“Iranian Nuclear Talks”

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Iran and the P5+1 group of countries (the United States, Britain, France, Germany, Russia, and China) are feverishly working to reach a final, comprehensive solution on Iran’s nuclear program before the November 24, 2014 extended deadline of the Joint Plan of Action (JPA). The November 2013 JPA set out a process aimed at limiting Iran’s nuclear program in exchange for relief from economic and financial sanctions. On a separate but linked negotiating track, Iran and the International Atomic Energy Agency (IAEA) have been working on a step-wise approach to address the IAEA’s concerns, particularly those about the alleged past and possibly on-going military dimensions (or so-called PMD) of Iran’s nuclear program. However, this process has stalled. Whether and how Iran complies with the IAEA’s concerns is currently being played out in the context of P5+1/Iran negotiations.

Despite hopeful signs of progress in the negotiations, much reportedly remains to be settled. If there is no deal, an extension of the JPA may occur while the parties attempt to continue to reach agreement. And if negotiations fail, the United States will likely face a daunting challenge of preventing the escalation of tensions while attempting to pressure Iran back to the negotiating table. The potential for the parties to commit to a bad deal that actually worsens tensions and mistrust in the long run is likewise a dangerous prospect. In order to avoid a bad deal, the P5+1 must hold strong on achieving an agreement that limits Iran’s nuclear program to a reasonable civilian capability, significantly increases the timelines for breakout to nuclear weapons, and introduces enhanced verification that goes beyond the IAEA’s Additional Protocol. A sound deal will also require Iran to verifiably address the IAEA’s concerns about its past and possibly on-going work on nuclear weapons, which means Iran must address those concerns in a concrete manner before a deal is finalized or any relief of economic or financial sanctions occurs.

Primary Goal of a Deal

The primary goal of a comprehensive solution is to ensure that Iran’s nuclear program is indeed peaceful, against a background of two decades of Iran deceiving the IAEA about its nuclear programs, including military nuclear programs. This long history of deception and violations places additional burdens on achieving a verifiable, long term agreement. To achieve a verifiable solution, Iran will need to limit specific, existing nuclear capabilities, including reducing significantly the number of its centrifuges and the size of its uranium and low enriched uranium stocks, and limiting its centrifuge R&D programs. As mentioned above, Iran should demonstrate in a concrete manner its intention to address allegations of past and possibly on-going work on nuclear weapons prior to the finalization of any deal. The agreement will need to include verification provisions that create a critical baseline of information, including how many centrifuges Iran has made, how much natural uranium it has produced and is producing annually, and its inventory of raw materials and equipment for its centrifuge program. This baseline is necessary if the agreement is to provide assurances about the absence of secret nuclear activities and facilities. Sanctions on proliferation sensitive goods will need to continue and will need to be enforced rigorously, while allowing exemptions for authorized nuclear programs. Iran will need to allow mechanisms to ensure that any further military nuclear related work would be detected on short order. Without these limitations on Iran's nuclear programs and expanded verification conditions, a long-term deal will likely fail or exacerbate the threat from Iran. However, an adequate agreement is possible and within reach of the United States and its negotiating partners.

Adequate Reaction Time

A key goal of the negotiations is to ensure that any deal provides adequate reaction time, namely, adequate time to respond diplomatically and internationally to stop Iran if it does decide to renege on its commitments and build nuclear weapons. According to Undersecretary of State Wendy Sherman, "We must be confident that any effort by Tehran to break out of its obligations will be so visible and time-consuming that the attempt would have no chance of success."[1] That goal must be at the core of any agreement.

Obtaining adequate reaction time requires that limitations are placed on Iran's sensitive nuclear programs, adequate verification is ensured, and concrete progress has been demonstrated that Iran will address the IAEA's concerns about its past and possibly on-going nuclear weapons efforts. Because of Iran's long history of non-compliance with its safeguards obligations, a deal must last long enough, on order of 20 years, so that there is little risk of Iran seeking nuclear weapons.

Covering all Breakout Paths to the Bomb.

If Iran were to make the political decision to produce a nuclear weapon after a comprehensive nuclear deal, it is not possible to second guess how it may proceed. Iran may use its declared nuclear facilities to secretly make enough highly enriched uranium (HEU) or plutonium for a bomb or it may build covert sites to make the HEU or separate the plutonium. Given that Iran has such a long history of building and conducting secret nuclear activities, U.S. negotiators need to take a broad view and secure a deal that makes all of Iran's paths to the bomb a time consuming, risky effort.

Some have advocated that only the covert route to nuclear weapons is likely. Those who favor this view often rely on the U.S. 2007 National Intelligence Estimate, *Iran: Nuclear Intentions and Capabilities*. It concluded, "We assess with moderate confidence that Iran probably would

[1] "Iran's Current Enrichment Level Not Acceptable: US," Agence France Presse. September 17, 2014.

use covert facilities—rather than its declared nuclear sites—for the production of highly enriched uranium for a weapon." That assessment may have been true in 2007 when Iran had few centrifuges, and in fact, we now know, was building a covert centrifuge plant at Qom, called the Fordow facility. However, that statement no longer holds true.

At this point in time, it is unlikely that Iran would rely entirely on the covert pathway option for fear of getting caught again as it did in building the formerly secret Fordow facility, and long before it has enough weapon-grade uranium or separated plutonium for nuclear weapons. The revelation about the Qom enrichment plant was highly damaging to Iran's international credibility. For example, Russia became much more critical of Iran after this revelation and the creation of damaging sanctions became easier. Therefore, Iran is unlikely to want to repeat that mistake without greater assurance of being able to successfully hide a covert program, something it likely lacks now and will not gain anytime soon if the long term deal is carefully crafted by the United States and its partners.

Iran is more likely today to choose a safe route to preserving and further developing a capability to produce fissile material for a nuclear weapon. In the case of gas centrifuges, it is likely to seek to maintain and increase its capabilities at declared centrifuge sites, the associated centrifuge manufacturing complex, and centrifuge R&D facilities. It would view this path as the preferred one, because it can simply and legitimately claim that all its activities are civil in nature, even if it is actually hiding the goal of eventually seeking nuclear weapons. If it opts to make nuclear weapons in the future, its declared programs could serve as the basis of whatever it does. Then, it could pursue breakout as it deems most appropriate, whether by misusing its declared centrifuge facilities, building covert ones, or using both paths together.

Thus, the U.S. goal should be limiting sharply the number of centrifuges at declared sites and constraining centrifuge manufacturing and R&D activities, both of which could help outfit covert programs. This approach would greatly diminish Iran's ability to breakout to nuclear weapons. If Iran decides to build nuclear weapons in the future, it would have to start from this relatively low level of capability, regardless of the path it would actually select in the future. The long timeline to acquire enough HEU for a weapon may turn out to deter Iran from even trying.

This strategy depends on creating a robust verification regime able to detect covert nuclear activities or a small hidden away centrifuge plant. Iran has assuredly learned from its mistakes at hiding the Qom enrichment site. In fact, it has likely developed more sophisticated methods to hide covert nuclear activities. But robust verification, which requires measures beyond the Additional Protocol, can provide assurance that Iran is not hiding centrifuge plants or other nuclear capabilities in the future. These additional verification measures would ensure that Iran would have a very hard time creating or maintaining a covert program outside of its declared programs after signing a long term agreement.

It is wiser to anticipate and block all of Iran's potential future paths to the bomb, rather than guessing and choosing the wrong one.

Quantifying Adequate Response Time: The Role of Breakout Calculations

One assured way to quantify the concept of adequate reaction time when discussing limitations on uranium enrichment programs is to link timely reaction time to breakout time. Breakout time is the amount of time Iran would need to create enough weapon-grade uranium for a single nuclear weapon, if it reneged or cheated on the agreement. Additional time would be needed to fabricate the nuclear weapon itself but the creation of enough fissile material (weapon-grade uranium or separated plutonium) is widely accepted as the "long pole in the tent" of making a nuclear weapon and the only part of this process susceptible to reliable discovery and subsequent pressure. Other nuclear weaponization activities, such as producing high explosive components, electronic components, or uranium metal parts, are notoriously difficult to detect and stop. By focusing on breakout time—as defined above—the agreement would grant the international community a guaranteed period of time to react and prevent Iran's success. The longer the breakout time, the more reaction options we have. A deal that enshrines a short breakout time is risky because if Iran were to make the decision to make a weapon, military intervention would be the only available response.

Thus, time for Iran's ability to produce enough weapon-grade uranium for a bomb must be sufficiently long to allow the international community to prepare and implement a response able to stop Iran from succeeding. Typically, the U.S. negotiators have sought limitations in Iran's nuclear programs that lead to reaction times of twelve months. ISIS has taken the position that under certain conditions six months could be adequate. To better understand the implications of breakout, we have prepared a range of breakout calculations under a wide variety of current and posited centrifuge capabilities that in essence convert the reaction time, i.e. breakout time, into an equivalent number of centrifuges and stocks of low enriched uranium.

One of the calculations considers an important case, namely the current, frozen centrifuge program under the JPA where Iran retains its existing, installed IR-1 centrifuges and no stocks of near 20 percent LEU hexafluoride. In this case, the breakout time is about two months, which is the same as public U.S. government estimates. If the number of IR-1 centrifuges were reduced to about 10,000, breakout time would grow to about three months, according to the ISIS estimates.

To achieve a breakout time of 6-12 months, which is more desirable, the calculations lead to a centrifuge program of about 2,000-4,000 IR-1 centrifuges. Thus, any nuclear deal should allow no more than about 4,000 IR-1 centrifuges.

Sound Negotiating Principles

Beyond technical limitations, the negotiations have shown that the principles driving the positions of the P5+1 differ markedly from those of Iran. Any deal should satisfy the following principles if it is to last:

- Sufficient response time in case of violations;
- A nuclear program meeting Iran's practical needs;
- Adequate irreversibility of constraints;
- Stable provisions; and
- Adequate verification.

These principles flow from the effort to ensure that Iran's nuclear program is peaceful and remains so. These principles also reflect long experience in negotiating arms control and non-proliferation agreements and a recognition of the strengths and weaknesses in those agreements to date.

Iran on the other hand has emphasized the principles of cooperation and transparency. These principles are predicated on its assertion that its word should be trusted, namely its pronouncement that it will not build nuclear weapons. These principles also reflect its long standing view that any agreement should have constrained verification conditions and minimal impact on its nuclear programs, even allowing for their significant growth, despite the current lack of economic or practical justifications for such growth. Many of Iran's negotiating positions have been rejected because they can be undone on short order, offering little practical utility in constraining Iran's future abilities to build nuclear weapons. Iran on numerous occasions in the past has shown a willingness to stop cooperation with the IAEA and reverse agreed upon constraints, sometimes rapidly. A robust and painstakingly built international sanctions regime on Iran cannot be lifted in return for inadequate and reversible constraints.

The negotiating process has shown the complexity of any agreement able to ensure that Iran's nuclear program will remain peaceful. But by sticking to sound principles, potential compromises can be better evaluated and any resulting deal will be more likely to last.

Specific Provisions

In the rest of my testimony, I would like to focus on several specific provisions or goals necessary to a successful deal. In particular, I will discuss the following:

1. **Achieve Concrete Progress in Resolving Concerns about Iran's Past and Possibly Ongoing Nuclear Weapons Efforts**
2. **Maintain Domestic and International Sanctions on Proliferation Sensitive Goods**
3. **Render Excess Centrifuges Less Risky**
4. **Institutionalize a Minimal Centrifuge R&D Program**
5. **Keep Centrifuge Numbers Below about 2,000-4,000 IR-1 Centrifuges and as a Supplementary Measure Achieve Lower Stocks of LEU hexafluoride and oxide**
6. **Beware the concept of "SWU" as a Limit**
7. **Ensure Arak Reactor's Changes are Irreversible**

1) Achieve Concrete Progress in Resolving Concerns about Iran's Past and Possibly Ongoing Nuclear Weapons Efforts

Despite a great effort over the last year, the IAEA has learned little from Iran that has added to the inspectors' ability to resolve their concern about Iran's past nuclear weapons efforts and possibly on-going work related to nuclear weapons. Recently, the IAEA has also been unable to reach agreement with Iran on how to tackle the remaining military nuclear issues. The IAEA has repeatedly emphasized that the military nuclear issues need to be addressed and solved.

For years, the inspectors have unsuccessfully asked the Islamic Republic to address the substantial body of evidence that Iran was developing nuclear weapons prior to 2004 and that it may have continued some of that, or related, work afterwards, even up to the present. Before a deal is concluded, concrete progress is needed on the central issue of whether Iran has worked on nuclear weapons and is maintaining a capability to revive such efforts in the future.

Addressing all of the IAEA's outstanding concerns about Iran's past and possibly on-going military nuclear efforts prior to the November deadline appears unlikely. Nonetheless, without concrete progress, which could take several forms, a deal should not be signed.

Supreme Leader Ali Khamenei often declares that nuclear weapons violate Islamic strictures. His denials are not credible. The United States, its main European allies, and most importantly the IAEA itself, assess that Iran had a sizable nuclear weapons program into 2003. The U.S. intelligence community in the 2007 National Intelligence Estimate (NIE) agreed: "We assess with high confidence that until fall 2003, Iranian military entities were working under government direction to develop nuclear weapons." The Europeans and the IAEA have made clear, the United States less so, that Iran's nuclear weapons development may have continued after 2003, albeit in a less structured manner. In its November 2011 safeguards report, the IAEA provided evidence of Iran's pre- and post-2003 nuclear weaponization efforts. The IAEA found, "There are also indications that some activities relevant to the development of a nuclear explosive device continued after 2003, and that some may still be ongoing." To reinforce this point to Iran, the United States in late August sanctioned Iran's Organization of Defensive Innovation and Research (SPND), which it said is a Tehran-based entity established in early 2011 that is primarily responsible for research in the field of nuclear weapons development. Thus, there is widespread evidence and agreement that Iran has worked on developing nuclear weapons and that some of those activities may have continued to today.

Addressing the IAEA's concerns about the military dimensions of Iran's nuclear programs is fundamental to any long-term agreement. Although much of the debate about an agreement with Iran rightly focuses on Tehran's uranium enrichment and plutonium production capabilities, an agreement that side steps the military issues would risk being unverifiable. Moreover, the world would not be so concerned if Iran had never conducted weaponization activities aimed at building a nuclear weapon. After all, Japan has enrichment activities but this program is not regarded with suspicion. Trust in Iran's intentions, resting on solid verification procedures, is critical to a serious agreement.

A prerequisite for any comprehensive agreement is for the IAEA to know when Iran sought nuclear weapons, how far it got, what types it sought to develop, and how and where it did this work. Was this weapons capability just put on the shelf, waiting to be quickly restarted? The IAEA needs a good baseline of Iran's military nuclear activities, including the manufacturing of equipment for the program and any weaponization related studies, equipment, and locations. The IAEA needs this information to design a verification regime. Moreover, to develop confidence in the absence of these activities—a central mission—the IAEA will need to periodically inspect these sites and interview key individuals for years to come. Without information about past military nuclear work, it cannot know where to go and who to speak to.

The situation today, unless rectified, does not allow for the creation of an adequate verification regime. Moreover, the current situation risks the creation of dangerous precedents for any verification regime that would make it impossible for the IAEA to determine with confidence that nuclear weapons activities are not on-going. Adding verification conditions to any deal is unlikely to help if the fundamental problem is the lack of Iranian cooperation. The IAEA already has the legal right to pursue these questions under the comprehensive safeguards agreement with Iran.

Despite the IAEA's rights under the comprehensive safeguards agreement, Iran has regularly denied the IAEA access to military sites, such as a site at the Parchin complex, a site where high-explosive experiments linked to nuclear triggers may have occurred. Iran has reconstructed much of this site at Parchin, making IAEA verification efforts all but impossible. Tehran has undertaken at this site what looks to most observers as a blatant effort to defeat IAEA verification. However, Parchin is but one of many sites the IAEA wants to inspect as part of its efforts to understand the military dimensions of Iran's nuclear programs. A full Iranian declaration may reveal even more sites of concern.

Iran continues to say no to IAEA requests to interview key individuals, such as Mohsen Fakrizadeh, the suspected military head of the nuclear-weapons program in the early 2000s and perhaps today, and Sayyed Abbas Shahmoradi-Zavareh, former head of the Physics Research Center, alleged to be the central location in the 1990s of Iran's militarized nuclear research. The IAEA interviewed Shahmoradi years ago about a limited number of his suspicious procurement activities conducted through Sharif University of Technology. The IAEA was not fully satisfied with his answers and its dissatisfaction increased once he refused to discuss his activities for the Physics Research Center. Since the initial interviews, the IAEA has obtained far more information about Shahmoradi and the Physics Research Center's procurement efforts. The need to interview both individuals, as well as others, remains.

If Iran is able to successfully evade addressing the IAEA's concerns now, when biting sanctions are in place, why would it address them later when these sanctions are lifted, regardless of anything it may pledge today? Iran's lack of clarity on alleged nuclear weaponization and its noncooperation with the IAEA, if accepted as part of a nuclear agreement, would create a large vulnerability in any future verification regime. How large? Iran would have clear precedents to deny inspectors access to key facilities and individuals. There would be essentially no-go zones across the country for inspectors. Tehran could declare a suspect site a military base and thus off limits. And what better place to conduct clandestine, prohibited activities, such as uranium enrichment and weaponization?

Iran would have also defeated a central tenet of IAEA inspections—the need to determine both the correctness and completeness of a state's nuclear declaration. The history of Iran's previous military nuclear efforts may never come to light and the international community would lack confidence that these capabilities would not emerge in the future. Moreover, Iran's ratification of the Additional Protocol or acceptance of additional verification conditions, while making the IAEA's verification task easier in several important ways, would not solve the basic problem posed by Iran's lack of cooperation on key, legitimate IAEA concerns. Other countries contemplating the clandestine development of nuclear weapons will certainly watch Tehran closely.

Clearly, there is little time for Iran to address all the IAEA's outstanding concerns prior to the November 24 deadline. However, an approach can be implemented whereby Iran can choose to admit to having had a nuclear weapons program, or at least accept a credible, international judgment that it had one, and allow IAEA access to key military sites, such as Parchin, and critical engineers and scientists linked to those efforts. If no such concrete demonstration is forthcoming by the end of November, negotiations should continue, although a deal should not be signed, unless it offers no significant relief from financial and economic sanctions.

2) Maintain Sanctions on Proliferation Sensitive Goods

A comprehensive nuclear agreement is not expected to end Iran's illicit efforts to obtain goods for its missile and other military programs. Iran appears committed to continuing its illicit operations to obtain goods for a range of sanctioned programs. On August 30, 2014, Iranian President Hassan Rouhani stated on Iranian television: "Of course we bypass sanctions. We are proud that we bypass sanctions." Given Iran's sanctions-busting history, a comprehensive nuclear agreement should not include any provisions that would interfere in efforts of the international community to effectively sanction Iranian military programs.

The deal must also create a basis to end, or at least detect with high probability, Iran's illicit procurement of goods for its nuclear programs. Evidence suggests that in the last few years Iran has been conducting its illegal operations to import goods for its nuclear program with greater secrecy and sophistication, regardless of the scale of procurements in the last year or two. A long term nuclear agreement should ban Iranian illicit trade in items for its nuclear programs while creating additional mechanisms to verify this ban. Such a verified ban is a critical part of ensuring that Iran is not establishing the wherewithal to

- Build secret nuclear sites,
- Make secret advances in its advanced centrifuge[2] or other nuclear programs, or
- Surge in capability if it left the agreement.

These conditions argue for continuing all the UNSC and national sanctions and well-enforced export controls on proliferation-sensitive goods. Such goods are those key goods used or needed in Iran's nuclear programs and nuclear weapon delivery systems, the latter typically interpreted as covering ballistic missiles.

Sanctions should continue on the listed goods in the UNSC resolutions, many of them dual-use in nature, and more generally on those other dual-use goods that could contribute to uranium

[2] Aside from the IR-2m and a few other centrifuge models, little is known about Iran's next generation centrifuges. Quarterly IAEA safeguards reports indicate that Iran has not successfully operated next generation centrifuges on a continuous basis or in significant numbers since their installation began at the Natanz Pilot Fuel Enrichment Plant. This suggests that Iran may be having difficulty with aspects of their design or operation. Iran's failure to deploy next-generation centrifuges in significant quantities is one indication that sanctions were effective to slow or significantly raise the costs of procurement.

enrichment, plutonium reprocessing, heavy water, and nuclear weapon delivery systems (see United Nations Security Council resolution 1929, par. 13). The latter is often referred to as the "catch-all" provision and mirrors many national catch-all requirements in export control laws and regulations. In the case of Iran, this provision is especially important. Without illicitly obtaining the goods covered by catch-all, Iran would be severely constrained in building or expanding nuclear sites.

The P5+1 powers need to manage carefully the transition to a time when imports of goods to Iran are allowed for legitimate nuclear and later possibly for civilian uses. Many proliferation sensitive goods are dual-use goods, which have applications both in nuclear and non-nuclear industries and institutions. Currently, the world is on heightened alert about Iran's illicit procurements for its sanctioned nuclear, missile, and military programs. Routinely, this alert has led to the thwarting of many illicit purchases and interdictions of banned goods. But as nations enter into expanded commercial and trade relationships with Iran, a risk is that many countries will effectively stand down from this heightened state of awareness and lose much of their motivation to stop banned sales to Iran even if UN sanctions remain in place. Despite the sanctions and vigilant efforts today, many goods now make their way to Iran illicitly that fall below the sanctions list thresholds but are covered by the catch-all condition that bans all goods that could contribute to Iran's nuclear program. The volume of these sales is expected to increase after an agreement takes effect and many more of these goods could get through successfully. **Unless carefully managed, a key risk is that the sanctions may not hold firm for the below threshold or catch-all goods**. Stopping transfers of explicitly banned items may also become more difficult as business opportunities increase and much of the world de-emphasizes Iran's nuclear program as a major issue in their foreign policies and domestic regulations. This could be particularly true for China and middle economic powers, such as Turkey, which already have substantial trade with Iran and are expected to seek expanded ties. Other countries with weak export controls may expand trade as well.

Verified Procurement Channel for Authorized Nuclear Programs

The six powers must carefully plan for these eventualities now and include in any agreement an architecture to mitigate and manage proliferation-related procurement risks. A priority is creating a verifiable procurement channel to route needed goods to Iran's authorized nuclear programs. The agreement will need to allow for imports to legitimate nuclear programs, as they do now for the Bushehr nuclear power reactor.

A challenge will be creating and maintaining an architecture, with a broader nuclear procurement channel, that permits imports of goods to Iran's authorized nuclear programs and possibly later to its civilian industries, while preventing imports to military programs and banned or covert nuclear programs. The UNSC and its Iran sanctions committee and Panel of Experts, the IAEA, and supplier states will all need to play key roles in verifying the end use of exports to Iran's authorized nuclear programs and ensuring that proliferation sensitive goods are not going to banned nuclear activities or military programs.

The creation of the architecture should be accomplished during the negotiations of the long-term deal, although its implementation may need to wait until the long term deal itself is fully implemented. It will be important that the architecture, whether or not implemented later, be established at the very beginning of the implementation of the long-term agreement in order to adequately deal with this issue. In essence, the creation of the architecture should not be left to later.

The reason for creating a verified procurement channel is that Iran's legitimate nuclear activities may need imports. The "modernization" of the Arak reactor would probably involve the most imports, depending on the extent to which international partners are involved. A sensitive area will be any imports, whether equipment, material, or technologies, which are associated with the heavy water portion of the reactor, in the case that the reactor is not converted to light water. Another sensitive set of possible imports involves goods related to the separation of radionuclides from irradiated targets, although goods for reprocessing, i.e. separating plutonium from irradiated fuel or targets, would be banned since Iran is expected to commit in the long-term agreement not to conduct reprocessing. Nonetheless, allowed imports could include goods that would be close in capability to those used in reprocessing, since the boundary in this area between sensitive and non-sensitive equipment is very thin. These goods will therefore require careful monitoring. Iran's centrifuge program, if reduced in scale to the levels required for U.S. acceptance of a deal, will result in a large excess stockpile of key goods for IR-1 centrifuges. This stock should last for many years, eliminating the need for most imports. Nonetheless, the centrifuge program may need certain spare parts, raw materials, or replacement equipment. If Iran continues centrifuge research and development, that program may require sensitive raw materials and equipment. Needless to say, the goods exported to Iran's centrifuge programs will require careful monitoring as to their use and long term fate.

Iran's non-nuclear civilian industries and institutions may also want to purchase dual-use goods covered by the sanctions, but this sector should not expect to be exempted from sanctions during the duration of the deal or at least until late in the deal, Iran must prove it is fully complying with the agreement and will not abuse a civilian sector exemption to obtain banned goods for its nuclear, missile, or other military programs. With renewed economic activity and as part of efforts to expand the high-tech civilian sector, Iranian companies and institutions engaged in civilian, non-nuclear activities can be expected to seek these goods, several of which would be covered by the catch-all condition of the resolutions. Examples of dual-use goods would be carbon fiber, vacuum pumps, valves, computer control equipment, raw materials, subcomponents of equipment, and other proliferation sensitive goods. Currently, these civil industries (Iran's petro-chemical and automotive industries are two such examples) are essentially denied many of these goods under the UNSC resolutions and related unilateral and multilateral sanctions. However, if civilian industries are to be eventually exempted from the sanctions, this exemption must be created with special care, implemented no sooner than many years into the agreement, and monitored especially carefully. Iran could exploit this exemption to obtain goods illicitly for banned activities. It could approach suppliers claiming the goods are for civil purposes but in fact they would be for banned nuclear or military programs. Such a strategy is exactly what Iran's nuclear program has pursued illicitly for many years, including cases where goods were procured under false pretenses by the Iranian oil and gas industry for the nuclear program. There are also many examples of illicit Iranian procurements for its nuclear program where Iranian and other trading companies misrepresented the end use to suppliers.

This architecture covering proliferation sensitive goods should remain in place for the duration of the comprehensive agreement. The six powers must carefully plan for eventualities now and design and implement an architecture that prevents future Iranian illicit procurements under a comprehensive agreement.

3) Render Excess Centrifuges Less Risky

If Iran accepts a sharp limit on the number of centrifuges that would enrich uranium in a comprehensive deal, what about the excess centrifuges? If the limit is about 4,000 IR-1 centrifuges, Iran would need to dismantle or render unusable over 14,000 IR-1 centrifuges and over 1,000 of the more advanced IR-2m centrifuges. These 1,000 IR-2m centrifuges are equivalent of about 3,000-5,000 IR-1 centrifuges. Thus, Iran would need to eliminate a large fraction of its centrifuge program.

The centrifuges in excess of a limit should ideally be destroyed. Failing that, it is critical to ensure that these centrifuges cannot be turned back on in a matter of months. If it can resume operations quickly, Iran could quickly reconstitute its larger enrichment program, and thereby a sizeable breakout capability, if it decided to renege on the deal. Thus, any proposal to keep excess centrifuges installed should be rejected.

Iran's reneging on a cap in centrifuges may happen outside of any overt nuclear weapons breakout. Iran may argue that the United States has not delivered on its commitments and build back up its number of centrifuges in retaliation. By assuaging the international community that it is not breaking out, Iran may make any meaningful U.S. response very difficult.

Some analysts, including those at ISIS, have discussed imposing essentially what have been called in the North Korean context "disablement" steps, which would delay the restart of installed centrifuges. However, ISIS's attempts to define disablement steps that leave the centrifuges and cascade equipment in place appear to be reversible in less than six months of diligent work. This time period applies to proposals to remove the centrifuge pipework from the centrifuge plants.

Moreover, this estimated time for reassembling the centrifuge cascades remains uncertain and it could be shorter. There is no practical experience in disabling centrifuge plants; North Korea's centrifuge program was not subject to disablement. It needs to be pointed out that some U.S. policymakers had a tendency to exaggerate the difficulty of undoing North Korean disablement steps imposed at the Yongbyon nuclear center on plutonium production related facilities. In fact, North Korea was able to reverse several of these steps relatively quickly. A lesson from the North Korean case is that disablement steps are highly reversible and in fact can be reversed faster than expected.

A sounder strategy involves including disablement steps with the destruction of a limited, but carefully selected set of equipment. For example, the deal could include the destruction of certain key cascade equipment, such as valves and pressure or flow measuring equipment.
An agreed upon fraction of centrifuges and associated cascade piping and equipment should be kept available under monitored storage away from the centrifuge plants as spares to replace

broken centrifuges and equipment. This number would be derived from the current rate of breakage which Iran would need to document with the aid of the IAEA. However, this rate is relatively well known now, as a result of the IAEA's monitoring of Iranian centrifuge manufacturing under the JPA. Iran has provided the IAEA with an inventory of centrifuge rotor assemblies used to replace those centrifuges that have failed, and the IAEA has confirmed that centrifuge rotor manufacturing and assembly have been consistent with Iran's replacement program for damaged centrifuges. Armed with a reliable breakage rate, the negotiators can define the limited stockpile of centrifuges necessary to avoid any Iranian manufacturing of IR-1 centrifuges.

4) Institutionalize a Minimal Centrifuge R&D Program

Another important limit on Iran's nuclear program aims to ensure that an advanced centrifuge R&D program does not become the basis of a surge in capability in case a deal fails or of a covert breakout. Iran's centrifuge research and development (R&D) program poses several risks to the verifiability of a comprehensive deal. Throughout the duration of a long-term comprehensive agreement, Iran's centrifuge R&D program should be limited to centrifuges with capabilities comparable to the current IR-2m centrifuge. The numbers of centrifuges spinning in development cascades should be kept to at most a few cascades.

An open-ended Iranian centrifuge R&D program aimed at developing more sophisticated centrifuges than the IR-2m makes little economic sense. Iran will not be able to produce enriched uranium competitive with that produced by exporting countries such as Russia or URENCO during the next several decades, if ever. Therefore, Iran's investment in a large centrifuge R&D program would be a waste of time and resources. Moreover, the goal of a long-term agreement is to eventually integrate Iran into the international civilian nuclear order (even as a non-exporting producer of enriched uranium). This integration would render mute Iran's claims for self-sufficiency in enriched uranium production or for continuing the program out of national pride.

A long-term agreement should reinforce sound economic principles universally accepted in the world's nuclear programs, all of which are deeply interconnected through an international supply chain based on reactor suppliers and enriched uranium fuel requirements. Building an agreement catering to open-ended, economically unrealistic ambitions is both unnecessary and counterproductive, and also sets dangerous precedents for other potential proliferant states. Iran's development of more advanced centrifuges would also significantly complicate the verification of a long-term agreement. In a breakout or cheating scenario, Iran would need far fewer of these advanced centrifuges in a clandestine plant to make weapon-grade uranium than in one using IR-1 centrifuges. For example, Iran recently claimed it has done initial work on a centrifuge, called the IR-8, reportedly able to produce enriched uranium at a level 16 times greater than the IR-1 centrifuge. Such a centrifuge, if fully developed, would allow Iran to build a centrifuge plant with one sixteenth as many centrifuges. Currently, Iran has about 18,000 IR-1 centrifuges and in a breakout it could produce enough weapon-grade uranium for a nuclear weapon in about two months, according to both U.S. and ISIS estimates. So, instead of needing 18,000 IR-1 centrifuges to achieve this rapid production of weapon-grade uranium, it would need only 1,125 advanced ones to produce as much weapon-grade uranium in the same time. Thus,

equipped with more advanced centrifuges Iran would need far fewer centrifuges than if it had to use IR-1 centrifuges, permitting a smaller, easier to hide centrifuge manufacturing complex and far fewer procurements of vital equipment overseas. If Iran made the decision to break out to nuclear weapons, the advanced centrifuges would greatly simplify its ability to build a covert centrifuge plant that would be much harder to detect in a timely manner allowing an international response able to stop Iran from succeeding in building nuclear weapons.
Advanced centrifuges bring with them significant verification challenges that complicate the development of an adequate verification system. Even with an intrusive system that goes beyond the Additional Protocol, IAEA inspectors would be challenged to find such small centrifuge manufacturing sites, detect the relatively few secret procurements from abroad, or find a small, clandestine centrifuge plant outfitted with these advanced centrifuges. Moreover, with such a small plant needing to be built, Iran would also have a far easier time hiding it from Western intelligence agencies.

5) Keep Centrifuge Numbers Below about 2,000-4,000 IR-1 Centrifuges and as a Supplementary Measure Achieve Lower Stocks of LEU Hexafluoride and Oxide

Although an important goal is reducing LEU stocks, their reduction without lowering centrifuge numbers significantly is not a workable proposition. In essence, the priority is lowering centrifuge numbers and strengthening that goal by also reducing the stocks of LEU, whether or not in hexafluoride of oxide forms. Limiting the amount of 3.5 percent LEU hexafluoride to no more than about 500 kilograms appears manageable, as long as the number of IR-1 centrifuges does not exceed roughly 4,000.

As some have proposed, treating these two, reinforcing steps instead as a zero-sum game is counterproductive to achieving an adequate agreement. In this scheme, the number of centrifuges would be raised substantially, to 7,000, 8,000 or more IR-1 centrifuges or equivalent number of advanced ones, while lowering the stocks of 3.5 percent LEU toward zero. In one version of this scheme, only the amount of 3.5 percent LEU hexafluoride would be reduced toward zero via conversion into LEU oxide. Once in oxide form, it would somehow be considered no longer usable in a breakout. But this is wrong. Both chemical forms of LEU have to be considered since Iran can in a matter of months reconvert LEU oxide into hexafluoride form and then feed that material into centrifuges, significantly reducing total breakout time.[6] Iran does not have a way to use large quantities of 3.5 percent LEU in a reactor, so irradiation cannot be counted on to render these oxide stocks unusable. This means that proposals that merely lower the quantity of LEU hexafluoride by converting it into oxide form or fresh fuel is an even more unstable, reversible idea than variants that lower total LEU stocks to zero.

Some background is helpful. This proposal is fundamentally based on Iran not possessing enough 3.5 percent LEU to further enrich and obtain enough weapon-grade uranium (WGU) for a nuclear weapon, taken here as 25 kilograms. If Iran had less than 1,000 kilograms of 3.5 percent LEU hexafluoride, it would not have enough to produce 25 kilograms of WGU. Its breakout time would increase because it would be required to also feed natural uranium into the centrifuges. It could not use the three-step process, where WGU is produced in three steps, with the greatest number of centrifuges taking 3.5 percent to 20 percent LEU, a smaller number enriching from 20 to 60 percent, and a smaller number still going from 60 to 90 percent, or WGU. Instead, Iran would need to add a fourth step at the "bottom" enriching from natural uranium to 3.5 percent LEU. This step would require a large number of centrifuges and thus fewer would be available for the other steps, lengthening breakout times.

Figure 1 shows mean breakout times for a four-step process, where the amount of LEU varies from 0-1000 kilograms of 3.5 percent enriched uranium hexafluoride and each graph represents a fixed number of IR-1 centrifuges, from 4,000 to 18,000. In this case, it is assumed that Iran would have no access to near 20 percent LEU hexafluoride, a dubious assumption (see below). In the figure, a six month breakout time is represented by the black horizontal line on the graph. Several cases are noteworthy. For less than 6,000 IR-1 centrifuges, all of the breakout times exceed six months. For 10,000 IR-1 centrifuges, the breakout time is six months for stocks of 1,000 kilograms of 3.5 percent LEU hexafluoride and exceeds six months for lesser amounts of LEU. For 14,000 centrifuges, when the stock is below about 500 kilograms of 3.5 percent enriched uranium hexafluoride, the breakout time is six months or more. For 18,000 centrifuges, a six month breakout time only occurs for an inventory of zero kilograms of 3.5 percent enriched uranium, a physical impossibility. That number of centrifuges would produce several hundred kilograms of 3.5 percent LEU hexafluoride every month. Much of this material would be in the product tanks hooked to the cascades and thus readily usable. So, cases of no LEU are not achievable.

If instead a one year breakout time was selected, the numbers of centrifuges and LEU stocks would be significantly less. For example, in the unrealistic case of no available near 20 percent LEU, a breakout time of one year would correspond to 6,000 IR-1 centrifuges and a stock of 500 kilograms of 3.5 percent LEU hexafluoride.

In fact, a major weakness in proposals to reduce LEU stocks while keeping centrifuge numbers relatively high is that the very product produced by the centrifuges, namely 3.5 percent LEU, would need to be regularly eliminated through some process. Obtaining this level of compliance would be challenging. Even if the LEU were to be shipped overseas, Iran could hold back sending it abroad, building up a large stock. Similarly, if it were converted into an oxide form, Iran could delay doing so, feigning problems in the conversion plant or delays in transporting it to the plant for conversion. Moreover, conversion to oxide as mentioned above can be rapidly reversed, allowing a three-step process and significantly faster breakout.

In the unlikely case of Iran not mustering any near 20 percent LEU hexafluoride, a plant with 10,000 IR-1 centrifuges would correspond to a six-month breakout limit if the stock did not exceed 1,000 kilograms of 3.5 percent LEU hexafluoride. In two months, however, another five hundred kilograms could be produced in this number of centrifuges, with the total 3.5 percent LEU stock reaching 1,500 kilograms and allowing a three step breakout, which could occur in a matter of a few months. Thus, in practice, LEU stocks would need to be maintained at levels far below 1,000 kilograms, even in the case of 10,000 IR-1 centrifuges. And keeping the stocks below this limit would be very challenging over the duration of a deal. If Iran kept more than 10,000 IR-1 centrifuges, the situation is more untenable.

The above discussion assumes that Iran could not use near 20 percent LEU hexafluoride. Why is this, in fact, unlikely to be the case? Iran has stockpiled relatively large quantities of near 20 percent LEU oxide, quantities way beyond what is necessary to fuel the Tehran Research Reactor. By using this stock, Iran could reduce breakout times considerably after reconverting the near 20 percent LEU oxide into hexafluoride form. Iran currently has enough near 20 percent LEU, if reconverted into hexafluoride form and further enriched, to yield enough weapon-grade uranium for a nuclear weapon. The comprehensive agreement should certainly further reduce the size of the near 20 percent LEU stock; however, Iran is not expected to eliminate this stock, as long as Iran will fuel the Tehran Research Reactor (TRR). In the future, Iran could start to reconvert this material to hexafluoride form in a matter of months and dramatically speed up breakout.

Figure 2 shows the impact of only 50 kilograms of near 20 percent LEU hexafluoride on mean breakout times, where again a four-step process is used. With just 50 kilograms of near 20 percent LEU hexafluoride, a stock of 500 kilograms of 3.5 percent LEU hexafluoride, and 10,000 IR-1 centrifuges, breakout time would be six months. For comparison, in the case of no near 20 percent LEU discussed above, 10,000 IR-1 centrifuges could achieve a six-month breakout only with a stock of 1,000 kilograms of 3.5 percent LEU hexafluoride. So, 50 kilograms of near 20 percent LEU hexafluoride is equivalent to roughly 500 kilograms of 3.5 percent LEU hexafluoride. If a stock of 50 kilograms of near 20 percent LEU hexafluoride is used in conjunction with a stock of 1,000 kilograms of 3.5 percent LEU hexafluoride, Iran would have enough LEU hexafluoride to use a three-step process to break out and achieve breakout times of a few months.

So, in a realistic case whereby Iran would need to accumulate only 50 kilograms of near 20 percent LEU hexafluoride, a six month breakout would correspond to 10,000 IR-1 centrifuges and a stock of 3.5 percent LEU that could not exceed 500 kilograms. While in theory this limit could be maintained, in practice that is highly unlikely. Each month, such a plant would produce almost 250 kilograms of 3.5 percent LEU hexafluoride. In two months, Iran could exceed the cap by 500 kilograms, reaching a total of 1,000 kilograms of 3.5 percent LEU hexafluoride, or enough if used in combination with the near 20 percent LEU hexafluoride stock to reduce breakout times to about four months, all the while claiming that some reasonable problems prevent it from removing the excess material.

If instead a one year breakout time was selected, the numbers of centrifuges and LEU stocks would again be significantly less. For example, a breakout time of one year would correspond to 6,000 IR-1 centrifuges and a stock of about 200 kilograms of 3.5 percent LEU hexafluoride. In the case of 4,000 IR-1 centrifuges, the breakout time would be about 12 months with about 700 kilograms of 3.5 percent LEU hexafluoride. If the LEU limit was set at about 500 kilograms of 3.5 percent hexafluoride, and given that a limit could easily be exceeded by a few hundred kilograms, the numbers of IR-1 centrifuges should not exceed 4,000.

In sum, lowering stocks in support of the fundamental goal of sharply limiting centrifuge numbers is a useful measure that would strengthen a deal. If stockpile limits are exceeded, that violation would pose minimal risk to the agreement as long as the centrifuge numbers are small.

6) Beware the concept of "SWU" as a Limit

Enrichment effort is measured in separative work units (SWU). However, setting limits on the annual SWU of a centrifuge plant has several problems. One is that determining the annual SWU of a centrifuge plant is difficult and its average value can change. Iran for example suggested in the negotiations that it would be willing to reduce the speed of its centrifuges and the amount of natural uranium fed into the centrifuge cascades, while it kept the same number of centrifuges. Both of these measures would reduce the annual SWU of the centrifuge plants, potentially significantly, even reduce it by a third of its existing enrichment output. But in a day, Iran could reduce these steps and reclaim its original enrichment capability; it is easy to increase the speed and the feed rate. Not surprisingly, Western negotiators soundly rejected this proposal.

While SWU has a role to play in determining the equivalence of different types of centrifuges, it should not be a limit in its own right.

7) Ensure the Arak Reactor's Changes are Irreversible

Iran appears to accept that it must limit plutonium production in the heavy water Arak nuclear reactor (IR-40), which is almost 90 percent complete and under a construction moratorium because of the interim nuclear deal. As presently designed, the reactor can be used relatively easily to make weapon-grade plutonium, at a production rate of up to about nine kilograms a year. This plutonium could later be separated and used in nuclear weapons.

Strategies for lowering plutonium production have been discussed publicly, where the reactor would use five percent enriched uranium fuel instead of natural uranium fuel and its power would be reduced by more than half, from 40 megawatts-thermal (MWth) to 10-20 MWth. This strategy would involve placing LEU fuel in a small fraction of the fuel channels in a. large vessel – often called a "calandria"—through which the heavy water moderator and coolant flows. The Arak calandria has about 175 fuel and control rod channels. The LEU would be inserted into the middle section of the calandria with the majority of channels left empty. There are two problems remaining in this strategy, namely whether the calandria would be replaced with one sized for LEU fuel and the heat exchangers would be downsized appropriately to those needed for a 10-20 MWth reactor.

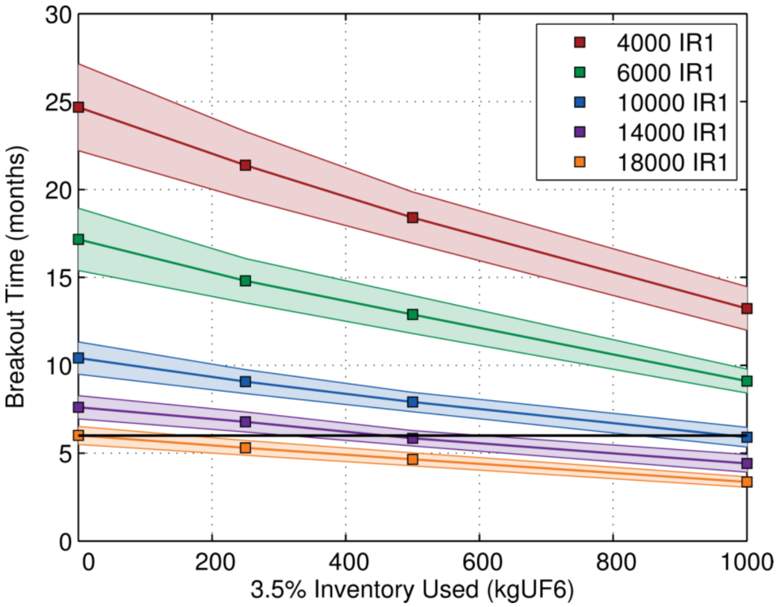
Although the outcomes of reduced power and enriched uranium fuel are preferred, leaving Iran with an unmodified Arak calandria and its original heat exchangers constitutes an unacceptable proposal. If the core and heat exchangers were left intact, Iran could in a straightforward manner switch back to a natural uranium core and 40 MWth of power, undoing this limitation on plutonium production. This reconversion could occur in the open and under IAEA safeguards where Iran creates some pretext. In terms of the natural uranium fuel, Iran has already made significant progress on preparing a core load of natural uranium fuel, which could be finished, or the experience used to fabricate another one. Once switched back, Iran could run the reactor under safeguards to produce plutonium, even weapon-grade plutonium. Since the reactor would be fully operational, its destruction via military means would be dangerous and highly risky, and on balance unlikely to occur. Then, at the time of its choosing, Iran could breakout, having only to separate the plutonium from the spent fuel, which could be done utilizing a covert, low technology reprocessing plant in a matter of a few months. The designs for this type of plant are unclassified and readily available and such a plant would be very difficult for the IAEA (or intelligence agencies) to detect either during its relatively short construction or subsequent operation.

At a minimum, Iran should remove the existing calandria and replace it with one sized appropriately for a core of the agreed upon number of LEU fuel assemblies. The existing one should be rendered unusable or removed from Iran.

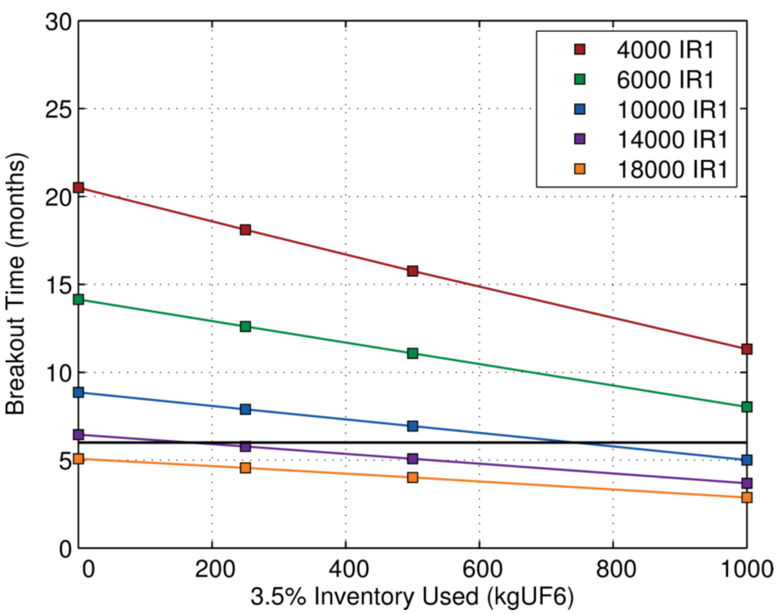
Despite the merits of modifying the Arak reactor, a more effective compromise remains upgrading the Arak reactor to a modern light water research reactor (LWR) which can be designed to be far more capable of making medical isotopes than the current Arak reactor design. It can also be designed to make plutonium production in targets much more difficult to accomplish than the Arak reactor or older style research reactors.

A proposal to do so involves ensuring that the LWR is built irreversibly with a power of 10 MWth. This would require remanufacturing of the Arak reactor and changes to the heat exchangers and cooling system. Under this proposal, there is no need to produce heavy water, and the current stocks could be sold on the world market. Production of natural uranium oxide powder, fuel pellets, rods, and assemblies for the Arak IR-40 would be halted. Moreover, the associated process lines would also need to be shut-down, including the production of specifically IR-40 relevant materials such as zirconium tubes. In return, the P5+1 could assist Iran in producing fuel for the LWR. Iran could produce the necessary LEU in its enrichment program.

Figure 1: Four Step Enrichment Predictions with no near 20 Percent LEU
Breakout Time Calculation (includes 2 week setup time)
4000, 6000, 10000, 14000, 18000 IR-1 Centrifuges
Range of 3.5% Inventory Used, 0-1000 kg UF_6



Mean (with range) breakout time versus 3.5% inventory used



Minimum breakout time versus 3.5% inventory used.

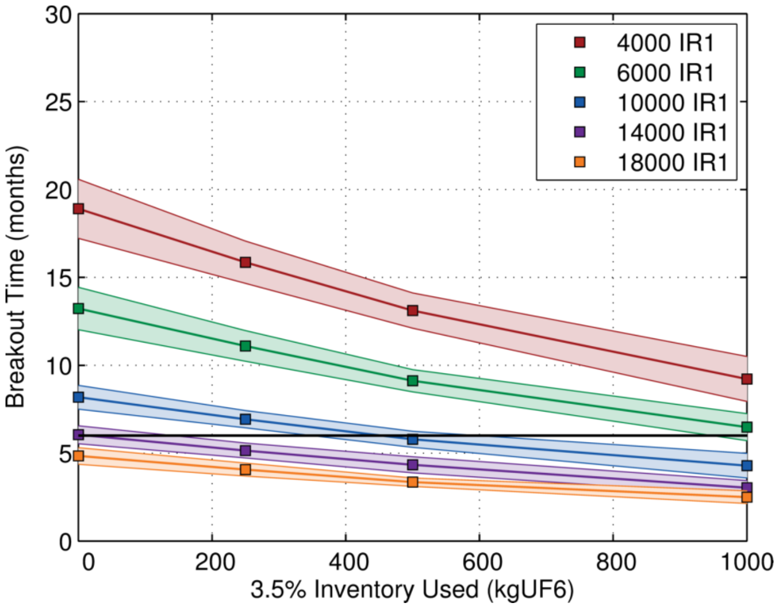
Note: The results are calculated as breakout times for various numbers of centrifuges and amounts of 3.5% inventory used, with multiple scenarios for each number of centrifuges matched with a specific 3.5% inventory. Two sets of breakout times are reported in the figures mean with range and minimum value of all scenarios. The results in the text use the mean values. The minimum values are viewed as worst case estimates which may be unlikely to be achieved in practice.

Figure 2: Four Step Enrichment Estimate with 50 kg near 20 percent $LEUF_6$ Used

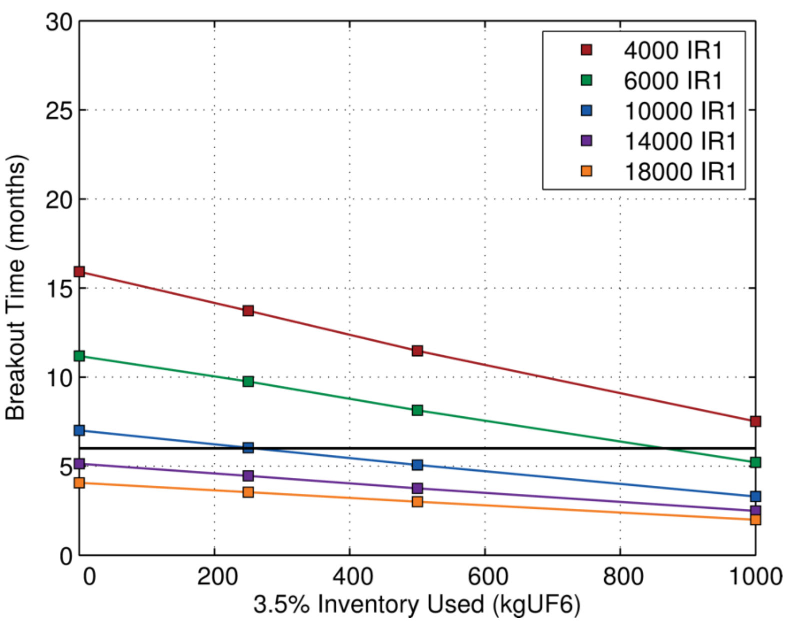
Breakout Time Calculation (includes 2 week setup time)

4000, 6000, 10000, 14000, 18000 IR-1 Centrifuges

Range of 3.5% Inventory Used: 0-1000 kg $LEUF_6$



Mean (with range) breakout time versus 3.5% inventory used



Minimum breakout time versus 3.5% inventory used

Note: The results are calculated as breakout times for various numbers of centrifuges and amounts of 3.5% inventory used, with multiple scenarios for each number of centrifuges matched with a specific 3.5% inventory. Two sets of breakout times are reported in the figures: mean with range and minimum value of all scenarios. The results in the text use the mean values. The minimum values are viewed as worst case estimates which may be unlikely to be achieved in practice.