgrade its existing nuclear infrastructure without violating a final deal.

Centrifuge Cascades

Uranium enrichment is a process wherein a centrifuge increases the concentration of fissile isotopes in uranium by separating the small quantity of fissile isotopes from the heavier, and much more common, non-fissile ones. The uranium input for a centrifuge is referred to as its "feed." The higher-enriched output is called the "product" (or "heads"), and the lower-enriched byproduct is called the "waste" (or "tails"). Because the difference in atomic mass between these two isotopes is just over one percent, individual centrifuges can only achieve a very minimal amount of enrichment. Therefore, large numbers of these machines are connected in stages, via tubes, to create a "cascade" that increases the enrichment level over that of a single centrifuge. These tubes take the product from one centrifuge, now slightly more enriched than before it was fed into that machine, and feed it directly into another centrifuge, which enriches it further, and so on. Separate tubes can also feed the waste from this process back into earlier stages of the cascade for further enrichment. Finally, multiple series of centrifuges are often connected in parallel to increase the product flow rate of a cascade.[3]

Under the Joint Plan of Action (JPA) interim deal on its nuclear program, Iran has slightly less than 10,000 operating centrifuges producing 3.5 percent low-enriched uranium (LEU). These are grouped into 60 cascades, each consisting of 164 or 174 centrifuges. Prior to the JPA, Iran interconnected some of these cascades in pairs – often referred to as "tandem cascades" – to enrich uranium to higher levels more efficiently than by using separate cascades. As part of Iran's agreement not to enrich LEU beyond five percent during the interim deal, the JPA required Iran to remove the tubes interconnecting these paired cascades. Though the original cascades continue producing 3.5 percent LEU, removing the interconnecting tubes between cascades makes it more difficult, though not impossible, for Iran to return to enriching uranium to 20 percent or higher if it chose to violate the JPA by doing so.

Figure 1: Model Iranian Tandem Cascade[4]



Issues for Implementation

Determining the impact on Iran's nuclear program of the P5+1's newest proposal depends on several unresolved issues. It can be presumed that the scale of disconnection would be much greater than what Iran has already done under the JPA: as Figure 1 indicates, the sheer number of tubes within a cascade is at least an order of magnitude larger than those between cascades. Furthermore, the JPA only required Iran to disconnect the tubes between two pairs of cascades at Fordow; under a final deal Iran possibly could have to disconnect the tubes within several dozen cascades.

There remain several other issues that would have to be resolved before being able to gauge the overall effect of such a proposal on Iran's breakout timing, including: the nature of disconnection; the number of cascades in which centrifuges would be disconnected; and the safeguards against Iran reconnecting the tubes. Importantly, none of these factors would roll back Iran's latent enrichment capability. As with the idea of capping SWU output, this proposal would not require dismantlement of any centrifuges or the facilities containing them. Iran could thus remain in position to enrich sufficient fissile material for a nuclear weapon, should it ever cheat on such an agreement. Moreover, it could maintain or even expand the overall capacity of its enrichment program under such a deal, potentially leaving it well-positioned for an industrial-sized nuclear program once a comprehensive agreement expires.

What would "disconnecting" the tubes entail?

The definition of "disconnect" would affect how far Iran's breakout timing could be rolled back. If it means "no connections" – paralleling the JPA's language on "no interconnections between cascades" – Iran would have to physically remove the tubes connecting individual centrifuges. According to various nonproliferation experts, it could take anywhere from several days to several months to reinstall the tubes and run the necessary tests to ensure the cascades function properly again. The wide range of estimates stems partly from the lack of any precedent by which to judge Iranian engineers' proficiency at reconnecting cascade tubes. This process may not simply be the reverse of disconnection, since the timeframe for the latter includes both disconnection and decontamination. Thus, the 1-2 days it took Iran to remove the interconnectors between the two pairs of tandem cascades at Fordow (as per the JPA) likely provides no more than a rough approximation of the time required to reconnect them.[5]

Alternatively, the term could imply merely shutting down the tubes, without removing them from the cascades. This would likely have minimal effect on Iran's breakout timing, because it could remain potentially just a flip of a switch away from reactivating the cascades in question. Either way, even if its breakout timing is affected, Iran's latent enrichment capability would remain intact. Disconnecting tubes would not involve removing or in any other way dismantling the centrifuges themselves. In fact, depending on what other constraints, if any, would be placed on its enrichment program under such a deal, Iran could potentially expand or upgrade its centrifuges as long as it did not connect them.

How many cascades would be disconnected?

In conjunction with the degree to which tubes are disconnected within a cascade, breakout timing would be affected by the number of cascades in which such disconnections occur. It would do so in two ways. First, the more tubes that would be removed, the longer it would likely take Iran

to reconnect them and run the necessary tests before reactivating the cascades. Second, the fewer cascades Iran would have operating, the more time-consuming it would become to enrich a bomb's worth of weapons-grade uranium. Though much of the debate over a final deal has concerned the number of centrifuges Iran would be allowed to keep, this is fundamentally a negotiation over the quantity of cascades, given the miniscule amount of enrichment achieved by unconnected centrifuges (even if thousands are operating in this manner). For example, increasing Iran's breakout timing to six months to a year – which would entail cutting its operating centrifuges from 10,000 to 2,000-4,000 operating centrifuges – equates to Iran disconnecting all but approximately 12-24 of the 60 cascades it operates under the JPA.

Consequently, the number of cascades to be disconnected could have a significant impact on Iran's breakout timing, assuming it would not be able to restart them. As with the issue of defining "disconnection," resolving this question would not by itself preclude Iran from maintaining or expanding the number of installed centrifuges.

What safeguards would be included?

As the preceding sections indicate, simply disconnecting the tubes within cascades would not be certain to roll back Iran's breakout timing significantly, and would not limit the size of its overall enrichment program. Thus, even if Iran were required to physically remove every tube from every cascade, safeguards would still be crucial to determining the effect on breakout timing. Physically removing tubes from the cascades would simplify the verification of Iranian compliance, as long as the equipment was mothballed off-site in locations under constant supervision of International Atomic Energy Agency (IAEA) inspectors.

Merely turning off the tubes without removing them would complicate verification. IAEA cameras at Iran's enrichment facilities monitor the feed and product levels at the beginning and end of a given cascade, respectively, but not the tubes within them, which must be accomplished during on-site inspections by IAEA personnel. If it chose to renege on the final deal, Iran could thus change the configuration of its dormant cascades to increase their latent enrichment capability without automatically being detected.

The IAEA Additional Protocol, to which Iran has agreed to adhere under a final deal, would not necessarily spell out airtight safeguards on either count. Access to storage facilities could presumably be the product of Iranian negotiations with the P5+1 and IAEA – as it is under the JPA – and therefore unlikely to include complete removal of the equipment from Iranian control. Moreover, while the Additional Protocol does allow unannounced inspections of cascade halls, these are regulated by the Low Frequency Unannounced Access (LFUA) regime, which limits such visits to 4-12 times per year. Even if the IAEA could carry out the maximum number of these visits annually, Iran might conceivably reconfigure its cascades before being detected, should it ever choose to do so.[6]

These IAEA safeguards would need to be understood in the context of any other constraints Iran negotiates with the P5+1 on its enrichment program. The most stringent limit on cascade tubing would do nothing to roll back Iran's nuclear program for the long term if it is not accompanied by dismantlement of key elements of its existing enrichment infrastructure – specifically centrifuges – and verifiable limits on centrifuge output, number and types of operating and installed centrifuges, research and development (R&D) activities, and enrichment levels and facilities, among others. Without these additional restrictions, Iran could expand its latent enrichment capability while adhering to a final deal.

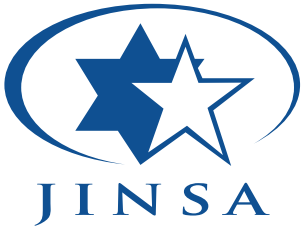
Implications

Beyond technical concerns over the viability of disconnecting cascade tubes, such a proposal would represent a rollback of U.S. redlines – and a reinforcement of Iran's – regarding the latter's nuclear program. Specifically, it would contradict statements by Administration officials since the JPA was agreed that Iran must dismantle significant amounts of its nuclear infrastructure, and that it must close its Fordow enrichment facility. Simultaneously, the proposal would underscore declarations by Iran's Supreme Leader Ali Khamenei, President Hassan Rouhani and leading Iranian negotiators that they would never agree to dismantle a single centrifuge or to close Fordow.

This would limit U.S. credibility when it comes to enforcing adherence to a comprehensive agreement. Promises to punish violations – whether by Iran, other countries or companies eager for the lifting of sanctions – would likely gain less traction if the United States was attempting to uphold a deal whose terms it had previously said were unacceptable. Furthermore, were Iran ever to decide to reconnect the tubes, the potential difficulties for the United States and its diplomatic partners of detecting such activities, discerning whether they constitute a clear violation and agreeing to an appropriate punishment before Iran had completed the process, could all compound the challenges stemming from limited credibility at the outset of the final deal.

Endnotes

1. JINSA Gemunder Center Iran Task Force, “Separative Work Units (SWU) and a Final Deal with Iran,” September 22, 2014.
2. David E. Sanger, “U.S. Hopes Face-Saving Plan Offers a Path to a Nuclear Pact with Iran,” *New York Times*, September 19, 2014.
3. For an overview of uranium enrichment technology, see: Ivanka Barzashka and Ivan Oelrich,”Enrichment Cascades,” Federation of American Scientists (accessed October 2014).
4. This figure is derived from models suggested by staff at the Institute for Strategic and International Studies. See, for example: Wiliam C. Witt et al., “Modeling Iran’s Tandem Cascade Configuration for Uranium Enrichment by Gas Centrifuge,” paper presented at INMM 54th Annual Meeting (Palm Desert, CA), July 14-18, 2013.
5. Time estimates for Iran to disconnect and reconnect centrifuge tubes were provided to Gemunder Center staff in not-for-attribution discussions with nonproliferation experts.
6. *Nuclear Safeguards and the International Atomic Energy Agency* (Washington, D.C.: Office of Technology Assessment, 1995), 72.



1307 New York Ave., NW • Ste. 200 • Washington, DC 20005 • (202) 667-3900
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