Iran's Nuclear Ambitions and Future Prospects

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International diplomacy efforts dealing with Iran's nuclear program continue to fill the daily news headlines. The efforts of P5+1, the International Atomic Energy Agency (IAEA) and the United Nations Security Council (UNSC) have tried, in various formats, to encourage and enforce Iran to comply with the provisions of the Non-proliferation Treaty (NPT) and its Comprehensive Safeguards Agreement (CSA) to ensure that Iran's nuclear program is not used as a cover for the development of nuclear weapons. The challenge of discovering what has taken place, as well as Iran's current nuclear ambitions, is difficult not only because of Tehran's obstructionism, but also because the same nuclear technologies, particularly uranium enrichment and spent fuel reprocessing, can be used for both civilian and military purposes.

This paper addresses current and near term uranium enrichment capabilities of Iran, and sheds light on the IAEA's practices with regards to drawing safeguards conclusions.

Acquisition of nuclear technology

Iran's nuclear aspirations date back to the 1950s. In the 1970s the US, France and Germany played key roles in the early days of Iran's nuclear program, which was planned on an ambitious scale to achieve 23000 MWe, with 23 nuclear power reactors by 1994. From the very beginning Iran was not only interested in having nuclear power, but was also pursuing efforts to have uranium enrichment and spent fuel reprocessing on its soil. This is reflected in 1975 memorandum of Henry Kissinger to the then Secretary of Defense[1], where Mr. Kissinger suggests a multinational reprocessing facility in Iran as a fall back position, but recommended the participation of Iran as an investor to an enrichment plant in the US. In 1974 Iran invested to EURODIF in France, and made an R&D agreement with an US company to embark on uranium enrichment using laser technology[2].

The political environment and priorities changed as a result of the revolution in 1979. The new regime was less interested in nuclear energy. Also, financial difficulties contributed to the halting of all nuclear construction activities, including that of the *Bushehr nuclear power plant (BNPP)*.

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[1] National Security Decision 292, National Security Council, Washington, DC, April 22,1975.

[2] G. Robert. Iran's Deal with L.A. Firm Widens Nuclear Capability. *Los Angeles Times*. August 22,1979,.

The staffing of the Atomic Energy Organization was reduced to below 1000 persons[3]. However, the new regime started from mid-1980's to revive its nuclear program, amidst a war with Iraq. By then the political and security environment had fundamentally changed. Sanctions, and, in particular American pressure, blocked the Iranian attempts to complete the BNPP and acquire new power plants, and fuel cycle technology from Germany, Brazil, France, Argentina and Spain. However, Iran successfully concluded a contract to build small nuclear research reactors with China to Isfahan. Iran also succeeded in the mid-1990's to start the reconstruction of the BNPP with the Russians. The BNPP has been operating since 2011.

From the mid 1980s Iran revitalized its efforts to acquire enrichment and reprocessing technologies with some success. In 1987, it received first gas ultracentrifuge components and drawings from the A. Q. Khan nuclear black market. It was able to obtain laser enrichment laboratory equipment from China[4], and in the late 1990s, secured additional more advanced laser equipment from Russia, with a planned *laser R&D enrichment facility* at Lashkar Abad[5]. This latter installation was dismantled in 2003.

During the 1980s and 1990s Iran conducted laboratory scale uranium enrichment and conversion R&D including acquisition of nuclear materials without reporting them into the IAEA. When this became public and in order to avoid referral to the UN Security Council, Iran agreed in November 2003 with the EU-3 (France, Germany and UK) to suspend the enrichment and reprocessing related activities until necessary confidence on the peaceful nature of its program has been built. Between 2003 and 2006, the EU-3 continued to negotiate with Iran despite several other agreements offered, with each facing its own implementation problems. In June 2006, China, Russia and the US joined the EU-3 (now called P5+1 process) and negotiations have been taking place since then under these auspices. In spite of the UN Security Council resolutions, by now half a dozen of them, Iran has not suspended enrichment activities called for in the resolutions, with the exception of the period of roughly a year in 2004.

Following revelations made by the leaders of France, the US and UK, Iran disclosed in September 2009 that it had been constructing in secrecy an additional underground enrichment plant at *Fordow* near the city of Qom. Iran had subsequently announced that it would build in the coming years ten additional enrichment facilities, but has not disclosed any technical details about the plans. By August 2012 Iran had installed altogether about 11000 centrifuges to the enrichment plants in Natanz and Qom. However, the centrifuges have been operating below their

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[3] A. Etemad, Iran, in A European non-proliferation policy, Edited by H. Mueller, Claredon Press, Oxford, 1987, p.208.

[4] Implementation of the NPT Safeguards Agreement in the Islamic Republic of Iran. Report by the Director General. IAEA, GOV/2003/75. November 10, 2003.

[5] Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions 1737 (2006) and 1747 (2007) in the Islamic Republic of Iran. IAEA, GOV/2007/58. November 15, 2007. P. 2.

design capacities. By then, Iran had been able to produce more than 6 tons of 3.5 % enriched UF6 using the IR-1 type centrifuges.

In February 2010 Iran started at the Pilot Fuel Enrichment Plant in Natanz the production of 20 % U-235 for the US-made *Tehran Nuclear Research Reactor (TRR)*, which has been in operation since 1967. In June 2009, Iran asked the assistance of the IAEA get new fuel for the reactor, but it did not agree with the conditions resulting from discussions with the 'Vienna Group' in October 2009. After failing to reach a later deal brokered by Turkey and Brazil in 2010, Iran expanded its enrichment activities to produce 20% enriched uranium at Qom. By June 2012, Iran had produced about 140 kg 20 % enriched uranium, out of which some has been moved to Isfahan for *fuel manufacturing*.

Iran has additionally in last two years been testing several more advanced centrifuges, but progress so far appears to have been modest. Whether this is to do with the design and manufacturing problems, or a lack of special raw materials such as carbon fiber and maraging steel resulting from sanctions, or due the IAEA's limited access to Iran's R&D sites and therefore limited knowledge, these variables are all plausible explanations.

What is known is that Iran has fairly modest domestic uranium deposits. As a part of the 1970s efforts Iran was able to obtain *uranium ore concentrate* (yellow cake) from South Africa in 1984. It has a uranium mine under construction in Saghand, a milling facility at Ardakan, and a small 20 ton per year uranium mining/milling installation in operation at Gcchine.

In early 1990 Iran concluded a contract with the Chinese to build a *uranium conversion facility (UCF)* to Esfahan. While Iran was able to acquire technology from China, it finally constructed the facility itself. Since 2004 UCF has produced 550 tons of UF6 using the South African origin material as feed. This amount is sufficient to feed the planned enrichment facilities for several years.

Iran continues the construction of a heavy water reactor at Arak. While Iran has currently enough uranium stocks for the fuel, the installation of the fabrication equipment at a fuel fabrication plant in Esfahan, the construction of the reactor, and the production of heavy water all proceed at a lower rate than originally announced. Iran claims that the IR-40 reactor will be operational in 2013.

Notwithstanding the reporting obligations required by Iran under its safeguards undertakings, IAEA Board of Governor's resolutions, numerous UN Security Council resolutions, and attempts undertaken by the P5+1 in seeking a political solution, and concurrent rounds of sanctions imposed, it has not stopped Iran continuing with nuclear enrichment. Reduced cooperation with the IAEA, non-implementation of the Additional Protocol, lack of answers to longstanding questions regarding the possible military dimension of the program, and back and forth approach to negotiating on its nuclear program, increases the opacity of Iran's nuclear dossier. The IAEA reports on June 2008 and November 2011 raised questions about Iran's activities over two

decades, which appear to be related to nuclear weapons R&D, judged by the IAEA to be credible information. These include work done from early 1990's in the Physics Research Center at Lavisan, then AMAD Plan, and after 2004 onwards at various institutes more recently under the umbrella of the Organization for Defensive Innovation and Research (SPND), which is under the Education Research Institute (ERI).

Status of the uranium enrichment program

Iran has currently three known uranium enrichment plants: Pilot Fuel Enrichment Plant (PFEP), Fuel Enrichment Plant (FEP), and Fordow Fuel Enrichment Plant (FFEP). The first two are located in Natanz, the FFEP in Fordow near the city of Qom. In addition, Iran has, at least, one known enrichment R&D facility, Kalaye Electric, in Tehran.

The FEP is the main enrichment facility which is using IR-1 centrifuges[6]. In August 21, 2012, the FEP had 55 cascades with 9330 centrifuges installed[7]. In addition, 6177 centrifuge cases had been brought to the facility indicating that Iran plans to go ahead with the installation of additional centrifuges. Since the beginning of the operation from 2007, the FEP has produced 6876 kg 3.5 percent enriched uranium hexafluoride (UF6).

The PFEP is a pilot facility which has mainly been used for testing of various types of centrifuges (IR-1, IR-2, IR-2m,IR-3 and IR-4). However, since 2007 the facility was producing first 3.5 percent enriched UF6, and from February 2010 20 percent enriched UF6.

FFEP, which like FEP, is an underground facility, which was revealed by the U.S in September 2009. Since then the purpose of the facility has been modified several times, but it currently appears to be dedicated for the production of 20 percent enriched UF6. In August 2012, FFEP had four IR-1 cascades operating in tandem[8] . In August, FFEP had additional 6 IR-1 cascades installed, but not yet operating. When combined, FPEP and FFEP had produced a total of 189.4 kg 20 percent enriched UF6.

Iran has stated that it produces 20 percent enriched UF6 to make fuel for the TRR. The IAEA report of August 2012 states that Iran has transferred 71.25 kg of 20 percent enriched UF6 to the Fuel Plate Fabrication Plant in Isfahan. This means that Iran had, in August 2012, about 90 kg of 20 percent enriched UF6 left at the enrichment plants. In addition Iran had, during the same

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[6] See the terminology from the S.Henderson and O. Heinonen, Nuclear Iran, A Glossary of Terms, available from http://belfercenter.ksg.harvard.edu/publication/22269/nuclear_iran.html?breadcrumb=%2Fexperts%2F2107%2Folli_heinonen.

[7] Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran. IAEA, GOV/2012/9. August 30, 2012.

[8] In order to use more efficiently its 3.5 percent LEU stock, Iran has interconnected two IR-1 centrifuge cascades together to a tandem cascade. The first cascade enriches from 3.5 percent UF6 to almost 20 percent UF6. The second one takes the tails from the first ones, enriches them to 10 percent LEU, and feeds the enriched uranium to the first one. As a result tails of the second are natural uranium.

period, about 5.3 tons 3.5 % enriched UF6 left at the enrichment plants when the feed to the 20 percent UF6 production is taken into account.

During the last few months the production at the FEP has been 250 kg 3.5 percent enriched UF6 per month. Here, several permutations are possible. Should FEP continue with this rate, Iran would have over 9 tons of 3.5 percent enriched UF6, by the end of 2013. However, if Iran proceeds with the installation of additional IR-1s at FEP using the historical commission speed of average two IR-1 cascades monthly, the cumulative production with the current IR-1 performance would be over 10 tons 3.5 percent enriched UF6 by the end of the next year. If Iran continues to use 3 tandem cascades the PFEP and FEP with the current rate production of 20 % enriched UF6, it will have by the end of 2013 about 360 kg 20 % enriched uranium UF6. If the currently installed two additional cascades are commissioned, the inventory would be 450kg, and with seven installed tandems more than 600 kg20 % enriched uranium UF6 by the end of 2013 .

The above scenarios are projected based on a map-out of enrichment according to an A.Q. Khan-type scheme. To enrich uranium so that the percentage of fissile isotope U-235 increases from 0.7% to 90%, the A. Q. Khan network provided its clients with a scheme, where UF6 gas is passed through four steps: (1) through two groups of 12 cascades of centrifuges, each having 164 machines, taking the enrichment level to 3.5%; (2) through eight cascades each of another 164 machines to increase the level from 3.5% to 20%; (3) through four cascades of 114 machines increase from 20% to 60%; (4) through two cascades of 64 machines each, to increase from 60% to 90%. At each stage, gas depleted of U-235 is passed back to the previous stage or out of the system completely.

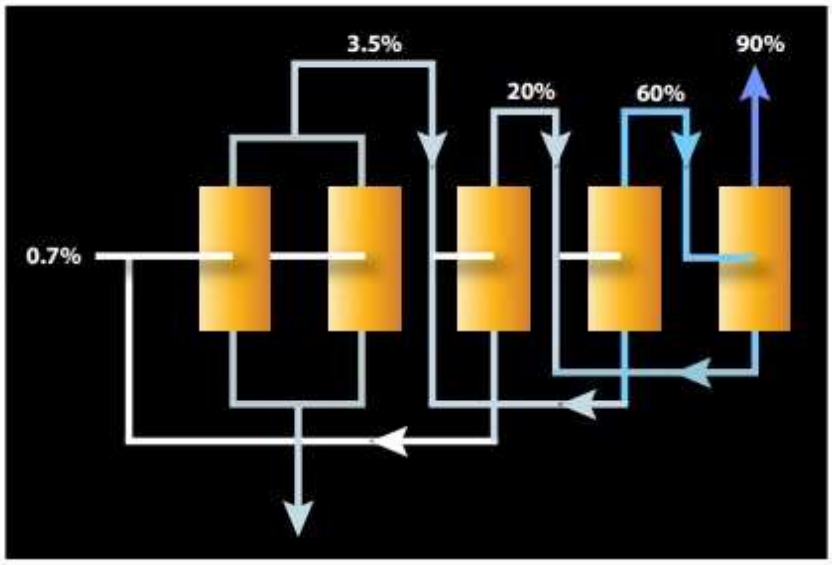
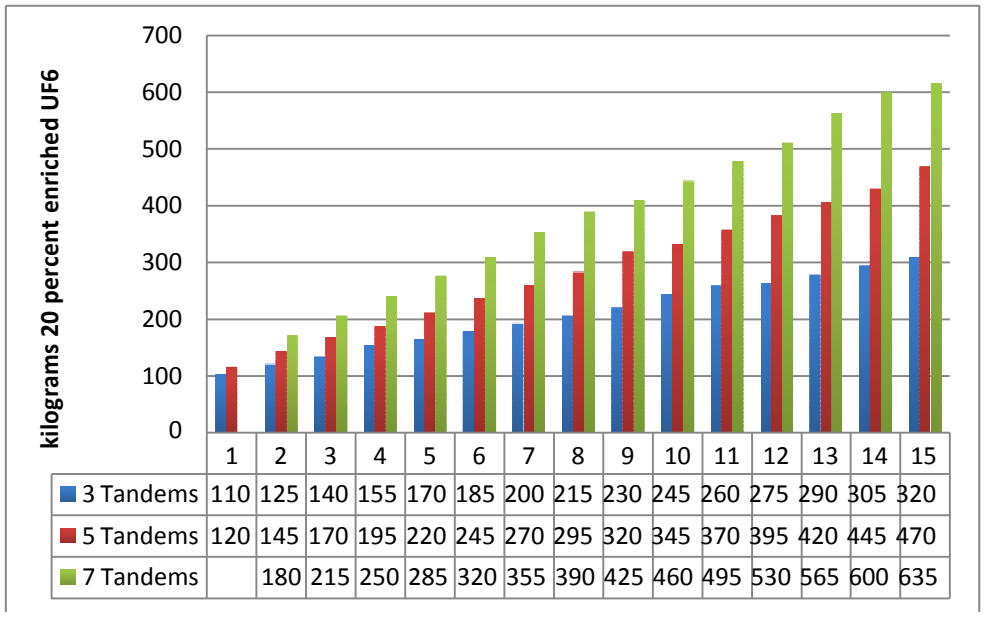


Fig.1. A. Q. Khan scheme for the production of 90 percent enriched uranium[9].

If Iran chooses to make 90 percent enriched uranium, there are several scenarios, which have been recently analyzed by the Institute for Science and International Security (ISIS), Washington DC[10]. According to the ISIS estimate that, if Iran would use its ***single cascades at the FEP*** to produce one SQ[11] in a minimum of ***0.9-1.2*** months with about 320-380 kg of 20 % UF6. If the FEP is reconfigured for ***tandem cascades at Natanz,*** time required would be slightly longer, but it would ***require far less 20 percent UF6 for a breakout***; roughly 180-230 kg, Such a quantity would be available between December 2012- May 2012 depending the ramping up of 20 percent enriched UF6 production (See Fig.2).



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
3 Tandems	110	125	140	155	170	185	200	215	230	245	260	275	290	305	320
5 Tandems	120	145	170	195	220	245	270	295	320	345	370	395	420	445	470
7 Tandems		180	215	250	285	320	355	390	425	460	495	530	565	600	635

Fig 2. Cumulative production of 20 percent enriched UF6 (in monthly intervals) with different number of tandem cascades operating. Month 1 is August 2012.

If Iran opts at the FEP to ***a three step process*** using 3.5 percent UF6 as feed and tandem cascades, the ***1st SQ is achieved in 3 months, 2nd SQ in 5 months, 3rd SQ in 7 months and 4th SQ in 9 months.*** Iran has currently sufficient amount of 3.5 percent UF6 for this scenario.

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[9] S.Henderson and O. Heinonen, Nuclear Iran, A Glossary of Terms, available from http://belfercenter.ksg.harvard.edu/publication/22269/nuclear_iran.html?breadcrumb=%2Fexperts%2F2107%2Folli_heinonen.

[10] W.C. Witt, C. Walrond, D. Albright, and H. Wood, Iran's evolving breakout potential, ISIS Report, October 8, 2012.

[11] Significant quantity: The approximate minimum quantity of nuclear material required for the manufacture of a nuclear explosive device. Significant quantities take into account unavoidable losses due to conversion and manufacturing processes. The IAEA has defined 25 kg of U-235 for high-enriched uranium (U-235≥20 %).

At FFEP in Fordow, with all planned centrifuges operational and organized in tandem, Iran could breakout in a minimum of ***2.0-2.2 months***. Iran would need a stock of about 200-220 kg of 20 % UF6 to produce one SQ this way, which should be available in the beginning of 2013.

The fastest breakout times in the ISIS study were generated by combining the ***single cascades at the FEP with the full capacity of the Fordow plant***, assuming those cascades were organized in tandem. In this scenario, Iran could produce one SQ with 240-270 kg 20 percent enriched UF6 in an estimated minimum of ***0.8-1.0 months***. If Iran instead used ***new tandem cascades at the FEP***, it could break out with less material, roughly 190-200 kg of 20 percent enriched UF6, but the breakout would take slightly longer, at ***1.3-1.4 months***.

Iran has sufficient UF6 resources. The Uranium Conversion Facility (UCF) in Esfahan has produced since Spring 2004 550 tonnes UF6, 91 tonnes of which has been sent to PFEP and FEP in Natanz to be used as a feed material[12].

In addition to yellow cake, which has been imported in 1980's from South Africa, Iran has in recent years produced additional material at the Gcchine mine and mill near Bandar Abbas. The IAEA has not disclosed in the safeguards reports the amount of yellow cake received from Gcchine, but the production of Gcchine is stated by Iran to be by the end of 2010 32.8 tons uranium[13].

Iran has announced that it will construct ten new enrichment facilities, the site for five, according to Iran, have been decided[14]. However, it has not provided the IAEA with any details on the plans.

During 1990's Iran made progress with R&D on atomic vapor laser isotope enrichment (AVLIS), but the installations in Lashkar Abad were dismantled in 2003. Iran has publicly announced being a technology holder on laser uranium enrichment[15], but has not provided any information about the current plans to the IAEA.

Heavy water reactor program

Iran continues the construction of IR-40, a heavy water moderated reactor, at Arak. The site has also a heavy water production plant, which is in operation, but Iran has not disclosed the amount of heavy water produced. Iran has stated that the reactor is due to commence operation in the third quarter of 2013, but, since fuel production has not yet started at the Fuel Fabrication Plant in Isfahan, it is not likely that this would happen. Once in operation, the 40 MWth reactor can produce plutonium roughly for one nuclear weapon per year.

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[12] Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran. IAEA, GOV/2012/9. August 30, 2012.

[13] Uranium 2011: Resources, Production and Demand A Joint Report by the OECD Nuclear Energy Agency and the International Atomic Energy Agency, p.280, 2012.

[14] Fars News Agency, Iran specifies location for 10 new enrichment sites, August 16, 2010.

[15] See the website of the Presidency of the I.R. of Iran, 7 February,2010, http://www.president.ir/en/?ArtID=20255.

The Arak complex was originally planned to have a fairly large hot cell complex, but Iran decided in 2004 not to proceed with its construction, citing sanctions as a reason that blocked acquisition of key components such as large scale manipulators.

Information analysis – finding needle from a hay stack

Given the hard case as reflected in the Iranian nuclear dossier in terms of the scope and nature facing implementing safeguards and other related UN resolutions, it important understand the capabilities by which the Agency possesses, as well as the limitations that it faces. To begin with, the IAEA makes its safeguards assessments as an independent technical organization. Implicit in this fact is the constant requirement of high quality and credibility of the statements made by the IAEA, arising from a rigorous vetting process of information obtained and analysis that complement safeguards inspections.

In recent years the IAEA has introduced **all-source collaborative information analysis** with the following principles.

All available information is used for analysis and assessment. Analytical teams consists a wide range of IAEA expertise covering all aspects of the program. It is important that teams work together complementing each other's competences and share conclusions. The team may draw additional resources from member states' experts, with final conclusions made by the Secretariat only. It is important to allow different views which are properly reflected in the final analysis provided to higher management.

The veracity and consistency of information is checked internally and with other information to ensure the credibility of information. It is also important to ensure that all information available to the IAEA are used for conclusions drawn.

Intel information generally leads information which guides the Agency to actual source(s). It can be actionable or non-actionable, or serve as for the background only. Some of it can be shown to the inspected party, some of it can be used to vet the completeness of responses.

Some of the information is quantitative, i.e. nuclear material accountancy which verification uncertainties can easily be quantified. Some other information, i.e. plans, intentions etc can be qualitative only which makes the overall estimate for uncertainties difficult.

It is essential to identify gaps on information and estimate uncertainties of conclusions. Playing "devil's advocate" is also one of the techniques that have proven useful.

Procurement information has been of great importance in helping the Secretariat understand the structure, capabilities and timeline of the Iranian nuclear program. Examples of success are the mapping of the structure of the military part of the nuclear program that is based, inter alia,

on procurement information over years[16], and scope and content of the uranium enrichment program. Information has been retrieved from open sources, inspectors' findings on ground, and / or provided by Member States or other entities.

There are, however, obstacles in using such information; some caused by the inspected party, and some by the information providers. Some states are still reluctant to provide information to the Agency. There are several reasons for such hesitation, including the active court cases which sharing of information is not possible due to legal procedures. Some states are also concerned about their proliferation image that it may suffer when illicit procurement activities are known to have slipped through their system. In some cases business ties with Iran may also have a perceived impact on the country with regards to the cooperation with and assistance from the Agency.

The IAEA derives its safeguards conclusions using all information available to it. This includes reinforcing an information gathering, evaluation and analysis process alongside Agency procedures that tallies the veracity of information received.

Conclusion

Iran's centrifuges continue to spin and additional machines are coming into operation, more enriched uranium is produced, and breakout times become shorter. All these are fueling fears that time is working in the Iran's favor. Iran is progressing towards a nuclear weapons capable state; indeed, excess enrichment capacity itself could be one such definition. But the permutations are complex and various elements enter the mix. The determination of Iran's nuclear path encompasses technical as well as political dimensions. Rigorous safeguards is not the only ingredient but is certainly a necessity one in addressing Iran's nuclear program

[16] Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran, Annex, para 18, IAEA, GOV/2011/65, 8 November 2011.