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The Clock is Ticking, But How Fast?

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The International Atomic Energy Agency (IAEA) privately briefed permanent members of the UN Security Council and Germany in mid-March that Iran was almost ready to start putting uranium gas into a group of 164 centrifuges at the Natanz uranium enrichment site. Iran is now on the verge of mastering a critical step in building and operating a gas centrifuge plant that would be able to produce significant quantities of enriched uranium for either peaceful or military purposes. However, Iran can be expected to face serious technical hurdles before it can produce significant quantities of enriched uranium.

Following the briefing, anonymous US officials quickly started to distort what the IAEA had said. These officials told journalists on a not for attribution basis that this action by Iran represented a significant acceleration of its enrichment program. US officials called several journalists to tell them that in the briefing IAEA officials were “shocked,” “astonished,” “blown-away” by Iran’s progress on gas centrifuges, leading the United States to revise its own timeline for Iran to get the bomb. In fact, IAEA officials have said they were not surprised by Iran’s actions. Although Iran’s pace is troubling and requires concerted diplomatic effort to reverse, it was also anticipated by other experts, including those at ISIS[1]. A senior IAEA official told the Associated Press that these US statements came “from people who are seeking a crisis, not a solution.”

Recent comments by US officials about Iran’s timeline to nuclear weapons differ from official, community-wide US intelligence assessments. In testimony before the Senate Intelligence Committee on February 2, 2006, John Negroponte, Director of National Intelligence, stated that Iran is judged as probably having neither a nuclear weapon nor the necessary fissile material for a weapon. He added that if Iran continues on its current path, it “will likely have the capability to produce a nuclear weapon within the next decade." The basis for this estimate remains classified, although press reports state that Iran’s lack of knowledge and experience in running large numbers of centrifuges is an

[1] “Iran’s Next Steps: Final Tests and the Construction of a Uranium Enrichment Plant,” by David Albright & Corey Hinderstein, January 12, 2006 (http://www.isis-online.org/publications/iran/irancascade.pdf).

important consideration. Most interpret Negroponte's remark to mean that Iran will need 5-10 years before it possesses nuclear weapons.

Government estimates of the amount of time Iran needs to get its first nuclear weapon are subject to a great deal of uncertainty. Many questions about Iran's technical nuclear capabilities and plans are unknown, and the IAEA has been unable to verify that Iran has fully declared its nuclear activities. Iranian denials that it has any intention to produce highly enriched uranium (HEU) or build nuclear weapons are viewed with skepticism. Nonetheless, there is no evidence of any decision by Iran to build a nuclear arsenal, let alone any knowledge of an official Iranian schedule for acquiring nuclear weapons.

Estimates of Iran's nuclear capabilities, accomplishments, and timelines need far greater public and Congressional scrutiny than they are currently receiving. This scrutiny becomes even more important as those in the Bush Administration who favor confronting Iran and pressing for regime change may be hyping up Iran's nuclear threat and trying to undermine intelligence assessments that Iran is several years from having nuclear weapons.

To understand the assumptions, key information, and uncertainties driving estimates of these timelines, we have developed two "worst-case" estimates of the time Iran would need to build its first nuclear weapon. In both of these estimates, which cover the most likely scenarios, Iran appears to need at least three years before it could have enough HEU to make a nuclear weapon. Given the technical difficulty of the task, it could take Iran much longer.

Iran Breaks the Suspension

Iran's actions appear aimed at rapidly installing and running gas centrifuges. In early January 2006, Iran removed 52 seals applied by the International Atomic Energy Agency (IAEA) that verified the suspension of Iran's P-1 centrifuge uranium enrichment program. The seals were located at the Natanz, Pars Trash, and Farayand Technique sites, Iran's main centrifuge facilities. On February 11, Iran started to enrich uranium in a small number of centrifuges at Natanz, bringing to a halt Iran's suspension of uranium enrichment that had lasted since October 2003. A few days earlier, Iran moved to end its implementation of the Additional Protocol, an advanced safeguards agreement created in the 1990s to fix traditional safeguards' inability to provide adequate assurance that a country does not have undeclared nuclear facilities or materials.

After removing seals, Iran started to substantially renovate key portions of its main centrifuge research and development facility, the Pilot Fuel Enrichment Plant (PFEP) at Natanz. Iran began construction on the PFEP in secret in 2001, and it installed up to 200 centrifuges in 2002 and 2003. The PFEP is designed to hold six 164-machine cascades, groups of centrifuges connected together by pipes, in addition to smaller test cascades, for a total of about a thousand centrifuges.

At Natanz and Farayand Technique, Iran quickly restarted testing centrifuge rotors and checking centrifuge components to determine if they are manufactured precisely enough to use in a centrifuge. By early March, Iran had restarted enriching uranium at the pilot plant in 10- and 20-centrifuge cascades.

Iran has also moved process tanks and an autoclave, used to heat uranium hexafluoride into a gas prior to insertion into a centrifuge cascade, into the underground Fuel Enrichment Plant (FEP) at Natanz. The FEP is the main production facility and is designed to hold eventually 50,000-60,000 centrifuges. Iran also told the IAEA that it intends to start the installation of the first 3,000 P1 centrifuges in the underground cascade halls at the FEP in the fourth quarter of 2006.

The Uranium Conversion Facility (UCF) at Isfahan has continued to operate since its restart in August 2005, following the breakdown in the suspension. By late February 2006, Iran had produced about 85 tonnes of uranium hexafluoride, where the quantity refers to uranium mass. With roughly 5 tonnes of uranium hexafluoride needed to make enough HEU for a nuclear weapon, this stock represents enough natural uranium hexafluoride for over 15 nuclear weapons. Although this uranium hexafluoride contains impurities that can interfere with the operation of centrifuges and reduce their output, most IAEA experts believe that Iran can overcome this problem and believe this problem has been overblown in the media. Iran is known to be working to improve the purity of its uranium hexafluoride. If necessary, Iran could use its existing stock of impure material, if it had no other material. It could take additional steps to purify this uranium hexafluoride, or it could use the material in its own centrifuges and experience reduced output and a higher centrifuge failure rate.

Iran's Next Major Technical Hurdle to Building a Centrifuge Plant

A key part of the development of Iran's gas centrifuge program is the operation of the 164-machine cascade at the PFEP at Natanz. The installation of the first test cascade was finished in the fall of 2003, but this cascade never operated with uranium hexafluoride prior to the suspension of October 2003.

Iran has needed to take several steps before it could introduce uranium hexafluoride into this cascade. It first had to repair or replace any damaged centrifuges. According to IAEA reports, about 30% of the centrifuges crashed or broke when the cascade was shut down at the start of the suspension. In addition, Iran disconnected some of the pipes and exposed the pipes to humidity which could have caused corrosion. After making necessary repairs, Iran must finish connecting all the pipes, establish a vacuum inside the cascade, and finish preparing the cascade for operation with uranium hexafluoride. Progress on these steps was central to the IAEA briefing in mid-March.

If Iran does not encounter any significant problems, Iran could then carefully introduce uranium hexafluoride into the cascade and start enriching uranium. Iran would want to operate the cascade for several months to ensure that no significant problems develop and gain confidence that it can successfully enrich uranium in the cascade. Problems could include excessive vibration of the centrifuges, motor or power failures, pressure and temperature instabilities, or breakdown of the vacuum. Iran may also want to test any emergency systems designed to shut down the cascade without losing many centrifuges in the event of a major failure. Absent major problems, Iran is expected to need roughly six months to one year to demonstrate successful operation of this cascade and its associated emergency and control systems.

Once Iran overcomes the technical hurdle of operating its test cascade, it can duplicate it and create larger cascades. Iran would then be ready to build a centrifuge plant able to produce significant amounts of enriched uranium either for peaceful purposes or for nuclear weapons. However, Iran may encounter additional problems when it tries to build and operate a plant.

Worst-Case Estimates

Developing an answer to how soon Iran could produce enough HEU for a nuclear weapon is complicated and fraught with uncertainty. Beyond the technical uncertainties, several other important factors are unknown. Will Iran develop a nuclear weapons capability but produce only low enriched uranium for nuclear power reactors and not any highly enriched uranium? Will Iran withdraw from the NPT, expel inspectors, and concentrate on building secret nuclear facilities? What resources will Iran apply to finishing its uranium enrichment facilities? Will there be military strikes against Iranian nuclear sites? Will the regime change fundamentally in the next several years?

Before developing a timeline, it is necessary to estimate how much HEU Iran would need to make a nuclear weapon. Iran could be expected initially to build a crude, implosion-type fission weapon similar to known designs. In 1990, Iraq initially planned to use 15 kilograms of weapon-grade uranium (HEU containing more than 90 percent uranium 235) in its implosion design. An unclassified design using almost 20 kilograms was calculated in a study co-authored by Theodore Taylor and Albright in about 1990. Thus, an Iranian nuclear weapon could be expected to need about 15-20 kilograms of weapon-grade uranium. A larger quantity of HEU is needed than the exact amount placed into the weapon because of inevitable losses during processing, but such losses can be kept to less than 20 percent with care. Thus, for the estimates presented here, a crude fission weapon is estimated to require 15-20 kilograms of weapon-grade uranium, where most losses would be recycled into successive weapons.

Clandestine Centrifuge Plant

Iran's most direct path to obtaining HEU for nuclear weapons is building a relatively small gas centrifuge plant that can make weapon-grade uranium directly from natural uranium. If Iran built such a plant openly, it would be an acknowledgement that it seeks nuclear weapons. As a result, Iran is likely to pursue such a path in utmost secrecy, without declaring to the IAEA the facility and any associated uranium hexafluoride production facilities. Without the Additional Protocol in effect, however, the IAEA would face a difficult challenge discovering such a clandestine facility, even as Iran installs centrifuges at Natanz to produce low enriched uranium. The IAEA has already reported that it can no longer monitor effectively centrifuge components, unless they are at Natanz and within areas subject to IAEA containment and surveillance. Alternatively, Iran may feel less assured about successfully deceiving the inspectors and proceed with such a plant only after withdrawing from the NPT and asking inspectors to leave. In either case, there is little chance that U.S. or European intelligence agencies would detect this facility.

The key to predicting a timeline is understanding the pace and scope of Iran's gas centrifuge program, in particular the schedule for establishing a centrifuge plant that would hold about 1,500 centrifuges. This capacity is sufficient to make more than enough HEU for one nuclear weapon per year.

Each P1 centrifuge has an output of about 3 separative work units (swu) per year according to senior IAEA officials[2]. From the A. Q. Khan network, Iran acquired drawings of a modified variant of an early-generation Urenco centrifuge. Experts who saw these drawings assessed that, based on the design's materials, dimensions, and tolerances, the P1 in Iran is based on an early version of the Dutch 4M centrifuge that was subsequently modified by Pakistan. The 4M was developed in the Netherlands in the mid-1970s and was more advanced than the earlier Dutch SNOR/CNOR machines. Its rotor assembly has four aluminum rotor tubes connected by three maraging steel bellows.

With 1,500 centrifuges and a capacity of 4,500 swu per year, this facility could produce as much as 28 kilograms of weapon-grade uranium per year, assuming a tails assay of 0.5 percent, where tails assay is the fraction of uranium 235 in the waste stream. This is a relatively high tails assay, but such a tails assay is common in initial nuclear weapons programs. As a program matures and grows, it typically reduces the tails assay to about 0.4 percent and perhaps later to 0.3 percent to conserve uranium supplies.

By spring 2004, Iran had already put together about 1,140 centrifuge rotor assemblies, a reasonable indicator of the number of complete centrifuges[3]. However, only about 500 of these rotors were good enough to operate in cascades, according to knowledgeable senior IAEA officials. The November 2004 IAEA report stated that from the spring to October 10, 2004, Iran had assembled an additional 135 rotors, bringing the total number of rotors assembled to 1,275. As mentioned above, a large number of these rotors are not usable in an operating cascade.

Iran is believed to have assembled more centrifuges prior to the suspension being re-imposed on November 22, 2004. Without more specific information, it is assumed that Iran continued to assemble centrifuges at a constant rate, adding another 70 centrifuges, for a total of 1,345 centrifuges. However, the total number of good centrifuges is estimated at about 700.

[2] "Centrifuge Connection," by David Albright & Corey Hinderstein, Bulletin of Atomic Scientists, March/April 2004 pp. 61-66.

[3] Director General, "Implementation of the NPT Safeguard Agreement in the Islamic Republic of Iran," International Atomic Energy Agency, June 1, 2004, GOV/2004/34, Annex 1, p. 11.

Iran has enough components for up to 5,000 centrifuges, according to senior diplomats in Vienna. However, other senior diplomats said that Iran may not have 5,000 of all components, and many components are not expected to pass quality control. In total, Iran is estimated to have in-hand enough good components for at least an additional 1,000 to 2,000 centrifuges.

If Iran decided to build a clandestine plant in early 2006, it could assemble enough additional usable centrifuges for this plant of 1,500 centrifuges by the end of this year or early next year. It would only need to assemble at its past rate, or about 70-100 centrifuges per month, to accomplish this goal.

In the meantime, Iran would need to identify a new facility where it could install centrifuge cascades, since it is unlikely to choose Natanz as the location of a secret plant. It would also need to install control and emergency equipment, feed and withdrawal systems, and other peripheral equipment. It would then need to integrate all these systems, test them, and commission the plant. Iran could start immediately to accomplish these steps, even before the final testing of the 164 machine cascade at Natanz, but final completion of the clandestine plant is highly unlikely before the end of 2007.

Given another year to make enough HEU for a nuclear weapon, where some inefficiencies in the plant are expected, and a few more months to convert the uranium into weapon components, Iran could have its first nuclear weapon in 2009. By this time, Iran is assessed to have had sufficient time to prepare the other components of a nuclear weapon, although the weapon may not be small enough to be deliverable by a ballistic missile.

This result reflects a worst-case assessment, and Iran can be expected to take longer. Iran is likely to encounter technical difficulties that would delay bringing a centrifuge plant into operation. Factors causing delay include Iran having trouble in the installation of so many centrifuges in such a short time period, or Iran taking longer than expected to overcome difficulties in operating the cascades as a single production unit or commissioning the secret centrifuge plant.

Break-Out Using FEP

Iran has stated its intention to start installing centrifuges in late 2006 in its first module of 3,000 centrifuges in the underground halls of FEP at Natanz. This module would give Iran another way to produce HEU for nuclear weapons, even though the module is being designed to produce low enriched uranium. Once Iran has an adequate stock of LEU, the time to produce enough HEU for a nuclear weapon in this facility could be dramatically shortened.

At above rates of centrifuge assembly, and assuming that Iran has or can produce enough P1 centrifuges and associated equipment, Iran could finish assembling 3,000 centrifuges for this module sometime in 2008. Although cascades would be expected to be built before all the centrifuges are assembled, Iran will probably need at least another year to finish this module, placing the completion date in 2009 or 2010. Unexpected complications could delay the commissioning date. On the other hand, Iran could accelerate the pace by manufacturing, assembling, and installing centrifuges more quickly. Given all the difficult tasks that must be accomplished, however, Iran is unlikely to commission this module much before the start of 2009.

If Iran decided to make HEU in this module, it would have several alternatives. Because of the small throughput and great operational flexibility of centrifuges, HEU for nuclear weapons could be produced by reconfiguring the cascades in the module or batch recycling where the cascade product is used as feed for subsequent cycles of enrichment in the same cascade.

Reconfiguration could be as straightforward as connecting separate cascades in series and selecting carefully the places where new pipes interconnect the cascades. This Iranian module is unlikely to be composed of only one cascade. Because of the risk that whole cascades can fail following the failure of a few centrifuges, a unit with 3,000 centrifuges would likely be composed of several cascades, each making LEU. In such a case, reconfiguration may not even require the disassembly of the individual cascades, and it could be accomplished within days. In this case, the loss of enrichment output can be less than ten percent, although the final enrichment level of the HEU may reach only 80 percent, sufficient for use in an existing implosion design albeit with a lower explosive yield. With a reconfigured plant, and starting with natural uranium, 20 kilograms of HEU uranium could be produced within four to six months. If Iran waited until it had produced a stock of LEU and used this stock as the initial feedstock, it could produce 20 kilograms in about one to two months.

Batch recycling would entail putting the cascade product back through the cascade several times, without the need to change the basic setup of the cascade. Cascades of the type expected at Natanz could produce weapon-grade uranium after roughly five recycles, starting with natural uranium. Twenty kilograms of weapon-grade uranium could be produced in about six to twelve months. If the batch operation started with an existing stock of LEU, the time to produce 20 kilograms of weapon-grade uranium would drop to about one to two months.

Whether using batch recycling or reconfiguration, Iran could produce in 3,000 centrifuges at Natanz enough HEU for its first nuclear weapon in less than a year. Iran could do so in considerably less than a year, if it used an existing stock of LEU as the initial feed. It is likely that Iran would operate the module to make LEU so that any production of HEU would be expected to happen quickly.

Using either break-out approach, Iran is not likely to have enough HEU for a nuclear weapon until 2009. This timeline is similar to that outlined in the clandestine plant scenario. In addition, technical obstacles may further delay the operation of the module in the FEP.

Conclusion

The international community needs to be committed to a diplomatic solution that results in an agreement whereby Iran voluntarily forswears having any deployed enrichment capability. Looking at a timeline of at least three years before Iran could have a nuclear weapons capability means that there is still time to pursue aggressive diplomatic options, and time for measures such as sanctions to have an effect, if they become necessary.

It is vital to understand what Iran has accomplished, what it still has to learn, and when it will reach a point when a plan to pursue nuclear weapons covertly or openly could succeed more quickly than the international community could react. Although these estimates include significant uncertainties, they reinforce the view that Iran must foreswear any deployed enrichment capability and accept adequate inspections. Otherwise, we risk a seismic shift in the balance of power in the region.