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WORKING PAPER

Limiting Iranian Nuclear Activities

Options and Consequences

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Introduction

How much Iranian nuclear capability is too much? The simplest answer is that any amount is unacceptable. By learning how to enrich uranium, Iran has given itself the potential to eventually produce enough weapons-grade material for one or more atomic bombs. That risk can only be removed if all Iranian enrichment programs are eliminated. This belief has long been a mainstay of U.S. rhetoric, if not policy, toward Iran.*

But it is far from clear that zero enrichment is a realistic goal. Indeed, despite recent setbacks, Iran's leaders appear determined to continue improving and expanding Iran's enrichment program; they may even have already decided to eventually build a bomb. The important question, then, is how much Iranian nuclear capability is too much, given the limited (and often costly) options available for curbing Iran.

It is thus essential that U.S. and other strategists, policymakers, and negotiators understand the consequences of different possible states of the Iranian enrichment program. These can be grouped into four basic categories. The first is zero enrichment, which is still the official goal of the United States and other UN Security Council members. The second is limited enrichment, in which Iran has some nontrivial enrichment capability but is unable to produce a bomb (or small arsenal) without risking strong international retaliation, including military destruction of its enrichment infrastructure, that would stop it from achieving its goal. Holding Iran to this level appears to be the goal of current U.S. policy, even if it is not typically articulated this way. The third category is robust enrichment, in which Iran is capable of producing a bomb (or small arsenal) without significantly risking strong international retaliation that would prevent it from completing that task. In this category, Iran still does not actually have the bomb, but it is genuinely "nuclear capable"; I will also refer to Iran as having a "robust breakout capability" here. The final category is a nuclear-armed Iran.

Two questions are critical to understanding this set of possibilities. First, where is the appropriate place to draw the line between limited enrichment and the sort of robust enrichment that would make Iran genuinely nuclear capable? In answering this question, I address the difficulties associated with knowing the precise state of the Iranian program. Second, what are the international consequences of a policy that leaves Iran in any particular one of these categories, beyond their direct impact on Iran's ability to build a nuclear bomb?

I do not recommend any specific goals or red lines for U.S. policy; such conclusions require analysis of the costs, not just the consequences, of achieving any chosen outcome. My aim, instead, is to illuminate the range of possible outcomes in order to better guide decisions on strategy.

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What Should Count as "Limited" Enrichment?

The two possible extremes for the Iranian nuclear program—zero enrichment and nuclear-armed status—are fairly easy to define. Some may debate whether Iran must destroy all of its enrichment equipment before qualifying as having zero-enrichment capability, or whether it must test a nuclear weapon before it can be considered to be nuclear armed, but aside from these marginal issues, these two categories are straightforward to understand. The line between limited and robust enrichment—that is, the line beyond which Iran becomes genuinely nuclear capable—is much more difficult to draw; indeed, it will inevitably be blurry.

To understand roughly where it lies, I work in reverse. I start by assessing U.S. options for responding to warnings of Iranian breakout, and ask two questions: How long would it take to mount a response, and how likely would that response be to stop the Iranian drive? (Some reserve the word "breakout" to refer to scenarios in which Iran uses only safeguarded facilities to enrich material for a bomb; I use the word to refer to any scenario in which Iran attempts to build a bomb despite international limits.) This provides rough guidelines: I estimate that the United States would need between two weeks and several months to mount a decisive military response, and half a year or more to organize an economic response that would have a credible chance of changing Iranian behavior. I then examine the potential of different Iranian enrichment arrangements to provide sufficient warning of breakout to enable one or more of these reactions. This analysis is confounded by the possibility that the United States may have severely limited knowledge of the state of the Iranian enrichment program.

RESPONSE OPTIONS

Given warning that Iran was rushing to build a nuclear bomb, the United States (and others) would have three basic sets of tools with which to respond: military action, economic pressure, and diplomatic engagement. Diplomacy alone is unlikely to stop Iran at a point where it had already decided to build a bomb. The real options, then, would be military strikes aimed at crippling the enrichment program; economic pressure aimed at coercing a change in Iranian behavior, whether unilaterally or through a negotiated resolution; and military pressure aimed at doing the same thing. Each of these tools might also be combined with diplomacy. Some have also called for U.S. efforts aimed at fomenting an Iranian revolution, but such a strategy would make little sense in a time-constrained scenario following the warning of an Iranian nuclear breakout.

The Military Option

Two conditions must be met for an effective military response to Iranian breakout. First, there must be enough time between the warning of an Iranian attempt to build a bomb (or small arsenal) and the point at which Iran may be able to retaliate with nuclear explosives, which would presumably deter any attack. Second, the responder must know which targets to strike.

How much warning would the United States need if it knew where to strike? Today, the primary targets would presumably be the uranium enrichment facility at Natanz and the uranium conversion facility at Esfahan; in the future, other similar facilities might be added. The United States would also, presumably, seek to suppress Iranian air defenses; in addition, it might target other parts of the Iranian nuclear (and perhaps biological weapons) infrastructure. These targets could be destroyed "in a few nights by U.S. bombs and cruise missiles" launched either "from aircraft carriers or, in the case of long-range bombers, from the continental United States," both of which will normally be available.[1] Even two weeks' notice, in this case, would probably be enough, technically, for the United States to take military action, assuming that plans had previously been developed.[2]

The United States would prefer to have more warning time for at least three other reasons. First, it might want time to gather diplomatic support (including overflight rights) for a strike. If the Iranian drive for a bomb was clear, such as might be the case if Iran had been caught secretly producing weapons-grade uranium, diplomatic support might be obtained quickly, perhaps in a matter of days. If the Iranian intent was more ambiguous, as might be the case if Iran kicked out inspectors while still producing only low-enriched uranium (LEU), it might take considerably longer, perhaps months, assuming that attracting diplomatic support was even possible. Second, the United States might want time to position the assets required to defend its friends and allies in the region from any counterattack. It would probably take at least a month to do this, and perhaps as much as two or three, depending on precisely what sort of equipment was needed and what was already in the region. Third, the United States might want a time buffer in case it was already tied up in another crisis elsewhere. If, for example, it was engaged in dealing with a crisis in North Korea when Iran began a clear rush for the bomb, it would be better if it had a few months of breathing room in which to deal with that situation before turning to Iran; indeed, the United States should expect Iran to pick a time in which the United States is occupied elsewhere during which to launch a drive to build a bomb. (It is, of course, impossible to precisely pin down the amount of time that it would take the United States to extricate itself from another crisis; I choose a few months as an illustrative guidepost.) The second and third factors could compound each other: commitments elsewhere would constrain the United States much more it if wanted not only to strike Iran's nuclear facilities but also to position reinforcements to protect friends and allies from any counterattack.

The United States, of course, is not the only country that might decide to strike Iran: Israeli officials have been debating the possibility.[3] The Israeli calculus would likely be different, and not only because of a different threat perception. Israel would probably require more time than the United States to organize and execute an attack, given its weaker military capabilities. On the flip side, it would probably worry considerably less about obtaining diplomatic support and would not need to worry about protecting others in the region (though it would want to protect its own population and might want overflight rights). Most significantly, though, the need to ensure that Israel was not caught with significant parts of its military already committed elsewhere would be paramount. Israeli planners are probably concerned, in particular, with the possibility that Iran would use Hezbollah to tie it down in a conflict in Lebanon before taking the final steps toward building a bomb, thus making quick Israeli reaction to a breakout attempt much more difficult. Because of this factor, if Israel did not believe that it could count on the United States to respond to signs of an Iranian rush to build the bomb, it would probably want at least a month or two of warning.

In sum, as little as two weeks of warning might suffice to enable the United States to stop a breakout militarily. That could, however, severely strain it. It would also require that full-blown strike plans had already been developed, and that the principal decision-makers were prepared to make a quick decision to attack. A warning time of two or three months would be far more preferable and allow for a more robust response.

Enrichment arrangements that would provide three or more months' warning of breakout should thus be regarded as at least somewhat limited. (This does not necessarily mean that they should all be considered acceptable.) Arrangements that would provide less than two weeks' warning should be seen as indicating a nuclear-capable Iran. Arrangements in between are murkier: whether policymakers judge them to be limited or robust should depend on their tolerance for risk and on their concerns about complicating factors that might delay a U.S. response.

Economic Responses

The United States and the international community might also choose to respond to an Iranian dash to a bomb with much stronger economic pressure than they have imposed thus far. To go significantly beyond the current sanctions, and to impose strong and immediate pressure on Iran, sanctions would need to be fairly comprehensive, probably including an embargo on Iranian oil exports. (Stronger sanctions on Iranian gasoline imports, which have been widely discussed and might have had a significant impact a year or two ago, no longer deliver much useful leverage, since Iran has curbed consumption and boosted domestic production, largely obviating the near-term need for imports.) The goal here would be to induce Iran to unilaterally cease its offending nuclear activities, or to create the conditions for a diplomatic settlement on terms that the United States and others could accept. This use of economic pressure could also be supplemented by (or even substituted for) punitive military strikes that were designed not necessarily to destroy Iranian nuclear facilities, but to put pressure on Tehran to make a deal; that said, such strategies have not been successful in the past.[4]

An economic response would be weaker than a military one in most regards: it would take longer to achieve its ends, and there is no guarantee that it would work. But it might be stronger in one important respect: to the extent that economic pressure was used to force Iran to retreat from its drive for nuclear weapons, there would be some chance that it could be used to stop activities not just at known facilities, but at clandestine facilities too. To achieve this outcome, economic pressure would need to lead to an agreed resolution that included strong inspections of Iranian territory. (The extent of necessary inspections is debatable: some would want intrusiveness akin to the pre–Iraqi Freedom inspections of Iraq, while others would be comfortable with something more modest.) Moreover, those inspections would need enough time to work before Iran was able to build a bomb; otherwise, Iran could use the promise of a deal as a stalling tactic while it completed construction of one or more weapons. If the United States and the world are to put any stock, then, in a possible economic response to Iranian breakout, they will probably need to be confident that they would have at least six months, and perhaps more, between the warning of an Iranian attempt at breakout and Iranian acquisition of a bomb.

Ultimately, the fact that economic responses are available should probably not change the line beyond which the United States considers Iran to be genuinely nuclear capable. The only exception is if policymakers have ruled out military responses to Iranian breakout (or if they deeply doubt that they would use them). In that case, any Iranian enrichment program that would allow Tehran to build a bomb with six months' warning or less should be seen as making Iran genuinely nuclear capable.

WARNING TIMES

What sorts of arrangements would provide the one-week to three-month warning required to facilitate military action? What types of approaches would deliver the six or more months of warning that would probably be needed for even severe economic pressure to have any hope of working?

Before looking at specific arrangements, another issue is essential: Iran may conduct substantial clandestine enrichment activities (and may be doing so already). This limits the ability of the United States to know which enrichment category Iran is in. Iran may also be able to conduct the initial phases of a breakout attempt at a known facility, and then complete its activities elsewhere.

Limits to Outside Knowledge of the Iranian Enrichment Program

Technical analysis of the Iranian enrichment complex naturally tends to focus on those elements known to the United States or others. The United States relies, in particular, on International Atomic Energy Agency (IAEA) inspections of known enrichment facilities to determine the state of the most developed parts of the Iranian program. (It often relies on national intelligence at earlier stages of facility construction.) It is entirely possible, though, that Iran has significant facilities whose existence or locations are unknown. In the extreme, Iran could produce one or more bombs with zero warning, based entirely on secret facilities; the recent revelation of a substantial uranium-enrichment facility in North Korea, whose existence was apparently entirely unknown to the United States previously, indicates the importance of not assuming that the world knows about all of Iran's most important activities.[5]

That said, several factors weigh against the possibility of a large-scale secret enrichment program, and thus suggest that the state of facilities under IAEA inspection may be a good approximation to the overall state of the Iranian program. First, Iran is a relatively open society (certainly compared to North Korea), making it difficult to produce materials and devote large numbers of people to a parallel program without raising suspicions. Second, Iran has repeatedly been unable to hide even moderate-sized enrichment facilities. While it is possible that other major Iranian facilities have not been found, and while Iran has faced only modest punishment once its facilities have been unmasked, it may still be deterred from developing a large clandestine program. In particular, Iran has been able to avoid severe penalties for its past activities in part because it has been able to present those to much of the international community as being for civil applications; creating a clandestine system purpose-built for weapons production would leave Iran in a more precarious position if its veil was removed.

It would be imprudent for strategists to assume that Iran has no major secret facilities. That would make them unprepared for surprise. But it would also be unwise to assume that Iran has a full-scale secret parallel program. Policymakers might then neglect to seek limits on known Iranian facilities, which might turn out to have far more significance than they have supposed. In the remainder of this paper, I assess enrichment arrangements assuming that Iran has no significant hidden facilities, unless I explicitly state otherwise.

A second element of uncertainty would probably be introduced during a breakout attempt: Iran would likely conduct bomb-making activities away from its known enrichment sites. For example, Iran might use Natanz to produce weapons-grade uranium, move that material somewhere else, and then fabricate it into a weapon; alternatively, it might move LEU from Natanz to another site before enriching it further. In any case, if the locations of the other facilities were not known to the attacker, a military strike would need to be conducted before the move happened, in order to be fully effective. In assessing the amount of warning that various enrichment configurations might provide, it is important to focus not only on the time required for Iran to build a bomb (or arsenal), but also on the time required for Iran to progress to a point where it could conduct the rest of its breakout at an unknown location.

Natanz

The enrichment facility at Natanz currently provides Iran with only a limited enrichment capability. The only way for this to change without expanding the facility is if Iran accumulates substantially more uranium enriched to 20 percent U^{235} (or some other similar or higher concentration) than it has to date. If Iran were to accumulate 250 kilograms or more of such material, it would be appropriate to consider it to be genuinely (though barely) nuclear capable.

This can be seen by assessing the three possible ways that Iran could use Natanz to produce material for one or more bombs. First, it could reconfigure the facility to produce weapons-grade uranium (defined here as uranium enriched to at least 90 percent U^{235}). Second, it could recycle enriched uranium through the facility several times (a process known as "batch recycling"), eventually enriching it to weapons grade. Third, it could combine batch recycling with an adjustment to Natanz's operating parameters, a process that could also be used to produce weapons-grade uranium. In each case, Iran might start with previously enriched material rather than with natural uranium.

The IAEA reported on November 23, 2010, that as of November 5, Iran was operating twenty-three cascades of 164 IR-1 centrifuges each and six cascades of 172 IR-1 centrifuges each at the Natanz Fuel Enrichment Plant (FEP), for a total of 4,804 centrifuges.[6] An additional twenty-five cascades (potentially totaling 4,100 centrifuges) were installed but were not being fed with uranium hexafluoride (UF_6); installation work was also ongoing at five other units, each of which can ultimately include eighteen cascades, for a total of ninety additional cascades and 14,670 centrifuges.

Translating these numbers into an assessment of Iran's enrichment capacity requires estimating the separative power of the Iranian centrifuges. There has been considerable debate as to the separative power of the IR-1 centrifuges. It is generally agreed that the nominal figure (that is, the capacity of an IR-1 if operated without problems) is slightly greater than 2 kilograms-SWU/year.[7] The actual performance of the IR-1, however, appears to be considerably poorer, with an effective rate of about 1 kilogram-SWU/year achieved in recent operation. (This figure is inferred from production figures published by the IAEA.) The reason for this shortfall is unknown: some have argued that Iran is not operating its centrifuges continuously, which would mean that the enrichment shortfall may not reflect technical problems, while others contend that it faces more fundamental issues.[8]

If Iran was to continue operating its current facilities with their current level of performance, it could expect to generate approximately 5,000 kilograms-SWU/year. The centrifuges are not currently configured for weapons-grade uranium production. If they were reconfigured to efficiently produce highly enriched uranium (HEU), the centrifuges currently operating at Natanz could produce about 25 kilograms of weapons-grade uranium in about ten months, enough for a basic nuclear weapon (and the threshold figure for other calculations used below).[9] Even if Iran needed only half as much material for a bomb, which is plausible, or if it was able to operate its current centrifuges at their maximum capacity, which might eventually be the case, it would still take many months to produce enough material for a weapon.

Any change in facility operations would undoubtedly be detected. Iran would need to reconfigure its cascades in order to achieve the rates of enrichment described here. It is generally believed that "it would be extremely difficult to reconfigure the cascades in the Natanz facility without detection."[10] Even if Iran could reconfigure its cascades in days, its actions would be detected at least half a year before it could produce enough material for a bomb, since routine IAEA inspections occur roughly once a month; that would easily facilitate either a military or economic response. In practice, it could take considerable time for Iran to reconfigure: predictions of how long it would take are extremely uncertain, but range from a few weeks to six months.[11] At the upper end, Iran would be caught before it could even start enriching uranium to weapons grade.

But what if Iran was to start with the LEU that it had already stockpiled? If Natanz could be reconfigured quickly, Iran could in principle start producing weapons-grade uranium before being caught. It has been accumulating reactor-grade uranium that is enriched to an average of 3.37 percent U^{235}. As of November 5, 2010, it had accumulated 2,120 kilograms of the material.[12] Starting with that, and assuming a maximally efficient configuration of the centrifuges at Natanz, Iran could produce enough weapons-grade uranium for a simple bomb after two or three months of additional enrichment; it could also produce enough weapons-grade uranium for two simple bombs after five to six months if it chose to proceed somewhat more slowly.[13] In either case, the world would have months of warning of an Iranian attempt to produce a weapon, providing ample opportunity for a military response. Moreover, increasing the amount of feedstock available would not significantly shorten the time required to produce enough weapons-grade material for a single bomb.

More interesting, then, may be scenarios in which Iran does not reconfigure its cascades. This removes one opportunity for detection. Instead, Iran could use the approach known as "batch recycling," in which it would repeatedly refeed enriched uranium into cascades that had been configured for LEU production. On each pass, the enrichment level of the product would increase; eventually, the process would yield weapons-grade material.

How long would it take to produce enough weapons-grade material for one bomb this way? Assume that all cascades are configured to produce 3.5 percent enriched uranium with 0.4 percent tails from natural uranium feedstock, approximately the current Iranian operating approach.[14] Recycling that material three times would bring the product to 83 percent enrichment, which might be sufficient for a simple weapon, while recycling it four times would take it to 96 percent, which would certainly be enough. (The lower enrichment level might not be sufficient for warhead-mounted weapons.) To produce 25 kilograms of the 96 percent enriched uranium, Iran would need 12,000 kilograms of feedstock, which massively exceeds Iran's current LEU stockpile, and about fifteen months of processing, which would provide an extraordinary amount of warning.[15] Even if Iran was satisfied with the 83 percent enrichment level, it would require 4,900 kilograms of feedstock (which still exceeds its current stockpile) and approximately six to seven months to produce enough material for a bomb—still plenty of time for a strong response.

These large feedstock and time requirements result from the extreme inefficiency of simple batch recycling. Iran might try to improve its performance by lowering the rate at which it fed uranium into its centrifuges.[16] Depending on how the centrifuges are currently being operated, that could significantly boost the enrichment of the product. (At a crude and intuitive level, feeding the material more slowly increases the amount of time that it spends in each centrifuge, which increases the degree to which it is enriched.) Alexander Glaser, for example, has modeled a scenario that begins with a 164-machine cascade of P-1 machines (which are similar to IR-1 centrifuges) configured to produce 3.5 percent enriched uranium with 0.4 percent tails from natural uranium, as is the case with the cascades at Natanz. He shows that if the feed rate is cut (roughly) by a factor of three, the enrichment factor (i.e., the change in the percentage of U^{235} from feed to product) increases considerably. In particular, if the cascade is fed with 16 percent enriched uranium (which can be produced by one stage of batch recycling from 3.5 percent enriched material), its product is now 90 percent enriched uranium. This would speed the process of going from 3.5 percent enriched to weapons-grade uranium: it would now take approximately three months to enrich to weapons grade, and require about 2,200 kilograms of feedstock, roughly the amount that Iran currently has.[17] Although this scenario would still provide significant warning time of a nuclear breakout, it is a much closer call than in the simple batch recycling model.

Iran may gain one additional option in the future without expanding or reconfiguring Natanz: it could start with 20 percent enriched uranium. Iran has been producing uranium enriched to 20 percent U^{235} at its pilot fuel enrichment plant at Natanz. As of September 18, 2010, Iran had produced 25.1 kilograms of UF_6 enriched to this level. If it accumulated approximately 450 kilograms of 20 percent enriched uranium, it could convert that to 25 kilograms of 87 percent enriched uranium through two stages of batch recycling in the fuel enrichment plant. This conversion would take approximately one month. Alternatively, if the centrifuges in the fuel enrichment plant were run more slowly, only a single stage and less than 250 kilograms of feedstock would be required; the process would only take about three weeks. Either of these actions could plausibly be done between IAEA inspections, assuming that Iran had accumulated enough feedstock, though Iran's room for error would be tiny.

Alternative Scenarios at Natanz

Iran could acquire a more plausible breakout option within Natanz by expanding the facility or by moving to more sophisticated centrifuges. It could also attempt to confuse international opinion as to its activities, making a response more difficult. Several routes to a genuinely robust enrichment capability are possible.

The most obvious path to a more credible breakout option would be to simply put more centrifuges in service. But Natanz would need to expand considerably before Iran would acquire the ability to sprint to a bomb without being detected too soon. Assuming that Iran does not have enough time to reconfigure its facility without risking detection, its quickest route to the bomb then involves one stage of batch recycling with the current configuration followed by a second with a slower feed. Today, with 3.5 percent enriched uranium as a starting point, it would take about three months to produce 25 kilograms of weapons-grade uranium. If Iran increased its number of centrifuges operating tenfold to the roughly fifty thousand that it claims to want, it would gain the ability to produce enough material for one bomb in about two weeks, which would make detection unlikely while still leaving some room for small errors; it would, to use my terminology, gain a robust enrichment capability. Any considerably smaller expansion would still fail to give Iran a robust breakout capability at Natanz (though it would put both the United States and Israel in a much more uncomfortable situation than they are in today).

Many also believe that Iran would not attempt to build a weapon unless it believed that it could produce several bombs before anyone was able to stop it. They argue that Iran would want two bombs at a minimum: one to test (and hence demonstrate its capability to the world) and one to possibly use. Ideally, many believe, Iran would want five or more bombs to be confident that they would not face a military attack aimed at stopping its activities. This greatly increases the technical burden on Iran.

The only route to a far more robust breakout ability at Natanz—that is, to one in which Iran could enrich enough material for multiple bombs without risking a military response—would be to move to much more powerful centrifuges. Iran is currently conducting experiments with more capable centrifuges (known as the IR-2 and IR-3) but has not deployed them at scale. Those centrifuges, many analysts believe, might have separative powers as high as 5 kilograms-SWU/year each. A facility of the same scale as the current fuel enrichment plant at Natanz that used such centrifuges would still be too weak to create a robust breakout option at Natanz. If, however, Iran was to build a full-scale (fifty-thousand-machine) facility using such more advanced machines, it would be able to produce several bombs worth of weapons-grade uranium between inspections (assuming that it had also accumulated a considerable amount of additional reactor-grade uranium). While it would take additional time to produce actual weapons—many analysts estimate that it would take another six months—that could be done off-site, making a military strike more difficult.

Finally, Iran could, in principle, produce weapons-grade uranium at Natanz in full sight and under IAEA safeguards, something that many analysts have warned of. Many in the region appear to believe that IAEA safeguards prohibit Iran from producing HEU. This is not the case: if the IAEA continues to inspect Iran, and if Iran cooperates with it (a condition that is not currently being met), Iran will be in compliance with its IAEA obligations. Such a situation would, of course, provide the world with strong warning of an Iranian move to a bomb. But depending on how the world viewed the acceptability of Iran's actions, the United States or others might have more difficulty attracting international support for military or economic action to stop Iran. Ultimately, developing weapons-grade uranium in plain view would be extremely risky for Iran: the United States or Israel might attack even absent international support. As a result, such a path is unlikely for Iran to cross the line from limited to robust enrichment, and further to being nuclear armed.

Less commonly considered, but in many ways more worrisome, is the opposite route: Iran could eject inspectors before attempting to produce material for a bomb. Such a move would risk creating a confrontation well before Iran was able to build a weapon, but it would also make the actual development of a bomb much more opaque. If Iran ejected inspectors on pretenses unrelated to any desire to produce weapons-grade uranium (perhaps on accusations of espionage), the world would become indefinitely uncertain as to whether Iran was actually producing weapons-grade material. That would make it more difficult for the United States to gather support for a strike, not only internationally but possibly domestically as well. Iran could thus cross the line from limited to robust enrichment without firm international knowledge that it had done so.

Diversion from Natanz

Many analysts believe that, because of the risk of getting caught at Natanz, Iran would be more likely to produce weapons-grade uranium at a clandestine site: they point to the enrichment plant discovered at Fordow in 2009 as evidence that Iran is willing to build covert facilities. Iran would either start with natural uranium at the covert site, allowing it to operate completely independently of Natanz, or it would divert low-enriched uranium from Natanz to use as feedstock, allowing it to build a bomb much more quickly, with a smaller facility, or both. If Iran diverted stockpiled material from Natanz, it would need to break IAEA seals, something that the agency would presumably detect promptly on its next inspection. As a result, the IAEA would probably discover such a diversion within a month, though it might take a few more weeks for the IAEA to investigate and (one hopes) reject whatever explanation Iran gave for the broken seals. By that time, however, the uranium would presumably have been moved to an unknown location, making it vastly more difficult to stop Iran militarily. A high-stakes campaign of economic (and possibly military) pressure would become the only option.

What would Iran need in order to create a credible option of this sort? It could, in principle, already have one. The 2,200 kilograms of reactor-grade uranium that Iran has stockpiled at Natanz (in the form of a greater mass of UF_6) has enough U^{235} in it for three simple nuclear weapons. If that material was diverted to a clandestine enrichment facility, it could then be converted to weapons-grade uranium.

It is impossible, of course, to know whether any such clandestine facility exists, and if it does, what its specifications are. For illustration, assume that any clandestine facility is similar to the one planned for Fordow, which was revealed in September 2009. That facility was intended to house approximately three thousand centrifuges. If those were of IR-1 type operating at the same level as those currently installed at Natanz, and were configured to efficiently produce weapons-grade uranium, it would take approximately three months to convert the material from Natanz into enough weapons-grade uranium for a bomb; it would presumably take as much as six more months to convert that material into a weapon. The net result would expose Iran to possible economic and military pressure for nearly a year before it was able to build a single weapon. It is not implausible that Iran would take this risk; it is, however, quite possible that Iran would consider it too great a danger. Moreover, Iran might choose not to configure its hidden facility specifically for HEU production, something that would make it more difficult to explain to the international community if it was discovered. If Iran adopted a less efficient configuration in the interest of maintaining a cover story, though, it would take it even longer to produce enough material for a bomb.

This calculus could change considerably if Iran developed more advanced centrifuges. If, for example, a Fordow-type plant was outfitted with three thousand P-2 centrifuges capable of 5 kilograms-SWU/year each, it could produce five simple weapons starting with reactor-grade uranium in as little as four months. (It would, however, require considerably more reactor-grade uranium than has been stockpiled to date at Natanz in order to do that.) If Iran was to accumulate several hundred kilograms of 20 percent enriched uranium, it would shorten that time (or reduce the plant requirements) much further. For example, a Fordow-size plant using low-quality IR-1 centrifuges could convert 500 kilograms of 20 percent enriched uranium to four bombs' worth of weapons-grade uranium in four to five months. (This amount of feedstock, it should be noted, if far more than what Iran has accumulated to date.) In a dash, it could extract one bomb's worth of weapons-grade uranium from this much feedstock in a few weeks.

It will ultimately be impossible to know whether Iran has crossed the line from a limited to a robust enrichment capability due to the development of covert facilities. What can be known, though, is that limiting the amount of enriched uranium accumulated at Natanz, and slowing Iran's effort to develop more sophisticated centrifuges, makes the existence of such a robust breakout capability less likely.

Institutional Approaches to Enhancing Warning

All of the estimates above assume that the current approach to IAEA inspections continues. A stronger system of safeguards could, in principle, be developed. By increasing warning of an Iranian dash to the bomb, a stronger safeguards system would push back the line between limited and robust Iranian enrichment.

New safeguards could have three targets. First, they could provide continuous monitoring of enriched uranium stockpiles at Natanz. This would provide immediate notice of any attempt to remove stockpiled material for further enrichment elsewhere. While this would not solve the entire problem—the United States might still not be able to destroy the facilities to which material had been diverted—it would provide some additional warning (and would remove opportunities for confusion). Second, new safeguards could provide remote monitoring of the enrichment levels and perhaps other operational parameters of Natanz. Iran would likely resist such measures strongly as overly intrusive; they could, however, increase warning of a breakout at Natanz, particularly in the context of a more robust enrichment capability there. Third, broader monitoring could be expanded if Iran accepted the Additional Protocol. This would require Iran to allow spot inspections anywhere in its territory, which would deter construction of clandestine plants; it would also require monitoring of uranium mining, which would constrain Iran's ability to develop a fully parallel enrichment effort. If Iran was, in addition, to accept monitoring of its centrifuge construction efforts, building a secret facility would become even more difficult. It is unlikely, though, that Iran will accept such measures, at least under today's circumstances.

The United States could also enhance its unilateral surveillance activities, particularly those focused on detecting covert sites. It is impossible to know, based on open sources, what knowledge U.S. surveillance currently provides, or the extent to which it could be improved. Regardless, in assessing the value of additional surveillance efforts, policymakers should ensure that any new investments help support effective responses to an Iranian breakout.

Some analysts have proposed that, rather than adding additional inspections and monitoring, multinational ownership of Iranian fuel cycle facilities could provide additional warning of Iranian malfeasance.[18] Arguments in favor of these arrangements tend to have two themes. First, multinational ownership would come with a continuous international presence throughout the Iranian enrichment program. As a result, there would probably be immediate warning of any change in operations, providing additional opportunity to respond. Second, some proposals for multinational ownership also assume that advanced foreign centrifuges are used, and that the use of quasi-indigenous Iranian centrifuges is halted. Iran would thus require foreign assistance to build additional centrifuges or to operate its existing centrifuges in a nonapproved fashion, both of which would make it much more difficult for Iran to create a clandestine enrichment facility or to repurpose its known ones. However, this argument does not address an important technical problem: Iran may have already acquired sufficient capability with its own centrifuges to build a clandestine enrichment plant without further experimentation in its main facility; switching that facility to advanced foreign centrifuges would thus fail to accomplish the intended goal. That may not have been the case when the original proposals for multinational enrichment centers in Iran were first made. Regardless, technical issues aside, the proposals for multinational enrichment centers in Iran have essentially no political prospects for the foreseeable future. Establishing them would require not only special legal and commercial arrangements but a formally negotiated political solution too. Much more likely (assuming that Iran stops short of a nuclear weapon) is a tacit understanding, where Iran limits its enrichment activities and the rest of the world limits its response, perhaps accompanied by changing the requirements for IAEA inspections.

Cross-Cutting Lessons

This analysis points to five conclusions. First, unless Iran has a robust clandestine enrichment program, it does not have a strong breakout option today, based either on Natanz or on the further enrichment of material accumulated at Natanz in other facilities. Second, any limits to the amount of enriched material accumulated at Natanz are valuable in keeping Iran away from a robust break-out capability, even if Iran retains enough material to convert to one bomb; limits on the amount of 20 percent enriched uranium accumulated are particularly valuable. Third, limits on Iran's ability to improve its centrifuges can be extremely important in pushing back the line between limited and robust enrichment, both by preventing Iran from moving to a much more capable facility at Natanz and in making more dangerous secret sites less likely. Fourth, while complex institutional arrangements hold little promise in providing extra useful warning of illicit Iranian activities, continuous IAEA monitoring would be invaluable if Iran significantly expands its Natanz operations. Fifth, the line between limited enrichment and a nuclear-capable Iran is fuzzy. It depends on the how much risk one believes Iran is willing to take; how much confidence one places in the ability of economic pressure to stop Iranian breakout; how many weapons one believes Iran would want to build during a dash to the bomb; and on what one believes about the ability and willingness of Iran to build hidden facilities.

CONSEQUENCES OF A NUCLEAR CAPABLE OR ARMED IRAN

There are thus significant differences between different situations in which some Iranian enrichment program remains. But a longstanding focus among analysts and policymakers on achieving zero enrichment has tended to obscure the varied consequences that would follow from Iranian progress to different non-zero levels of nuclear capability. In addition to the immediate consequences for the world's ability to stop Iran's rushing to build a nuclear bomb, different statuses of the Iranian program would have different implications for regional security and global nonproliferation efforts.

Limited versus Robust Enrichment

Holding Iran to a limited enrichment capability—whether through negotiations, pressure, or a mix of the two—would have consequences beyond simply keeping Iran a good distance from the bomb. At a regional level, while many states have already started hedging by working to acquire nuclear expertise, few if any would likely go further in seeking their own nuclear weapons capabilities as a response to a stable and limited Iranian capability. In addition, without strong prospects of Iran being able to develop an arsenal on demand during a conflict, Iranian possession of a limited enrichment capability would have scant impact on crisis stability in the region. Perhaps the largest effect would be to tempt others, particularly Israel, to escalate a separate conflict with Iran by destroying its nuclear facilities.

Holding Iran to a limited enrichment capability would also benefit global nonproliferation efforts. Every time the Iranian enrichment program crosses a new line, it weakens the credibility of international efforts to restrict the spread and abuse of fuel cycle facilities. This is exacerbated when the international response to such Iranian actions is relatively weak. Halting the Iranian program well short of a weapon would help correct any signal that advanced development of enrichment facilities is invariably acceptable.

To be certain, there might also be negative nonproliferation consequences of resolving the Iranian program in a way that keeps Iran's enrichment system limited. Some analysts oppose any arrangements in which the international community would even tacitly accept some level of Iranian enrichment activity. The Institute for Science and International Security, for example, recently argued against a proposal to have Iran send its LEU to Russia for immediate conversion to nuclear fuel.[19] They argue that such an arrangement would legitimize the Iranian enrichment program, undermining international demands that Iran suspend its enrichment activities and helping Iran make the case for accepting an even bigger commercial enrichment program eventually. It would also, they worry, undermine the U.S. stance against the spread of enrichment technology, and hence nonproliferation. These are legitimate concerns, but they should not obscure the fact that Iranian acquisition of a robust breakout capability—which could lead to one or more nuclear bombs—would dwarf their impact on the nonproliferation regime worldwide.

Nuclear Capable versus Nuclear Armed

Just as various Iranian enrichment options have often been blurred, so has the line between nuclear capable and nuclear armed. Indeed many analysts and politicians tend to refer simply to a "nuclear Iran," either ignoring the distinctions encompassed within that or deliberately avoiding them.

Yet the distinction between a nuclear-capable and a nuclear-armed Iran matters, for at least five reasons. First, one of the principal risks associated with new nuclear powers is the prospect of accidental use of nuclear weapons. Indeed, many observers who believe that a nuclear-armed Iran could be effectively contained in the long term worry about the risks associated with a newly nuclear Iran. In particular, they express concern that a newly nuclear Iran, like any other newly nuclear state, would not have sophisticated command and control capabilities, and would thus be prone to accidental use. If Iran does not actually build and deploy weapons, though, there is no risk of accidental use. Moreover, if Iran retains a breakout capability based on a robust uranium enrichment infrastructure rather than on stockpiling of actual weapons-grade uranium, any risk of weapons-material transfer to terrorist groups, whether authorized or not, would be eliminated too.

Second, Iranian possession of actual nuclear weapons would have different consequences for crisis stability than simple Iranian possession of the ability to quickly make atomic bombs. Iranian proxies such as Hezbollah, for example, could not take risks and expect Iran to quickly back them up with a nuclear arsenal, if Iran was perpetually several months away from having a bomb. Even though Iran might be nuclear capable by dint of its ability to produce a bomb with little outside warning, that does not mean that it would not take Iran a significant amount of time to actually make a bomb.

Third, Iranian possession of actual nuclear weapons would likely make the United States more hesitant to involve itself in conventional military conflicts in the region.[20] If it was accompanied with a demonstrated medium-range ballistic missile capability, it could also threaten the strength of U.S. alliance commitments beyond the region, including in Europe. Development of ballistic missile defenses could help blunt that, but they would need to become far more robust than they are today.

Fourth, other regional powers would likely respond differently to a nuclear-armed Iran than to a nuclear-capable one. To be sure, in some cases, countries would feel the need to hedge against Iran's nuclear capability with a near-weapons capability of their own. But others might not. To many in the region, the threat posed by the Iranian nuclear program stems as much from the prestige and hence influence that it brings to Tehran as from the potential for it to give Iran a military capability. To the extent that regional leaders see the Iranian program this way, their natural response is to develop their own nuclear energy programs, but not necessarily nuclear weapons programs. This can be seen most clearly in the UAE, which has pursued nuclear power but has shown no interest in obtaining the full nuclear fuel cycle. Insofar as this is how some states respond to a nuclear-capable but not nuclear-armed Iran, the distinction has important consequences. In other cases, leaders may not want to pursue nuclear arms but may face public pressure to do so; again, having Iran remain nuclear capable but not nuclear armed could help their case.

Finally, many in the region continue to insist on adherence to IAEA rules as the indicator of whether Iran has crossed an unacceptable line.[21] Since it is possible for Iran to become nuclear capable without violating IAEA rules, many leaders will judge Iran to be safe even when it is not. This may, nonetheless, benefit the region even if those assessments are ill-founded. For example, if Turkey bases a decision of whether to pursue its own deterrent on whether Iran is complying with IAEA rules, and Iran continues to do so, the region may benefit from Turkish restraint—even if the Iranian activity should be considered dangerous.

Israel would also respond differently to a nuclear-armed Iran than to a nuclear-capable one. Israel has long maintained that it will "not be the first to introduce" nuclear weapons into the Middle East. Given that Israel is widely believed to already have a significant nuclear arsenal, this has been interpreted to mean that if another Middle Eastern state declared itself a nuclear power, Israel would do the same too. If Iran became openly nuclear armed, then, Israel could be expected to not only declare itself a nuclear power but also pursue qualitative (and possibly quantitative) improvements to its arsenal. Such a move would further erode whatever (presumably small) legitimacy the nuclear Nonproliferation Treaty enjoys in the region; it would also put the United States in the awkward position of needing to decide whether to assist Israel in any way.

Beyond the Middle East, an Iranian move from being nuclear capable to being nuclear armed would also have big consequences for global nonproliferation efforts. The problem is simple: failing to prevent another state from acquiring nuclear weapons would severely damage the credibility of the nonproliferation regime. That would make it harder to gather support for preventing other states from acquiring nuclear weapons too. U.S. policymakers have been extremely frustrated with many countries' insistence that Iran has a right to continue developing its enrichment capacity, so long as it adheres to IAEA rules. But one redeeming side effect of this has been that these countries can accept what Iran is doing without weakening their attachment to nonproliferation. Iranian acquisition of nuclear weapons would shatter that peace.

As with the line between limited and robust enrichment, some will argue that any agreed outcome that legitimizes Iranian enrichment is too high a price to pay for maintaining the line between a nuclear-capable and a nuclear-armed Iran. This approach is, once again, shortsighted: it undervalues the grave consequences for nonproliferation of Iranian nuclear acquisition.

Conclusions

As policymakers attempt to rally support for their preferred ways of limiting the Iranian nuclear program, it will be tempting to blur various possible states of that program together. Those seeking to completely eliminate the program will tend to ignore differences between limited and robust enrichment; those focused on drawing a line at the current level of Iranian capacity may treat the division between nuclear-capable and nuclear-armed status as being of secondary importance. But each of these distinctions—between zero, limited, and robust enrichment, and between all of those and a nuclear-armed Iran—matter. Strategists will need to balance the costs of trying to stop the Iranian program at various possible points with the consequences of failing to do so. But they should ensure that they remain keenly aware of the differences among the potential outcomes.

Endnotes

1. Ashton B. Carter, "Military Elements in a Strategy to Deal With Iran's Nuclear Program," in James N. Miller, Christine Parthemore, and Kurt M. Campbell, eds., *Iran: Assessing U.S. Strategic Options* (Washington, DC: Center for a New American Security, 2008).

2. If the United States happened to have three carrier battle groups in the region, it could probably respond in one week. If it was forced to use U.S.-based bombers, it would be severely restricted in the number of sorties it could execute daily, and could require as much as two weeks to hit all necessary targets. The author thanks Micah Zenko for helpful discussions on the technical limits to U.S. strike options.

3. For an extended discussion of the possibility of an Israeli strike on Iran, see Steven Simon, *An Israeli Strike on Iran*, Contingency Planning Memorandum No. 5 (New York: Council on Foreign Relations Press, 2009).

4. Robert A. Pape, *Bombing to Win: Air Power and Coercion in War* (Ithaca, NY: Cornell University Press, 1996).

5. The United States has been aware for many years of clandestine North Korean enrichment activities in general; it apparently was not, however, aware of the specific activities at Yongbyong that were revealed in November 2010.

6. *Implementations of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran,* IAEA Report, International Atomic Energy Agency, November 23, 2010, pp. 1–2.

7. See, for example, Joshua Pollack, "Consensus Emerges on Iran's Centrifuges," Armscontrolwonk.com, February 14, 2010. Supplemented by the author's calculations based on the most recent IAEA report.

8. David Albright and Christina Walrond, *Iran's Gas Centrifuge Program: Taking Stock*, Institute for Science and International Security, February 2010.

9. This assumes 10,600 kilograms of natural uranium feedstock and a 0.5 percent tails assay. It is impossible to significantly reduce the enrichment time by increasing the tails assay. On the other hand, lowering the tails assay would significantly slow the process. There is no apparent reason, though, why Iran would want to do this.

10. Paul K. Kerr, *Iran's Nuclear Program: Status*, CRS Report, Congressional Research Service, November 12, 2009, p. 14.

11. David Albright and Jacqueline Shire, "A Witches Brew? Evaluating Iran's Uranium-Enrichment Progress," *Arms Control Today*, November 2007.

12. The most recent IAEA report indicates a stockpile of 3,135 kilograms of reactor-grade UF_6.

13. The former case assumes 2.34 percent tails; the latter assumes 1.28 percent tails. It is theoretically possible to produce three simple bombs from this much feedstock. That would, however, require roughly sixteen months (including about five months for the first bomb) and would assume 0.2 percent tails.

14. David Albright and Paul Brannan, "Further Comments Regarding the BAS Article on Fordow," December 4, 2009, http://www.isisnucleariran.org/news/detail/further-comments-regarding-the-bas-article-on-fordow.

15. This calculation is based on methods in Gregory S. Jones, "Iran's Centrifuge Enrichment Program as a Source of Fissile Material for Nuclear Weapons," April 8, 2008, http://www.npolicy.org/files/20081017-Jones-IranEnrichment.pdf. To calculate the numbers given in the main text, note that the throughput will be determined by the rate at which the cascades can produce product, rather than by SWU calculations. In the most recent IAEA report, Natanz is reported to have produced 48 kilograms of LEU product in fourteen days, equivalent to an annual rate of 1,250 kilograms. Applying that rate to the amount of product that must be produced at each stage of the batch recycle process leads to the conclusion given in the main text. Note that the main factor here is the amount of material that must be produced in the first recycling stage.

[16] *Iran's Nuclear, Chemical, and Biological Capabilities* (London, UK: International Institute for Strategic Studies, 2011), p. 73.

17. To calculate this, we observe that Glaser estimates 37 kilograms of 91 percent product given 360 kilograms of 16 percent feed with the slower enrichment. This implies a need for 243 kilograms of 16 percent feed to produce 25 kilograms of product. We estimate the time taken to produce the 243 kilograms of feed using the 1,250 kilograms/year of throughput estimated above, and the additional time to produce 25 kilograms of weapons-grade uranium using a rate 3.07 times slower (which reflects the reduced throughput). The time to produce enough material for a weapon is substantially reduced because the process uses 16 percent enriched uranium much more efficiently, which, in turn, means that less of it must be made in the first place.
18. The most prominent proposals are Geoffrey Forden and John Thomson, "Iran as a Pioneer Case for Multilateral Nuclear Arrangements," MIT Working Paper, May 2007; and Thomas R. Pickering, William Luers, and Jim Walsh, "A Solution for the US-Iran Nuclear Standoff," *New York Review of Books*, March 20, 2008.
19. David Albright, Paul Brannan, and Andrea Stricker, "Avoiding the Legitimization of Iranian Enrichment: Better to Discourage Options Involving the Conversion of Iran's LEU Stock into Bushehr Reactor Fuel," Institute for Science and International Security, October 26, 2010.
20. Matthew Kroenig, *Exporting the Bomb: Technology Transfer and the Spread of Nuclear Weapons* (Ithaca, NY: Cornell University Press, 2010).
21. In many cases, this appears to be based on an incorrect belief that the IAEA does not allow enrichment to greater than 20 percent U_{235}.

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