VERIFICATION RESEARCH, TRAINING
AND INFORMATION CENTRE

Development House, 56–64 Leonard Street
London EC2A 4LT, United Kingdom

Tel +44 (0)20 7065 0880
Fax +44 (0)20 7065 0890
Website www.vertic.org

THE IAEA, IRAN, AND THE MILITARY FUEL CYCLE

By Andreas Persbo
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Good afternoon everyone and thank you for coming to this afternoon's session. It is indeed a great honour to be here, at the Sant'Anna School of Advanced Studies. Your school has a long and distinguished history and several notable personalities amongst its alumni and faculty. This is one of the finest schools in all of Italy, and what we are about to talk about ranks amongst one of the most difficult foreign policy questions I have ever worked on. So it's a suitable setting.

Iran poses a very difficult foreign policy problem indeed, and the international community as a whole, I would argue, is seeking a solution. So I would encourage you to continue to analyse the problem, to keep the discussion going, and to publish your findings.

I intend to give you a run through of the nuclear fuel cycle, and some fundamentals of weapons design first. I will the go through Iran's present fuel cycle capabilities before ending the presentation with an overview of the latest report, and some observations of my own.

Nuclear military fuel cycle

Let me first go through the two principal ways in which one could acquire a nuclear weapon. It is an oft-repeated saying in the arms control community that you cannot get a nuclear bomb unless you first get hold of enough nuclear material. Even the most technologically advanced country in the world can do little without access to uranium. And you will need a lot of uranium ore, which you will then need to process and enrich, to construct a single device. Building a nuclear bomb is, frankly speaking, a massive industrial undertaking that will employ hundreds, if not thousands, of people and require vast amounts of financial investment.

The two pathways to a nuclear bomb are called the uranium route and the plutonium route, after the two principal materials needed for the construction of a weapon. What you see here is but a very simple representation of the two routes. The real pathway is considerably more complex, and involves many more materials and product streams. The IAEA uses something called 'the physical model' which examines these broad streams in smaller parts. Looking at how materials flow towards a nuclear weapon is sometimes called doing a 'pathway analysis'.

It all starts with the uranium ore. And you need lots of it. It takes many hundreds of tons of uranium ore to build one simple nuclear device. This ore needs to be dug up and processed into a pure powdery substance called uranium oxide - or yellowcake. This is the base material for the two routes.

Using the plutonium route, to your right, the state in question will take the yellowcake and smelt it into purified uranium dioxide. The uranium is still un-enriched. This material will then be shaped into nuclear fuel, sometimes in the shape of dark brownish rods, which will be put into a reactor. When the reactor irradiates the rods, the uranium will occasionally capture a neutron, making the element heavier. Since these fuel rods contain mostly uranium-238, they are very useful for making large quantities of element 239: plutonium. You need to keep the reactor running at precisely the right rate - with the right 'burn-up' as the technical term is - to avoid having element 239 capture yet another neutron, so becoming the considerably harder to work with metal plutonium-240. Usually these reactors are graphite or heavy water moderated, and with a relatively modest effect: 20 to 40 megawatts-electric will do. The irradiated fuel will then be shipped off to a reprocessing facility where it will, essentially, be dissolved in acid. The plutonium will be separated chemically from the other materials in the rod, the uranium and fission products. You will eventually have some well-behaved plutonium nitrate to work with when shaping the metal for use in a core of a nuclear weapon.

Now, using the uranium route is considerably shorter. You convert the yellowcake into a compound known as uranium hexafloride gas, or UF6. The interesting thing about this material is that it is solid until heated to 57 degrees celsius. It goes straight from its solid phase, where it resembles rock salt, to a gas without becoming a liquid. It only becomes liquid at temperatures over 67 degrees and, importantly, at pressures greater than one and a half times atmospheric pressure. This makes the compound easy to transport, and easy to use in gaseous centrifuges.

Weapons don't work if you're using uranium rich in uranium-238. Rather, you want metal rich in isotope 235. You get this by enrichment. There are a number of ways of doing this. Uranium enrichment using gas centrifuges is today the most effective system. An average centrifuge requires very little electricity, and takes up very little floor space. But it is also a very difficult method to master. In order to get the centrifugal forces necessary to separate two elements with a minute weight difference, you need a machine that rotates exceptionally fast. Most centrifuges today rotate faster, much faster, in fact, than a jet fighter flies straight. The rotation speed can reach more than twice the speed of sound. Consider the challenge of having a tall and very thin cylinder, about my size in fact, rotating at those speeds. It's a job for those who desire a challenge.

Once you've enriched the material so that more than 90 per cent is isotope 235, you withdraw the uranium hexafloride gas from the enrichment plant. You let it cool, so that it gets back into its rock salt shape, and you ship it off to get it converted into a metal. You can then use the metal, usually enriched to over 90 per cent in the isotope 235, in a bomb.

Design choices

It is always sensitive to talk about design choices, but I thought I'd just raise a few points. Once you have the material in metal shape, you can put it into a weapon. It is sometimes said that making a uranium device is easier than a plutonium device. This is generally correct. The easiest nuclear device you can make is what's referred to as a 'gun-shot' device. I won't go into details, but uranium does not need to be 'assembled' as quickly as plutonium. This means that you could use a relatively slow explosive, such as cordite, to propel a uranium bullet into a uranium target. Once those assemble completely, and form a supercritical mass, the thing goes off. You need quite a lot of material for this though, which means that gunshot devices are generally bulky. Therefore, most weapons design operates on an implosion principle. You need less material, and the weapon becomes lighter and more portable.

Plutonium emits more neutrons, so the core needs to assemble more rapidly for it to detonate effectively. Conventional explosives are too slow. The core won't assemble completely before a neutron shoots off and starts the chain reaction. This is called predetonation. You therefore need specialized high explosives to do the job. A more advanced bomb is a fission/fusion device, pictured on the below right. These operate on the same physical principles as the sun, but the forces needed to start a fusion process are so powerful that only a nuclear bomb can set it off. The largest such device ever constructed yielded about 50 megatons. It was detonated over Siberia but still made windows rattle in several hundred kilometres away, and the shockwave travelled several times around the earth.

On a note, let me just mention that the forces involved here are truly monumental. Not all material fissions, you see. Let's take Hiroshima as an example. The assembly contained some 64 kilograms of uranium. Of that, only about one kilogram fissioned, and less then a gram was converted into energy. It is, of course, almost beyond belief to think that a teaspoon of matter can raze an entire city. However, such is the power of Einstein's equation: that energy equals mass times the speed of light squared. Of course, today's nuclear weapons are far more effective then the primitive ones detonated over Japan. Today's weapons can cause mayhem on a scale difficult to imagine.

Iran's fuel cycle

So why is all of this relevant to the latest IAEA report on Iran? Well, I wanted you to have a rudimentary understanding of the facilities needed and choices required to make a nuclear bomb. Iran maintains several key facilities at the moment, which cover large areas of what's referred to as the 'front-end' of the nuclear fuel cycle. But I want to make it clear, from the outset, that my presentation in this part is value neutral: it does not assume military intent. It simply goes through what's on the ground.

At the moment, Iran is operating two principle uranium mines. In the first one, Gchin, the uranium ore is extracted through open-pit mining. It contains relatively little uranium, perhaps some 100 tonnes in all, scattered in ore with a high grade. Operations have been ongoing at this site for many years now, and it is not clear how much uranium may be left in it.

The second mine, Saghand, may contain 900 tons of uranium, perhaps more. This is an underground mine. Operations are scheduled to start any time now, and may in fact already have started. The ore grade is much lower, some 500 parts per million. In other words, you'll have to bring up and grind many thousands of tons of ore to get to that uranium. Mining is an expensive undertaking.

Iran has a yellowcake production plant in Ardakan, which should be able to convert the milled rock into what's known as uranium yellowcake, or U3O8. It has a similar production line in Gchin.

In addition to this, Iran has a stockpile of imported yellowcake, some 600 metric tonnes imported from South Africa in the 1970s. It is not clear to what degree they have depleted this stock through conversion.

Iran's principal conversion facility is located in Esfahan, in the centre of the country. This factory is responsible for the production of hexaflouride gas, for use in centrifuges, but also for reduction of enriched gas to metal. The facility will also make uranium dioxide for use in Iran's reactors.

Quite a lot of attention has over the years been given to Iran's enrichment programme. Experts have outdone themselves in producing various estimates about how much material Iran could produce and within what timelines. There is very little point in doing this any more, so I'm not going to give you any conversion figures or production timelines. Iran has almost 9,000 installed centrifuges in its Natanz Fuel Enrichment Plant. It is fair to say that this is capacity enough to kick-start a small weapons programme, should Iran desire to do so.

Recently, the Iranians have set up a smaller facility in an underground facility close to the holy city of Qom. This facility was only declared by Iran in 2009. It is designed to hold up to 3,000 centrifuges, and installation of machines here is now underway.

Iran claims to have mastered the art of making fuel for reactors. Admittedly, this is not the most technologically challenging of the areas. Some have noted the similarity between the fuel bundle design, shown on the left, with Russia's RBMK design. The Russian RBMK uses slightly enriched fuel, is graphite moderated and light water cooled.

Iran is presently completing construction of the Arak IR-40 heavy water moderated reactor. This reactor is expected to be fuelled by natural uranium fuel. How much material it will be able to produce depends on several factors, but it is widely assumed that it will be able to produce up to 12 kilograms of plutonium in its spent fuel per year. That's about two weapons worth.

Safeguards

So that is the status of Iran's fuel cycle at the moment? There are other facilities worth mentioning. If you're interested in learning more, the International Institute for Strategic Studies in 2010 released a net assessment of Iran's nuclear, chemical and biological capabilities. This report goes through the fuel cycle in more detail, and gives a good historical background also.

The good news is that Agency safeguards are applied on Iran's fuel cycle. This gives the international community, those concerned about Iran's intentions, some warning if Iran were to use their facility for weapons purposes. It is very important to stress the word warning. Agency safeguards are not designed to be a 'lock' that prevents misuse. Rather, look at them as a burglary alarm. Safeguards will raise the alarm, but cannot prevent misuse from occurring.

So what is the status of safeguards at the moment?

As David Cliff, one of my researchers wrote in a recent VERTIC blog post on this very issue: 'Overall, the Agency's report of November 2011 noted … that the IAEA is able to verify the non-diversion (from peaceful uses) of declared nuclear material in Iran.'

He continues,

> 'But as it has similarly admitted on many previous occasions, it is unable to provide "credible assurance" of the absence of undeclared nuclear material and activities in Iran, and therefore unable to conclude that all nuclear material in Iran is in peaceful uses … In other words, the Agency is able to verify the correctness of Iran's declaration under its IAEA safeguards agreement - but not whether that declaration is complete.'

So, what does that mean?

To understand this, one has to look at what types of safeguards are in force in Iran. At the moment, Iran applies what's known as comprehensive safeguards.

This means that material accountancy is being applied at all key facilities 'down-stream' from the conversion facility. In general, accountancy is very effective, especially when facilities are small, like in Iran. Small deviations in the material balances at each facility can be readily discovered. And larger deviations, weapons worth of material, will almost certainly be detected.

So all material down-stream from the conversion facility in Esfahan is, according to the IAEA, accounted for and in peaceful use. And this is good. However, this agreement, as with all such agreements, only goes so far.

Let's go back in history to see why. Let's revisit Iraq in the late 1980s.

Inspectors visited Iraq several times before the first Gulf War. They took samples where they were supposed to take them, measured and weighted materials, and came to the conclusion that all materials were as declared. Like at the research centre at Tuwaitha, pictured at this slide. As you can see, this is a large site, with two reactors and a fuel fabrication laboratory. Inspectors may have noted activity in the other buildings, but had no authority to ask penetrating questions, so they did not.

And, it appeared to them that a lot had been happening right under their noses. The site was bustling with activity. Iraqi researchers were examining most aspects of weaponization. They were doing computations and practical experiments and, as you can see, they did all this right under the noses of the inspectorate. This was a dark time for the safeguards regime. Its credibility was called into question almost overnight.

The Agency realised that its standard safeguards agreement was insufficient to guard against the possibility that states would simply not tell it everything.

In response, the Agency set about reforming the way they did safeguards under their existing authority. They started asking more questions, and deploying new tools, such as on-site sampling. This new approach quickly yielded results in North Korea, where new approaches discovered glaring discrepancies in the DPRK's accounting. This is, however, another story.

Moreover, the Agency realized that they needed stronger authority beyond that of comprehensive safeguards, so they developed the so-called Additional Protocol - a voluntary instrument rolled out in 1997 and currently in force in 114 countries around the world.

The Additional Protocol's significance is twofold: first, and most importantly, it requires to states to provide the Agency with more information about their nuclear activities, covering more of their nuclear fuel cycle; and second, it allows IAEA inspectors greater freedom of movement around nuclear sites. Overall, the Additional Protocol gives the IAEA a far better ability to judge whether a state's declaration is complete as well as just correct.

Iran, though, is not implementing an Additional Protocol - although it signed one in December 2003 and implemented it on a provisional basis (pending ratification) for a couple of years. In February 2006, in protest at the Agency referring Iran to the UN Security Council, it ceased implementation of the Protocol, which has never resumed.

It is fair to say, though, that the situation in Iran could be far worse, verification-wise. The country remains a member of the Nuclear Non-Proliferation Treaty (NPT), and under Iran's NPT-required safeguards agreement inspectors do at least continue to have some measure of regular access to key Iranian facilities. In nothing else, we do have some idea of what's going on, and at what rate of progress - at least in those facilities that are we know about.

An Iranian Additional Protocol would be a huge boost for verification efforts and for our understanding of the full picture. However, it goes almost without saying that it will be difficult getting Iran to restart implementation of the Additional Protocol. It may even be impossible given the poisoned atmosphere between Iran and the West that exists at the moment. It cannot be discounted, also, that Iran may simply not want to comply with the Protocol because since 2006 it has been conducting undeclared activities and building facilities that it wants to stay hidden.

But implementation of the Additional Protocol may also be Iran's best chance of forestalling any military strike and persuading countries that over the longer-term it should be allowed to keep its controversial enrichment activities - activities that many in the West see as having far from peaceful applications.

Which brings us neatly to the possible military dimensions to Iran's nuclear programme.

Possible Military Dimensions

For the last several years, a section on 'Possible Military Dimensions' has become a regular feature in successive IAEA reports on safeguards implementation in Iran. As I'm sure you will be aware, the most recent such report noted that Iran appears to have carried out nuclear weaponization activities under a 'structured programme' prior to the end of 2003, and that activities relevant to the development of a nuclear device have carried on beyond that date.

It is not an encouraging read. The report summarizes that Iran have been involved in:

1. Efforts, some successful, to procure nuclear related and dual use equipment and materials by military related individuals and entities;
2. Efforts to develop undeclared pathways for the production of nuclear material;
3. The acquisition of nuclear weapons development information and documentation from a clandestine nuclear supply network; and
4. Work on the development of an indigenous design of a nuclear weapon including the testing of components.

It also highlights that preparatory work to fabricate uranium components for a weapon may already have been carried out. The Iranians have also been working on detonators capable of exploding charges simultaneous to within one microsecond, which is a sufficient level of synchronization for an implosion device.

Despite its protestations to the contrary, it would seem that Iran also has done some large-scale experiments on high explosives, with assistance from a foreign expert, a Mr Vyacheslav Danilenko. This is actually nothing new. I started hearing rumours about this as early as 2008, and wrote down my thoughts in a 10 October 2008 presentation entitled Russia and Iran. 'In the summer of 2007', I wrote, 'there was a lot of whispers at the All-Russian Institute of Technical Physics (VNIITF) located at Snezhinsk that 'someone' there had assisted the Iranians with warhead technology - fairly recently'. I observed back then that I hope that it was all Chinese whispers, but that were there is smoke, there may sometimes be fire. It wasn't the VNIITF, after all, and we should be grateful for this, but it was someone formerly associated with the vast Russian nuclear weapons manufacturing complex.

There is more, much more, in the IAEA assessment. Iran may have been working on hydrodynamic testing, conducted modelling and calculations, done research on a neutron initiator, work on a fusing and arming system. It states that Iran may even have done feasibility studies on nuclear testing.

In the Agency's judgement, some activities may also still be ongoing. A recent high-level IAEA delegation to Iran appears to have achieved little, if anything, in the way of allaying fears of Iranian weaponization activities - past or present. Another trip is planned for the near future, but prospects for any kind of breakthrough on that mission look similarly bleak.

The Agency has the right, and I would argue the obligation, to continue to investigate these matters. Not all nuclear weapons-related activities involve nuclear material, true. But however tangential or theoretical, any kind of work on developing a nuclear device - even a roomful of technicians sketching out plans for a bomb on a chalkboard - indicates a possible, perhaps even likely, intention to divert material at some later stage. This, in my opinion, is all the authority the Agency needs when considering its future verification activities.

Projections

So where do we go next?

Friends, forecasting the future is never easy. My own experience in the third sector tends to give weight to the argument that us so-called ‘experts’ are more often right than wrong. So I tend not to give advice, or make projections, in public. But let’s nevertheless see what we have to work with.

For starters, I find it difficult to believe that Iran would suddenly decide to implement the Additional Protocol. I find it equally difficult to think that Iran will subject itself to intrusive inspection. There are no immediate prospects, in my mind, for a comprehensive investigation into weaponization.

The confidence deficit between the western world and Iran will therefore remain vast, and perhaps even deepen. And now, Iran’s neighbours are also making noises. Saudi Arabian officials speak openly about the need to acquire a capability of their own. Israel speaks of time running out. The tension in the international system is at an all-time high, I think. All sides seem to be locked into their positions, with little room to manoeuvre. This leaves the ball in Iran’s court, I think. Because there are things Iran can do if it has nothing to hide.

It can cooperate with the Agency’s investigation. It can implement the Additional Protocol.

In return, we may see a de-escalation of the rhetoric on both sides, creating bargaining space on the rest of the nuclear programme. Perhaps the recent offer by the Iranians to enter into negotiations with the P5+1 group will be the starting point for a renewed process?

I hope so.

The diplomatic game with Iran can be likened to the game of musical chairs. You know, when you have to rush to grab a chair when the music stops. The music is slowing down, I think. It’s about to stop. And the question then is, who will be left standing when all seats have been taken?

That concludes my talk. If you want any more information, I would encourage you to visit the following sites. www.isisnucleariran.org contains much information, and so does www.iranwatch.org. You can also find much analysis on the webpage of the International Institute for Strategic Studies.

Thank you for your attention.

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