Iran's Nuclear Program: Status and Uncertainties

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The nuclear crisis in Iran continues to pose serious challenges to international peace and security. Since mid-2002, when an Iranian opposition group revealed the existence publicly of secret nuclear activities in Iran, the world has struggled to develop an adequate response to the Iranian challenge. ISIS remains concerned that the Bush Administration places too much emphasis on military action or regime change to solve the crisis, causing its diplomatic initiatives to be weakened or to be launched too late to have a significant impact. ISIS believes that a diplomatic, peaceful solution to the Iranian situation is both preferable and more likely to prevent Iran from acquiring nuclear weapons.

During the coming months, it is vital to understand what Iran has accomplished in its nuclear program, what it still has to learn, and when it might reach a point when a plan to pursue nuclear weapons covertly or openly could succeed more quickly than the international community could react. However, this task is difficult, and the risk of exaggerated or simply incorrect analyses about Iran's nuclear effort remains, potentially leading to a military conflict with Iran. It is essential, therefore, that Congress insist on transparency from the administration and a full, fair, unclassified debate about the substance of Iran's nuclear efforts, and what can be done to defuse the looming crisis diplomatically. Toward that goal, I thank the committee for holding this hearing today and inviting me to testify.

Iran's Nuclear Program

Iran has invested heavily in nuclear industries in the last twenty years. It has sought a wide range of items overseas, including nuclear reactors, uranium conversion facilities, heavy water production plants, fuel fabrication plants, and uranium enrichment facilities. Many of its overseas purchases were thwarted, such as multiple efforts to buy research reactors and an attempt to purchase a turn-key gas centrifuge plant from Russia in 1995. However, in general, Iran found suppliers to provide the wherewithal to build nuclear facilities. A. Q. Khan and business associates in Europe and the Middle East, commonly called the Khan network, provided Iran the ability to build and operate gas centrifuges. Without their assistance, Iran would have likely been unable to develop a gas centrifuge program.

Iran's current nuclear infrastructure is large and growing. Although many key facilities are not finished, Iran is close to operating a large power reactor at Bushehr and has started relatively large fuel cycle facilities. Table 1 summarizes the main declared

nuclear facilities in Iran. Some of these facilities, such as Kalaye Electric, the formerly secret gas centrifuge R&D site in Tehran, are closed and others, such as the Arak heavy water reactor and the Natanz Fuel Enrichment Plant (FEP), are under construction. But the list shows that Iran intends to have one of the largest nuclear fuel cycle programs in the developing world. If Iran finishes its declared nuclear facilities, it would have a capability to produce highly enriched uranium (HEU) and weapon-grade plutonium for nuclear weapons.

Although most of the facilities listed in table 1 will be used for civil purposes, the fate of others remains difficult to determine. Determining the purpose of these facilities has been complicated, because Iran acquired so many capabilities in secret and did not fulfill its obligations under the Nuclear Non-Proliferation Treaty (NPT) to declare all its facilities, materials, and activities.[1]

The International Atomic Energy Agency (IAEA) has reported regularly on Iran's lack of adequate cooperation to allow the inspectors to fully reconstruct the history of Iran's nuclear program. In addition, Iran decided early last year to no longer implement the Additional Protocol and other transparency measures required by the IAEA. The February 22, 2007 IAEA report concluded that without more cooperation and transparency, the IAEA "will not be able to provide assurances about the absence of undeclared nuclear material and activities or about the exclusively peaceful nature of that program."[2]

State of Iran's Uranium Enrichment Effort at Natanz

Under current and expected developments, Iran's gas centrifuge program provides the quickest route to the indigenous production of nuclear explosive materials. As a result, the gas centrifuge program is the main focus of my testimony. The following are answers to questions from Committee staff.

What is the current state of development at the Natanz site?

The Natanz site houses two separate facilities to enrich uranium in addition to a wide range of support facilities. Figure 1 is a recent commercial satellite image from GeoEye of the site, showing the location of the pilot plant and the underground Fuel Enrichment Plant (FEP).

The pilot enrichment plant is an above ground facility that can hold up to six 164-centrifuge cascades and several smaller cascades. As of the end of February 2007, only a few small cascades and two 164-centrifuge cascades were installed and operational. The cascades enrich uranium periodically and produce only small amounts of low enriched uranium (see below). The enriched uranium product of one 164-machine cascade is

[1] Iran's NPT Violations: Numerous and Possibly On-Going?, Jacqueline Shire and David Albright, September 29, 2006, http://www.isis-online.org/publications/iran/irannptviolations.pdf.
[2] IAEA, "Implementation of the NPT Safeguards Agreement and Relevant Provisions of Security Council Resolution 1737 (2006) in the Islamic Republic of Iran," GOV/2007/8, February 22, 2007.

dumped into the same tank as the waste, or "tails." The product from the second cascade is collected and saved.

In January, Iran started to install about 3,000 centrifuges underground in the FEP. The centrifuges are slated to be organized into eighteen 164-machine cascades that operate together under a common control system to produce low enriched uranium, what Iran calls a "module." The underground halls of the FEP can hold about 17-18 modules, for a total of about 50,000 to 53,000 centrifuges.

In mid-February 2007, Iran informed the IAEA that two 164-machine cascades were installed and under vacuum, an operational state established prior to enriching uranium.[3] Two other 164-machine cascades were in the final stages of installation.

As of late February, no uranium hexafluoride had been introduced into either of the two cascades under vacuum. The area where uranium hexafluoride would be introduced is under IAEA seal, and thus the IAEA would be notified once enrichment started. The reason Iran had not yet introduced uranium hexafluoride is unknown.

The rate of future cascade installation is unknown, but Iran has stated that it wants to finish installation of all 3,000 centrifuges in May 2007. To meet this schedule, Iran would need to install about one cascade a week during March, April, and May.

Has Iran mastered centrifuge technology?

This question remains difficult to answer. Iran is under no obligation to inform the IAEA about such matters and has chosen not to do so. Defining mastery is also difficult, particularly given the differences between gas centrifuge programs in Europe and Iran. It is unrealistic to assume that Iran could meet the European company Urenco's definition of mastery over the "P1" and "P2" centrifuges, two early generation Urenco machines, whose designs and copies Iran obtained illicitly from the Khan network . In fact, it is unlikely that Iran will ever operate its gas centrifuge plant as well as Urenco does. Thus, it is better to discuss mastery with the recognition that the Iranian program will be significantly less proficient than a Urenco program, but Iran will still be able to eventually produce large quantities of enriched uranium. A better formulation might be whether Iran has developed adequate competency in building and running centrifuges.

The most important aspect of this question is whether Iran has achieved adequate competence in the operation individually and in groups of gas centrifuge cascades, particularly the 164-machine cascade, the workhorse of the Iranian program. It appears to know how to make all the centrifuge components of the P1 centrifuge, the one being deployed at Natanz, and to operate the P1 centrifuge alone and in small cascades. It does not appear to have mastered the construction of the P2 centrifuge or a version derived from this design, although the IAEA no longer has access to this program and as a result much less is known about this program.

[3] IAEA, "Implementation of the NPT Safeguards Agreement and Relevant Provisions of Security Council Resolution 1737 (2006) in the Islamic Republic of Iran," GOV/2007/8, February 22, 2007.

The question about the operation of P1 cascades can be assessed using information from the IAEA. Iran reveals to the IAEA when the cascades enrich uranium and the amount of uranium hexafluoride introduced into each cascade and the quantity of enriched uranium produced. Based on this information, Iran has been enriching uranium in the two 164-machine cascades in the pilot plant at Natanz during the last year, but the cascades have enriched uranium intermittently. Iran enriches uranium in a cascade for a relatively short period of time and then stops the enrichment for a longer period of time.

During the roughly three month period between November 2, 2006 and February 17, 2007, each cascade enriched uranium an average of about 19 percent of the time, based on an Iranian definition of the optimal operation of the cascade.[4] In terms of days, each cascade enriched an average of about 20 of the 106 days in this period. For illustrative purposes, this would be the equivalent of enriching uranium about 4.5 hours per day (although it is important to note that cascades are not operated in this manner).

Thus, Iran is gaining valuable experience in operating cascades, but it has still not operated its cascades continuously. Such operation is necessary to be able to produce significant amounts of enriched uranium.

In addition, Iran's centrifuges fail relatively often, according to the IAEA. This has led to speculation that the centrifuges do not work. However, each centrifuge operates independently. If one machine fails, it can be switched off and replaced. Thus, machine failure does not fully explain the limited operation of the test cascades. The high machine failure rate should probably be interpreted as an inevitable limitation of Iran's technical capacity to build and operate centrifuges.

Four explanations for the limited operation of the test cascades are possible:

- The centrifuges have experienced an unknown technical problem that prevents continuous operation;
- Iran is slowing its program down so as not to alarm the international community;
- Iran is already competent in operating cascades to enrich uranium, but that competency is being hidden. For example, Iran may have received undeclared assistance from the Khan network in this area; or
- Iran is simply implementing its own plan for cascade installation that includes its own method to become proficient, according to its own timetable, and has chosen not to share it with the IAEA or the outside world.

Despite limited cascade operation, Iran is in the process of installing 3,000 centrifuges in the underground hall of the Natanz Fuel Enrichment Plant (see below). This has complicated answering the competency question. Why would Iran move to the industrial-scale without knowing how to operate the cascades continuously?

[4] Jacqueline Shire and Albright, "Iran's Centrifuges: How Well Are They Working," ISIS report, March 14, 2007.

The IAEA expects to know more about the answers to these questions shortly. In essence, Iran will need to play its hand soon if it is going to enrich uranium underground.

The bottom line is that Iran is becoming more competent at running centrifuge cascades, but it has not yet demonstrated to the IAEA or the outside world that it can run these cascades continuously. Barring political developments, Iran should be able to demonstrate competency in running individual 164-machine cascades by the middle of this year. Operating a large number of these cascades as a unit would be expected to take longer.

Is Iran likely to finish its first module in May 2007?

Most are skeptical that Iran can finish installing 3,000 centrifuges in May 2007, let alone getting them all to enrich uranium. As discussed above, Iran would need to install about one centrifuge cascade a week to accomplish this goal.

Media reports suggest that Iran has enough components to assemble 3,000 centrifuges. The exact number of assembled centrifuges is unknown, although if Iran had 3,000 assembled centrifuges, this information would suggest that in the last year, Iran has been assembling centrifuges more rapidly than it did while under IAEA scrutiny. Because the IAEA is no longer provided such information by Iran, this media information must be treated carefully.

Iran, however, is known to be working steadily to build the cascades in the underground hall. Iranians have been installing the necessary infrastructure for the entire module. As of late February, only the 18th cascade was composed only of its concrete foundation and pedestals that will eventually hold the centrifuges. All the other cascade positions had some amount of equipment already installed. As mentioned above, as of the middle of February, four cascades were under vacuum or in the final stages of installation.

As part of installing a cascade, Iranians must test each centrifuge, including all of the switches, sensors, and fast-acting valves, and ensure that each centrifuge works properly. Only after finishing these tests and leak testing the centrifuge is the cascade ready to be turned on and placed under vacuum, prior to the introduction of uranium hexafluoride. Accomplishing all these tasks complicates a schedule of installing one cascade each week.

Pending more information, it is possible, though not likely, Iran will meet its May deadline for 3,000 fully installed and operational centrifuges. If the experience of more advanced centrifuge programs is a guide, Iran may need several more months to a year to get the module fully operational. It will also need to continue making centrifuges to replace failed machines.

Once the module is fully operational, Iran would need approximately 6-12 months to produce enough highly enriched uranium for its first nuclear weapon. The shorter time period assumes that the cascades operate near their theoretical peak performance. This

estimate assumes, of course, that Iran decides to take this path of producing HEU, because it would be seen as violating all its earlier promises and tantamount to seeking nuclear weapons.

A more likely scenario under currently expected conditions is that the plant would produce low enriched uranium. However, this stockpile could be used later in a "break-out" scenario to produce HEU relatively quickly in this plant or a clandestine one.

Is the IAEA capable of monitoring Iran's nuclear program?

If Iran implemented the Additional Protocol, including its additional transparency measures, the IAEA could effectively monitor Iran's nuclear program. However, Iran is doing neither, which explains the IAEA's recent statement that it will no longer be able to provide assurances about the absence of undeclared Iranian nuclear facilities or activities.

Thus, under current circumstances, Iran could build a secret gas centrifuge facility without being detected by the IAEA. The chance that intelligence agencies might detect such a facility is remote, absent a stroke of luck or excellent human intelligence.

Despite the limitations, the IAEA remains the best source of information on Iran's nuclear program—its inspectors, even with limited access to people and places, are on the ground on a regular basis and are well qualified to assess the Iranian program. Intelligence assessments based on other, non-IAEA information are more limited and should be viewed with some skepticism in light of past failures in Iraq and elsewhere.

A pressing issue is whether Iran will accept adequate monitoring in the underground cascade hall of the Natanz enrichment plant under traditional safeguards. To effectively inspect the operation of the first module of centrifuges to ensure that nuclear material is not diverted, the IAEA needs to be allowed to either conduct unannounced inspections or install remote camera monitoring of the entire cascade hall so that the inspectors can view all the centrifuges on a real-time or near real-time basis. Currently, the cameras cover only a portion of the cascade hall and are not allowed to operate remotely. Arranging unannounced inspections in Iran is not practical, so the IAEA prefers to install remote monitoring.

The IAEA has told Iran that once 500 centrifuges are enriching uranium, it will need to change the safeguards arrangements to include unannounced inspections or remote monitoring of the entire hall. Iran could soon have that number of centrifuges enriching uranium.

What are some of the upcoming key benchmarks at the Natanz site?

To give a better sense of how far along Iran may soon be, the following are some upcoming benchmarks and what they mean:

500 centrifuges installed in the FEP and ready to begin enriching uranium: At this point, which Iran may reach within a month or less, traditional safeguards will be tested. The IAEA has told Iran of the need for remote monitoring of all centrifuges or unannounced inspections once this threshold is reached. The IAEA prefers the former option. Iran will have to make a decision about whether it will comply with the IAEA's request.

1,000 centrifuges at the FEP enriching uranium: The international community will likely view this development with great alarm. Iran would be credited with being able to build a centrifuge plant, although it would also be expected to continue experiencing significant inefficiencies in the plant's operation. This benchmark could be reached within a half year.

3,000 centrifuges enriching uranium: Few would doubt that at this point Iran has a nuclear weapons capability, whether or not the plant produces HEU. This number of centrifuges could make enough highly enriched uranium for one or two nuclear weapons per year, or create a large stockpile of low enriched uranium that could be used in a break-out strategy to produce HEU quickly either in the same facility or in a covert centrifuge plant. This benchmark could be reached within a year or two.

The State of Progress of the Arak Heavy Water Reactor?

Iran is progressing on developing an indigenous method to produce weapon-grade plutonium. It continues to build a heavy water reactor at Arak, despite repeated international requests that Iran discontinue this project. Iranian officials have stated that the reactor is scheduled to be completed in 2009, although this schedule could be delayed for a few years due to problems in building and starting up such a reactor. When fully operational, the reactor is estimated to be able to produce about 9 kilograms of weapon-grade plutonium per year, enough for one or two nuclear weapons per year. Iran has told the IAEA that it does not intend to build reprocessing facilities to separate plutonium from this reactor. It did state that it was planning to build hot cells to separate "long-lived radioisotopes," but said that it was having problems obtaining the necessary manipulators and lead glass windows. IAEA investigations into Iran's past reprocessing activities continue, despite decreased cooperation from Iran.

Final Comment: The Danger of Military Action

The pace and scale of Iran's uranium enrichment effort has been increasing in recent months. The possibility of a preemptive attack by Israel or the United States may increase as the enrichment effort progresses.

ISIS remains concerned about the potential for such an attack. Too often we have heard those in or close to the Bush administration observe that the President does not intend to leave the Iran nuclear issue for the next President. For a number of reasons, but especially due to the dispersed and hardened nature of Iran's nuclear facilities, an attack is unlikely to be surgical or limited and would constitute an attack against the entire

country. As you well know, U.S. military action would also increase the risk of sparking a broader war and undermining U.S. efforts to stabilize Iraq. Many military leaders have expressed opposition to the use of military force in Iran, but it is of concern that the Bush administration will pursue a military option nonetheless.

Those supporting a military option may be tempted to generate or accept exaggerated or false claims about Iran's progress or intentions. This temptation could increase because of the IAEA's diminished ability to report on the activities at declared sites such as Natanz and provide assurances about the absence of undeclared nuclear activities. Thus, Congress, the media, and the public need to be vigilant in ensuring a full, unclassified debate about Iran's nuclear program and the threat it poses.

Figure 1. Natanz Uranium Enrichment Plant

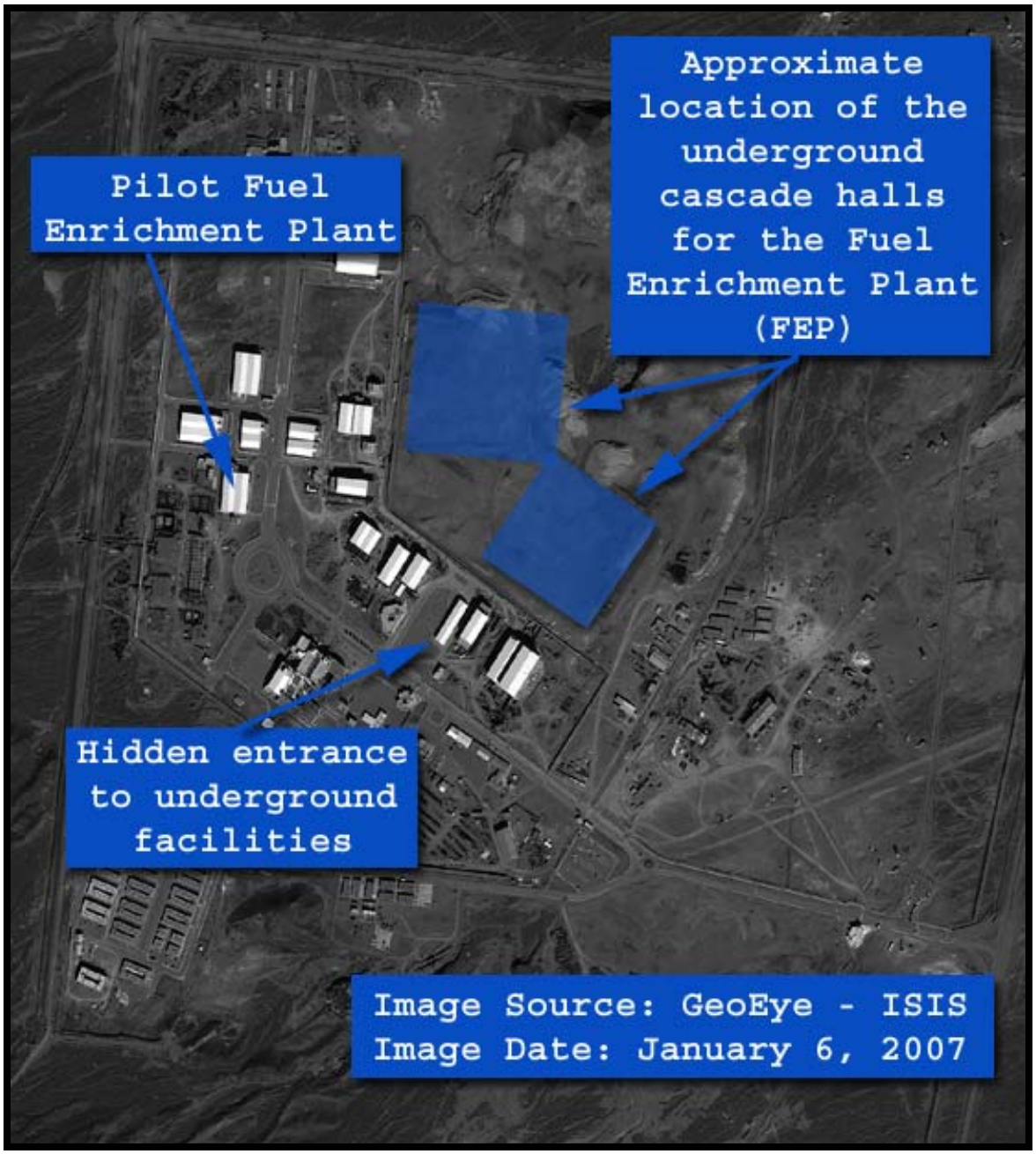

Table 1. Iran's Main Declared Nuclear Sites

Uranium Mining and Milling	**Saghand Mine and Mill** **Gchine Mine and Mill**
Nuclear Research & Development	**Jabr Ibn Havan Multipurpose Laboratories (JHL)** **Radiochemistry Laboratories of TNRC** **Tehran Research Reactor (TRR)** **Uranium Chemistry Laboratory (UCL)** **Research reactors at Esfahan** **Molybdenum, Iodine and Xenon Radioisotope Production Facility (MIX Facility)**
Uranium Conversion	**Uranium Conversion Facility (UCF)**
Centrifuge Research & Development and Manufacturing	**Kalaye Electric Company (closed)** **Farayand Technique (status unknown)** **Pars Trash (status unknown)** **Other centrifuge manufacturing sites**
Centrifuge Uranium Enrichment	**Pilot Fuel Enrichment Plant at Natanz** **Fuel Enrichment Plant at Natanz**
Laser Uranium Enrichment (program ended)	**Lashkar Ab'ad** **Karaj Agricultural and Medical Center**
Fuel Fabrication	**Fuel Fabrication Laboratory (FFL)** **Zirconium Production Plant (ZPP)** **Fuel Manufacturing Plant**
Heavy Water-Related Facilities	**Heavy Water Production Plant** **IR-40 Heavy Water Reactor** **Hot Cells**
Nuclear Power Generation	**Bushehr Nuclear Power Plant (BNPP)**
Waste Disposal	**Anarak**
Suspect Sites	**Parchin, Lavisan-Shian**