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SCIENCE, TECHNOLOGY AND GLOBAL SECURITY WORKING GROUP
Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge, Massachusetts 02139

Iran as a Pioneer Case for Multilateral Nuclear Arrangements

by

Geoffrey Forden and John Thomson

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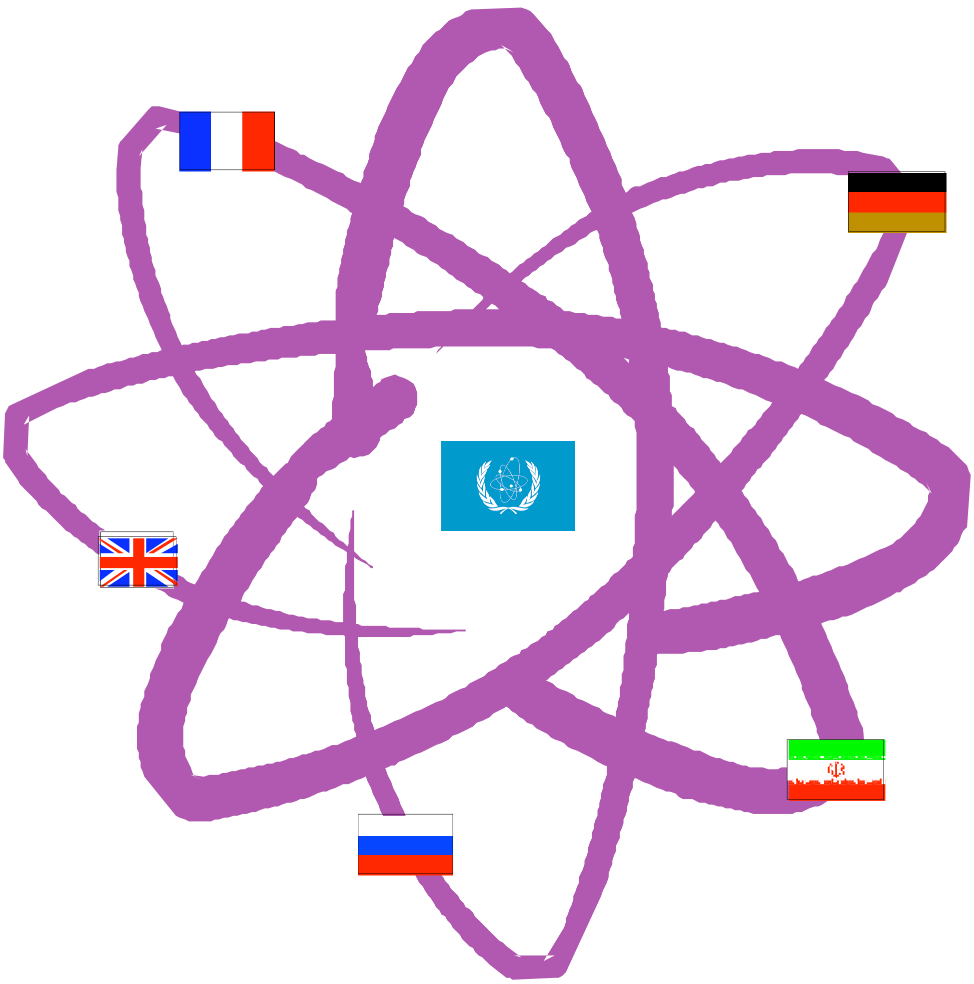

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Summary

This paper is an expansion of previously published pieces but differs from them in giving pride of place to our plan for dealing with the Iran crisis while relegating to Appendix I our discussion of multilateralism as a tool for protecting non-proliferation. We do this because the crisis has gone from bad to worse and is now in urgent need of negotiation and compromise.

The Forden-Thomson plan essentially proposes a modern multilateral enrichment facility on Iranian soil with the capacity to provide material for a virtual fuel bank if the IAEA so wishes. Given that the escalating dispute has carried the parties well beyond an ideal agreed solution, the plan is put forward as the best option in a bad situation. It meets the bottom line on both sides, enrichment on Iranian soil but no Iranian bomb.

A treaty between Iran and the EU-3, Britain, France, and Germany, would establish a commercial partnership with the governments as shareholders; others could be invited to join. The capital would be provided by the shareholders. Iran would lease all its enrichment-related equipment and facilities to the partnership and would undertake not to enrich and reprocess except through the partnership. The board of the partnership would determine policy and control the budget. It would appoint an international company to run the day-to-day operations.

Operations would begin with the Iranian P-1 centrifuges but on cost-efficiency grounds these would be retired and replaced with much more efficient non-Iranian centrifuges well before P-1s would produce enough material for a weapon. The choice of a non-Iranian centrifuge to be leased to the Board would lie between the current standard URENCO centrifuge (theTC12), its eventual improved replacement (the TC21) and the Russian centrifuge which has already been sold to the Chinese. The pros and cons of each are calm are compared and the figures set out at Table 1 on page 14.

The LEU produced would be sold commercially on the global market and profits distributed according to shareholding. The Iranians would be customers like all others. Whereas the P1s will never produce enough LEU for more than one reactor, the non-Iranian machines can easily satisfy the needs of the full Iranian programme (20 reactors by 2035) and still have approximately half the output to contribute to a virtual fuel bank under IAEA control.

The IAEA would be consulted on the design of the plant and would operate three forms of safeguards: full-scope, Additional Protocol, and specially agreed transparency measures. Each shift of workers would have a majority of non-Iranians and non-Iranians would hold key positions in the management company. Together, these measures would protect both against diversion of material and against the establishment of a clandestine facility. Other security measures, especially “black boxing” and disabling mechanisms are considered.

The risks of an Iranian “breakout” by expropriating the multilaterally owned facility are minor and the risks that the Iranians would and could establish a clandestine facility are, in comparison with other schemes, negligible.

The plan meets the bottom line on both sides, enrichment on Iranian soil and no nuclear weapons in Iranian hands. The Iranians have officially indicated an interest in a multilateral solution. This needs to be followed up and worked through.

Iran as a Pioneer Case
for Multilateral Nuclear Arrangements

Purposes

This paper serves three purposes:

- It describes a possible resolution of the current Iranian nuclear problem.
- It is an exploration through the examination of one particular case of how a policy of multilateralism might work to strengthen the global non-proliferation regime.
- It suggests a means to meet the non-proliferation goal of a guaranteed fuel supply without political strings.

While our principal overall objective is to protect and strengthen the non-proliferation regime, we begin with an examination of the Iran crisis and our proposals for dealing with it. In doing so, in this the third edition of our paper we are reversing the order of presentation in the first two editions. We do this because the quarrel over the Iranian nuclear programme has developed into a full- blown crisis replete with threats of military action, war, economic disruption and terrorism and with deadlines, which as we write, may be distant by only a few weeks. There is no time to be lost in reaching an accommodation which averts a significant threat of conflict and proliferation affecting the whole Middle East and much of the world besides. In this critical situation, it is less and less realistic to hope that the major parties, especially Iran and above all the U.S. will try to settle their quarrel in the context of a general reform of the non-proliferation regime. That would have been the mark of statesmanship but the main players are unfortunately not statesman.

Yet, the need to deal urgently with a bad-tempered, scrappy quarrel in which the big issues of non-proliferation are submerged beneath personal prejudice, deception, willfulness, nationalism and misrepresentation will not dispose of the requirement to reform the non-proliferation regime and that at an early date. A comprehensive reform is beyond the scope of this paper but we continue to urge that multilateralism and a guaranteed fuel supply without political strings are elements which ought to be included. Their demotion in this edition to Appendix 1 does not imply that they have grown less important. On the contrary, the clumsy handling of the Iranian issue is itself an argument for reforming the regime lest we bring on a repeat performance.

We turn first, therefore, to the Iranian crisis with a lively expectation that if it goes badly, the non-proliferation regime will be sorely damaged. We harbor a fainter hope that if it receives a constructive solution, the regime will be strengthened. As the crisis staggers from bad to worse, we stress that our plan is not ideal. It has costs and risks. However, compared with the present policies and with those alternatives, of which we are aware, it has considerable merits. We advance it in a difficult and dangerous set of circumstances as the best available option.

The Urgent and Critical Nature of the Iran Crisis

Iranian authorities at every level claim that they are behaving in accordance with the Non-Proliferation Treaty (NPT) and are not aiming to make a nuclear weapon. Western countries disbelieve this claim and assert with varying degrees of assurance that Iran seeks to make a bomb. Russia and China are in-between, believing apparently that the most probable explanation for Iranian behavior is bomb-making but also believing that the West is using this issue to cloak its real objectives: regime change in Iran, promotion of Israeli power, Western dominance of the Middle East and its energy resources. The Iranians share these suspicions.

Thus each side, Iran and the West, is convinced that the other has bad intentions, is deceptive and probably will stop at nothing to get its way. A huge issue of confidence separates the two sides and after four fruitless years of on-again, off-again negotiations, bad tempers dispose each side to think the worst of the other. At bottom, it is a matter of suspicion; there is no absolute proof of either side's allegations.

Some people on each side hold that it is or may be mistaken to suppose that the other has a clear and firm policy. Maybe it is a case of tendencies without actual decisions. For instance, the Iranians may have had a military nuclear programme until it was discovered in 2002 that they ran large secret operations. They may then have stopped or suspended that programme as they turned urgently to convince the IAEA that all their activities were peaceful. That would explain the lack from 2003 onwards of convincing evidence of a continuing military programme. On the U.S. side, numerous large-scale military movements both announced and unannounced may not betoken a firm decision to strike Iran. They can be seen as merely ratcheting up the pressure on the Iranian government and people to accede to Western demands. It may be that President Bush has taken a decision not to strike Iran or more probably that he has postponed any decision as he waits to see what diplomatic pressures will achieve and what might be the risks of military action in 2008.

Opacity on both sides should suggest caution but as always, those who are certain of their allegations have an advantage over those who hedge their conclusions. Pressure on Iran, particularly military pressure, and the reaction to it in Tehran is strengthening the case of those who want a nuclear deterrent against the U.S. In a curious parallelism, there are people in both Tehran and Washington who hope that negotiations will break down. Tension and dogmatism tend to favor the hard-liners on both sides and unfortunately weaken those moderates in Iran who are not fixed on a weapons programme.

Time works against the West in this and other more important ways. President Bush has defined three "red lines" that Iran must not be allowed to cross: no nuclear weapons, no machines that could be used to make them, no technical know-how to run the machines. But the Iranians already have the essential machines, the P-1 centrifuges. According to the IAEA, the Iranians have several hundreds, if not thousands, of these centrifuges in store and are constantly making more. Although the Pakistanis with an industrial base inferior to Iran's, mastered the art of making these inefficient centrifuges work, the Iranians have not yet quite done so. They have got small numbers of them spinning sufficiently to produce a tiny amount of Low Enriched Uranium (LEU), but they have not achieved a large continuous flow. What they lack is not the basic science but certain engineering tricks. The best estimate is that they may master the techniques to the point of extracting LEU from five hundred centrifuges any day now. On the same basis, it is assessed that they may be creating LEU from 1000 centrifuges in the fall of 2007.[1]

In short, the Iranians have already crossed President Bush's red line in regard to possession and production of machinery and partly crossed it in technical proficiency. When their mastery of the technology is confirmed, their negotiating position will be strengthened and the West will be left only with the red line of no weapons. Fortunately, this is the only really crucial point.

Good negotiators know it is an error to persist with a policy, which has been tried over several years and has largely failed. However sensible the Western demands may have been and however desirable they still are in principle, none of them in its present form is attainable. As we have noted, the requirement that Iran should have no centrifuges has, as a matter of fact, been lost and the denial of technology is all but lost. When the Western powers recognise that they have failed to eliminate any possible Iranian capability to make weapons, some or all of them may demand that the Iranians roll-back their knowledge of how to make centrifuges and how to run them. In the present day and age, destroying knowledge is not a practical objective. Politically, the prospects of getting the Iranians to give up what they already have and know are virtually nil. Iran is not North Korea. If we are to rein in Iranian capability, the fewer centrifuges and the less technology they have the better but the longer we persist on our present course, the more they will have of each, deal or no deal. So, again, time is against the West.

Western policy is avowedly gradualist. The essence is progressively to ratchet up pressure on Iran to accept Western demands. In addition, some carrots formerly offered and spurned by Iran remain available. But the policy is primarily a matter of sticks, especially formal and informal economic sanctions designed to hurt the general public and particularly influential groups such as the bazaar. Also included are restrictive measures intended to damage the nuclear programme and the top people who run it. Iranians are hurt by these measures and want to get rid of them.

But is their pain sufficient to make them resile from the national objective of enrichment on Iranian soil? Almost certainly, no.

But what if, as the West intends, the pressures (and presumably the pain) mount with each turn of the sanctions screw? The West—or at least the Europeans—have always declared that they will operate the ratchet patiently, progressively and proportionately. They admit that it will take a long time. Logically, they have a point: there must be some threshold of pain at which the Iranians would give up. But the history of sanctions whether U.S. against Iran since 1980 or U.S. against Cuba or international against Serbia and South Africa bears out the saying that "there is a lot of ruin in a nation". These sanctions all created pain but they did not produce their intended result quickly or, in some cases, at all. The Iranian economy has many weaknesses but is more resilient that most. Maybe on one distant day the Iranians would cry "uncle" but there is virtually no chance of this in 2007 or 2008.

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[1] 'Iran's Nuclear Program: Status and Uncertainties', Prepared testimony by David Albright, President, Institute for Science and International Security (ISIS 15 March, 2007 before the House Committee on Foreign Affairs, Subcommittee on Terrorism, Non-Proliferation and Trade, Subcommittee on the Middle East and Asia URL http://www.isis-online.org/publications/iran/AlbrightTestimony15March2007.pdf.

As we have seen, that distant day will be far too late to prevent Iran from having a weapons capability and probably to forestall the making of an actual weapon. Worse than that, persistence in the present policy is counter-productive. Effectively, it allows the Iranians to get more centrifuges and more technology. Staying the course is condemned as an option by the time discrepancy between Iranian progress with centrifuges and technology on the one side and on the other, the slowness of progressive sanctions to create sufficient pain. The verdict is reinforced by the Western challenge to Iranian nationalism on the one issue which bonds the leadership and the nation, by the inadequacy of the negotiating carrots, the smallness of the sticks and by the leadership's insistence that enrichment on Iranian soil is non-negotiable. Khamenei, the Supreme Leader publicly reaffirmed this in the plainest terms as recently as the third week of March 2007. Staying the course reduces the arguments for Iran to compromise and raises the barriers which the West will have to surmount if it is to keep nuclear weapons out of Iranian hands.

Yet all is not lost. Western policy can be modified without retreating from the objective of no weapons in Iranian hands. How? Amongst the ideas mentioned publicly, several propose to cap the Iranian centrifuge programme, probably at the number in use at the time. From this comparatively small number Iran could continue to produce LEU under strict IAEA surveillance. This "pilot plant" idea could be put into effect quickly and cheaply and would be a good option if gaining time was the object. But it is hard to imagine that it could be a permanent solution. It would leave Iran both with a national nuclear programme capable, albeit very slowly, of bomb production and with ideal cover for clandestine operations.

We prefer a multilateral solution which leaves no enrichment-related facilities exclusively in Iranian national hands and which is permanent. However, it might be possible as an interim measure to start by capping the programme before moving on to a properly worked out multilateral solution. In the following paragraphs, we describe in some detail the main lines of such a solution.

The Forden-Thomson Plan

The Essence of Our Plan

We propose an agreement between a small number of governments to set up a large, high-quality enrichment plant in Iran under multilateral ownership and control and subject to stringent safeguards, including by the IAEA.

The Formal Structure

A treaty is the preferred form of agreement. It binds all parties in a solemn and formal way. None will lightly break their obligations, penalties can be specified, means of arbitration provided and arrangements for winding up the operation by mutual agreement laid out. In addition, the principles upon which the operation is to be run should be broadly stated. The agreement should aim (a) to avoid unwelcome surprises down the road, (b) to endow the parties with the ability to adjust the agreed structure to changing circumstances and with the flexibility needed to make the business a commercial success. It would specify that no enrichment-related activities or equipment other than those conducted by the multilateral organisation would lawfully take place in Iran. The treaty would also ban reprocessing in Iran: the Iranians say they have no intention to build a reprocessing plant.

The original parties should be Iran and the EU-3, that is France, Germany and the UK. The Netherlands as the partner of Germany and the UK in owning and operating URENCO should be offered the opportunity to join. Because of Russia's existing commitments to the Iranian programme, a similar invitation might be extended to her. Given the high cost involved, the original parties might consider inviting one or two states flush with oil money to join the enterprise. The UAE and Norway come to mind. Others could be added later at the unanimous invitation of the original parties. The proposal meets the declared wish of the Director of the Iranian Atomic Energy Organisation, Gholamreza Aghazadeh, to enroll foreign partners in the financing of Iran's enrichment programme.

The treaty would create a holding company owned by the participating governments as the sole shareholders. The simplest arrangement would assign them equal numbers of shares but this could be a matter for negotiation. In any event, two provisions would be incorporated in the treaty and would not be subject to amendment. One would provide a mechanism so that no one country irrespective of the size of its shareholding could override the others. The second would allow Iran after giving appropriate notice (? three years) to require the removal from Iranian soil of all the moveable facilities belonging to the holding company with the costs borne by Iran.

The costs of the operations authorised by the holding company would be met by the shareholders on a proportionate basis and profits would be distributed likewise. The holding company would determine policy and would operate as much as possible by consensus. However, subject to the non-proliferation commitment of the shareholding governments, it would operate as a commercial company and its Board would be guided by commercial considerations.

The Iranian government would make available for lease by the Board all enrichment related equipment and facilities in Iran, a matter to be closely defined in the treaty. Thus no enrichment- related facilities would remain or be allowed in exclusively Iranian national possession. All conversion and fuel fabrication facilities as well as enrichment and storage would be included.

The Board would also lease from URENCO or the Government of Russia centrifuges to produce LEU. We have in mind three models of centrifuge- the standard URENCO TC-12, the ultra-modern URENCO TC-21 and the Russian centrifuge, which the Chinese bought and are currently operating. Somewhat different considerations apply to each model and these are discussed below. In the event that the holding company was wound up, the leased equipment and facilities would return automatically to their original owners.

The Board would hire an international management company to conduct the day-to-day operations. That company would follow the guidance of the Board and report to it. The fee paid to the company would have some relation to its commercial success. The company must be highly qualified technically and it must employ nationals of all the original shareholders though not necessarily in proportion to their shares. Probably, a new company will have to be formed especially for this purpose. The jobs must be assigned so that neither commercial nor proliferation secrets are breached. The CEO of the management company would be a national of one of the three URENCO countries.

All the enrichment related operations of the holding company and the management company would be subject to full scope IAEA safeguards, the Additional Protocol and other transparency procedures to be agreed between the Board and the IAEA. Both the Board and the CEO of the management company would keep in close touch with the IAEA and would be sensitive to their suggestions. IAEA representatives could be invited to take part in meetings when appropriate.

Location of Facilities

When after several years the operation is in full swing it will consist of a facility at Natanz with up to 50,000 centrifuges together with facilities designed to support enrichment (or reprocessing) operations. Several of these will be at Esfahan. Because they could be used in steps towards the production of plutonium, the facilities at Arak would also be included. The Iranian authorities would own and operate the facilities for the production of electricity such as the Bushehr reactor and subsequent power reactors.

Uranium Deposits in Iran

We do not think it appropriate or necessary for the mining and initial treatment of uranium ore in Iran to become the responsibility of the multilateral consortium. Control over that should remain with the sovereign government of Iran. However, for political reasons, we think the Board should agree to use Iranian uranium as the input for the P-1 centrifuges. Since it appears that the Iranians already have in hand a considerable quantity of mined uranium, this may in any case be the cheapest solution. The P-1s will soon be phased out and for the URENCO or Russian centrifuges the Board through the Management Company must deal in the global market as advantageously as possible.

Nevertheless, it will be interesting to have some idea of the possible contribution to that market by the Iranian mining industry. According to the IAEA, Iran's proven deposits are some 3000 tons, an amount that happens to provide the fuel for the initial loads of 20 reactors but not to sustain them for long. The IAEA estimate there may be a further 20,000 to 30,000 tons that could be mined. If this turns out to be true, that would be enough to keep 20 reactors running for around seven years. In short, the best available figures show that Iran is not rich in uranium and will in any case have to buy on the open market if it is to sustain its reactor programme.

Supply of Uranium

Customers seeking enrichment normally themselves supply the necessary uranium but when it is a question of enriching for Iranian customers or for the proposed virtual fuel bank, the procedure might be on the following lines.

Under guidance from the Board of the holding company, the Management Company will determine according to commercial considerations where to purchase uranium, either indigenously from Iran or from abroad and in what form. The yellowcake would be converted into UF_6 at the leased conversion facilities and transported to the enrichment facility at Natanz.

But again, commercial considerations would be critical. If the Iranian-produced UF6 is of an inferior quality (as suggested by recent media reports) the Board would have to decide whether to improve the equipment and technology and perhaps the skills of the operators or to close the Iranian conversion plant and buy from abroad. Obviously, the issue would have a political dimension but this would not be decisive if it was contrary to an overwhelming commercial case.

The Iranian P-1 and P-2 Centrifuges

The Iranians have admitted acquiring from abroad designs and parts for two types of centrifuge, the P-1 model and the more capable P-2. They have shown the IAEA two working cascades each of 164 P-1s. In our scheme, these cascades together with any other machines (whether or not in a cascade) plus spare parts would be leased by the holding company as would the facilities for manufacturing centrifuges.

The P-1 machines will do the job (as they did in Pakistan) but will take a long time to fuel a single reactor with LEU. The P-2 machines, which the Iranians have not yet managed to get into production despite several years work, should have a capability more than twice that of the earlier model but even so they will take quite a long time to produce a significant quantity of LEU. The exact times depend upon the numbers of centrifuges and the way they are configured and run.

Given the nature of the P-1s and the state of Iranian technology, we believe it would be politically advantageous and also acceptable in terms of the risks of misuse, to start multilateral operations with the two P-1 cascades. By using existing Iranian machines, the multilateral enrichment process could begin soon after the ratification of the treaty and, provided there was no cheating, could help to build confidence. A limited number of P-1 centrifuges (e.g. 5x164) could presumably operate in an existing building. Aboveground buildings are preferable to using the existing underground space secretly constructed by the Iranians. The main reason is safety for the operators but there is also a political argument. If the Iranians were (foolishly) to expropriate the enrichment facilities it would be easier to use military means to destroy an aboveground than a hardened under-ground facility. This should be counted by the Iranians as a cheap way of building confidence amongst Western governments. Incidentally, it would help also to undercut arguments for new earth-penetrating nuclear-tipped weapons.

All existing Iranian P-1s would be included in the startup programme either in cascades or held in readiness to replace broken or malfunctioning centrifuges. For the sake of argument, let us assume five cascades each with 164 centrifuges with an additional 164 to be held in reserve for spare parts and replacement of malfunctioning machines. This total number of P-1 centrifuges, 820 in operation plus 164 in reserve, is too small to run efficiently because of mixing problems. If that number operated for as much as two years before the first batch of URENCO or Russian centrifuges came online, it would produce about 450 kg of LEU (at 4.3% enrichment). (It should be noted that even if all of that LEU was diverted for making HEU in a secret enrichment facility, it would produce approximately 20 kg of HEU at 90% enrichment; not quite enough for even a single nuclear weapon.) But, the P-1s are likely to be phased out well short of two years. Whichever non-Iranian centrifuges- the Russian or one of the two URENCO models- is used, we assume that within a few months of the basic agreement, it would supercede the inefficient P-1 on grounds of cost-efficiency. Even a few non-Iranian centrifuges would produce more LEU than 820 P-1s. At that point, the latter would be destroyed or put in secure storage. This being the prospect there would be no case for making or repairing P-1s after the ratification of the treaty and still less for further attempts to develop P-2s.

Non-Iranian Centrifuges

The choice of centrifuge on which to base the commercial and non-proliferation objectives of the multilateral holding company is fundamental but not obvious. The pros and cons for each of the three candidates are discussed in the following paragraphs. Salient, factual points are set out in Table 1.

Table 1 Comparison of Non-Iranian Centrifuges

Number of Reactors Sustained	Cascade Capacity SWU-kg/yr	TC-12 (Current URENCO Centrifuges)		TC-21 (Next Generation URENCO Centrifuges)		Russian Generation 6 (?) Centrifuges	
		Number of Centrifuges	Total Capital Investment Required	Number of Centrifuges	Total Capital Investment Required	Number of Centrifuges	Total Capital Investment Required
1	120,000	3,000	$56M - $84M	1,200	$45M - $67M	48,000	$66M - $82M
20	2,400,000	60,000	$1.1B - $1.7B	24,000	$0.9B – $1.3B	960,000	$1.3B - $1.6B
42	5,000,000	125,000	$2.3B - $3.5B	50,000	$1.9B - $2.8B	2,000,000	$2.7B - $3.4B

Note: The above calculations are based on an exchange rate of €1=$1.2

The URENCO TC-21

As Table 1 reveals, this is the most cost-efficient of the three options – a major point in itself, especially for the commercial success of the enterprise. In addition, there are two significant presentational advantages. So far, only the U.S. (in the form of Louisiana Energy Supplies) and France (for use in its George Besse II facility) have this very advanced machine and so for it to be operating at Natanz would be pleasing to Iranian pride. Even more to the point, URENCO has the contractual agreement of the Americans and French to "black box" these centrifuges in order to preserve commercial secrets. It is inconceivable that they would agree to any lesser provision for a consortium (incidentally including France) with its operations in Iran. Nor would Iranians have a leg to stand on in arguing against "black boxing".

But this option has the defects of its merits. If the Iranians broke out and expropriated the enrichment facility, they would be in control of the most sophisticated centrifuges in the world. True, the level of sophistication is such that at this stage of their learning process, the Iranians might find it impossible to copy them. However, in a couple of decades that might cease to be the case. Nor can it be absolutely guaranteed that the "black boxing" would be effective permanently. Also, URENCO might not be able to provide the machines as speedily as would be desirable. For URENCO to supply them at all would require a positive decision by the three owners, the Dutch, German and British governments, which might not be easy despite all three being members of the multilateral holding company and providing personnel to run the operation.

The URENCO TC-12

Until the TC-21 definitely comes out of development, the TC-12 can be described as the foremost state of the art centrifuge. Table 1 shows that it has some marginal cost advantages vis-à-vis the Russian model and it is probably cheaper to operate. So it has some of the commercial and presentational advantages of the TC-12 but at a lower level. It too could be black boxed but that might be less acceptable to Iran.

Its disadvantages are similar to those of the TC-21 but on a lower scale. Probably it cannot be leased "off the shelf" but the waiting time is likely to be less than for the TC-21.

The Russian Centrifuge

This is operated currently by Russia and China and therefore has some of the prestige quality of the URENCO machines but it is probably more expensive to operate than they are. It is a significantly different type of machine requiring very large numbers (and therefore large buildings) to produce a given quantity of LEU. Since it is already in the possession of the Chinese, the Russians might not require it to be black boxed and in any case it is unlikely that the technology employed would help in the development of the P-1 machine. If the Russian model was leased probably the Russians would become partners in the multilateral holding company whereas if URENCO machines were used they probably would not.

Russian centrifuges are as vulnerable in principle to expropriation as URENCO machines but having Russia as an enemy as well as the Europeans might raise the costs of an Iranian "break out". For this and other reasons it may be fair to say that the proliferation risks involved in using the Russian model are less than those implicit in employing URENCO machines. But against that, it seems likely that they have some disadvantage commercially. A different kind of problem may arise in Iranian dislike of any dependence on Russia.

The Choice

The data available is inadequate to make a firm informed choice. Yet, given the suspicion with which our proposal has been met in some Western capitals and also the relatively small disadvantages of the Russian centrifuge, it may be politically best to opt for that model.

Black boxing

Each shift of operators (whether for the P-1s or the Russian or the URENCO centrifuges) would be composed of at least three different nationalities. The sensitive parts of the P-1s would be "black boxed" and thus unavailable to non-Iranians just as the "black boxed" parts of the URENCO centrifuges would be available only to URENCO nationals. When a centrifuge had to be replaced or repaired, it would be removed bodily by appropriate technicians—Iranians for P-1 centrifuges, URENCO representatives for the TC-12s or TC-21s, Russians for their centrifuges—and taken to its place of manufacture. In the case of the URENCO centrifuges, that would mean shipping them to Europe under safeguards while the Russian centrifuges would be sent to Russia.

Iran's Nuclear Programme

The economic justification for a nuclear programme in a country so rich in hydrocarbons as Iran is, lies in the fact that it has little else to sell but oil and gas. In the most recent budgets, 60% -70% of the country's GDP is derived from its energy exports. At present, Iran consumes at home about one-third of its oil production. It has a young population that is expected to double in less than 30 years. At that point, Iran might well consume two-thirds of its oil and possibly more. So Iran apparently feels it needs a large increase in the amount of oil for sale abroad and an efficient way to achieve this is to make savings at home through the use of nuclear energy.

Iran has announced an ambitious programme to produce electricity from nuclear reactors. Their first 1000-MW reactor currently being built and fueled by the Russians is supposed to begin operations in 2007. But at present, the Russians are withholding the necessary fuel. Iran has announced plans for six more reactors to be in operation by 2020 building thereafter to a total of twenty by 2035.

To fuel these reactors, Iran plans a 54,000-centrifuge plant. It intends to manufacture the centrifuges itself based on the P-1 machine whose design and many components Iran bought from the Pakistani A.Q. Khan. In the mid-1970's, much of the basic knowledge that went into the P-1 was stolen by Khan from URENCO. It was the first machine used by Pakistan to produce highly enriched uranium (HEU) for its weapons.

The successor machine P-2, which has apparently not yet been mastered by Iran, should produce a little more than twice the fuel produced by the P-1 in the same period. But that is still far from enough to meet the needs of the reactor programme. A plant with 50,000 P-1 centrifuges will have an annual capability to produce 17 tons of LEU at 4.4% enrichment, an amount that will sustain one reactor only. The equivalent figure for the P-2 is 52 tons. And so it could sustain perhaps three reactors. Compared with a need to sustain 20 reactors, the Iranian centrifuge programme looks like a disaster.

The whole nuclear power programme, not just the centrifuge part of it, is gravely inadequate for anything but a small number of reactors, probably one. The UF6 production facility would be well matched with a 50,000 P-1 centrifuge facility run at approximately 80% design capacity. The fuel fabrication facility with a planned output of 20 tons per year is also consistent with fueling a single reactor.

These figures taken together with Iran's meager uranium deposits make the idea of a significant (in terms of Iran's electricity needs) self-sufficient civil nuclear industry seem a distant dream. And not only distant, but also expensive. There is nothing in the Iranian national programme to suggest that it will be able technically to play in the same league as China and India, let alone Europe and Russia.

Treatment of LEU

The amount of LEU produced depends upon a variety of factors, including which model of non-Iranian centrifuge is chosen, the number employed, whether run on high or low "tails", the level of demand and the policy of the holding company.

To illustrate, let us assume what is probably the most cost-efficient set of circumstances, namely a multilateral enrichment facility that will eventually (probably seven or more years from the start) be operating with 50,000 URENCO TC-21 centrifuges. On that assumption, a lot of LEU will become available. We estimate that the facility's annual production of LEU at 4% enrichment will be about 840 tons. That would suffice to provide all the fuel needed to sustain forty-two 1000-MW reactors. Since Iran plans to have twenty such reactors in 2035, we assume that that country would be a regular customer. In other words, roughly half the production of the facility once it has eventually reached full capacity might go to Iranian customers. If so, this would provide relatively secure economic underpinning. The other half would be available for other customers including the proposed virtual fuel bank. Such customers would need to be in good standing with the NPT and accept the appropriate IAEA safeguards.

The international market for reactor fuel is complicated by the diversity of reactor types and the specifications and regulations of a multitude of countries; essentially, every reactor requires its own unique levels of enrichment. In fulfilling precise contracts for Iranian or any other reactors, the UF6 would be enriched to the specified level and then turned into fuel rods at a fabrication plant, possibly that belonging to the Board at Esfahan. However, a considerable cost is associated with bringing the centrifuges up from stationary to their operating speeds. Thus, to be cost-effective, the enrichment facility would be run more or less continuously and, in all likelihood, would produce more LEU than was immediately needed.

Non-contracted for LEU would be enriched only to 3% and would be stored, on site, in cylinders containing two tons of UF6; each cylinder would be placed under IAEA seals and other safeguard mechanisms such as cameras and motion sensors that the Western partners of the joint venture could require. The storage of LEU on site, in any form but especially as UF6 which can be directly used in an enrichment process, represents some level of risk for theft and diversion. However, we believe that the risk is low and controllable given the physical properties of UF6—it is a solid below roughly 130 degrees Fahrenheit and is highly toxic and corrosive—and the safeguards mentioned above. When further enriched to meet a contract, the LEU would be quickly turned into uranium oxide—a much more proliferation resistant form—and either processed into pellets and fuel rods or immediately shipped out of the country for processing elsewhere.

Commercial Demand for Enrichment

The recent "meteoric" increases in the price of uranium will for cost efficiency reasons affect the demand for enrichment. For many years the relatively low price of uranium has discouraged investment in enrichment facilities. With a low price, profit normally dictates high "tails", that is spending a relatively small sum to extract a relatively small amount of the available U-235 from a low cost ore. But with high cost ore, the economics reverse: that is spending more to extract more of the available U-235 i.e. low "tails", is cheaper than buying more high cost uranium. More extraction means more demand for enrichment facilities and the lead-time to provide these is measured in several years. So, purely on grounds of cost it appears that the world is going to need more efficient enrichment facilities, phasing out the old expensive gaseous diffusion plants.[2] *

If, on top of this, one factors in a generally expected rise in demand because more people want more electricity and because nuclear reactors come to be preferred on environmental grounds to coal and oil-fired power stations, it is reasonable to suppose that there is room in the global market place for a new modern enrichment plant built in stages and expanded in relation to demand.

Finance and Costs

Based on information about URENCO's enrichment plants built for the Louisiana Energy Services and for the George Besse II in France, we estimate in current prices that the cost of a 15,000 centrifuge facility of TC-21s would be about € 570 M ($700 M), while a 50,000 centrifuge facility would cost about €1.5B ($1.9B) -- €2.3B ($2.8 billion), depending on conditions in Iran. There would of course be many other costs, for instance for conversion to UF6 and for fuel fabrication. Since all shareholders would be governments, there would be no carrying costs.

The large costs involved, irrespective of which non-Iranian centrifuge is chosen, emphasise the importance of planning on the basis of commercial considerations. And that in turn means that it will be important for the shareholders to exercise through the Board close control over policy and expenditure and to be ready to adjust in the light of expectations about future market

[2] This paragraph draws heavily on Thomas L. Neff, "Uranium and Enrichment-Fuel for the Nuclear Renaissance" in Nuclear Energy Review, Dec. 2006 URL http://www.touchbriefings.com/cdps/cditem.cfm?NID=2402.

conditions. It goes without saying that the management company will have to be highly professional, closely knit, properly compensated and transparently accountable to the Board. It is obvious also that there will be a special responsibility on the host government to facilitate the operations in every possible way. Some of these ways will be financial and others administrative. The facilities and the necessary personnel must be made safe from unwarranted and harassing legal actions in-country. One possibility would be to accord them many of the same rights and privileges as IAEA personnel (Article XV of the IAEA Statutes).

Apart from noting these general points, it is premature to enter further into a detailed discussion of costs and profits.

Spent Fuel and Nuclear Waste

These are issues which will have to be addressed explicitly in the treaty. Safety is paramount. Earthquake-prone Iran is not an ideal place in which to store dangerous material. The Russians have offered to take back the spent fuel from the Bushehr reactor. It would be helpful if at least for a time they would take all the dangerous unwanted products of the multilateral operations. In the longer term, we hope that another multilateral organisation explicitly for the storage of spent fuel will be established elsewhere, for example in Australia. Meanwhile, the dangerous waste produced in the enrichment facility in Iran will remain legally the property -- and the responsibility -- of the shareholders.

Strengthening the Non-Proliferation Regime

Non-proliferation ultimately fails or succeeds according to the decisions of individual governments. It will fail if governments, perhaps only one or two of them, decide that they can get away with going nuclear, that the benefits outweigh the costs. In this decision, they will be greatly influenced by what others do and don't do. That is why the example of only one or two governments may ensure failure. Success is harder because it requires all governments always to decide not to go nuclear. This will happen only if all governments accept a fair and workable set of rules and if there is a climate of opinion in favor of abiding by them. Then governments are likely to conclude each time they ask themselves whether to go nuclear that the balance of considerations is against it. Both points -- the rules and the climate -- are achievable and indeed were achieved, not quite perfectly but nearly so, for thirty years up to 1998. If they are not re-established soon, non-proliferation will fail. The NPT provides the bedrock rules and so it needs to be reaffirmed and strengthened. This depends crucially on the great powers providing impeccable examples.

The treaty setting up the enrichment facility should recognise explicitly that:

- France, the UK and Russia (if an original shareholder) base their actions on Article I of the NPT in which Nuclear Weapon States (NWS) undertake "not in any way to assist, encourage, or induce any Non-Nuclear Weapon State (NNWS) to manufacture or otherwise acquire nuclear weapons ... or control over such weapons...";

- Iran reconfirms its undertaking in accordance with Article II of the NPT "not to manufacture or otherwise acquire nuclear weapons ... and not to seek or receive any assistance in the manufacture of nuclear weapons...";
- in accordance with Article III of the NPT, all Parties have obligations in respect of safeguards which they will respect individually and as partners in the joint venture;
- "the inalienable right of all the Parties [to the NPT] to develop research, production and use of nuclear energy for peaceful purposes..." (Article IV, paragraph 1) is reconfirmed;
- the multilateral enrichment enterprise is established in line with Article IV, paragraph 2 ("Parties to the Treaty in a position to do so shall also cooperate in contributing alone or together with other States or international organisations to the further development of the applications of nuclear energy for peaceful purposes, especially in the territories of Non-Nuclear Weapon States Party to the Treaty, with due consideration for the needs of the developing areas of the world.");
- the same paragraph provides the basis for the arrangements being made for secure fuel supplies to NNWS members of the NPT in good-standing and accepting appropriate safeguards;
- all Parties undertake in accordance with Article VI to take fresh steps towards "cessation of the nuclear arms race" and towards "nuclear disarmament";
- all Parties undertake to seek to amend the NPT by dropping Article X, paragraph 1 which provides for withdrawal if supreme interests are jeopardised.

Basing action on the NPT and employing its language makes use of Iran's repeated declaration of loyalty to this Treaty and helps to stress the equality of the Parties to the deal.

The Risks of a "Break Out

Iran could, at least in theory, "nationalise", that is expropriate the proposed multilateral enrichment facilities. That would be a huge political challenge conveying an almost undeniable presumption of a military programme. It would involve the withdrawal of IAEA inspection and leave Iran (or any other country) in an "outlaw" position flouting the NPT and the IAEA. In practice it would directly challenge the powerful governments whose property was expropriated and would lead at once to Security Council action. A provision to this effect would be included in the treaty. And if that were inadequate there remains the possibility of military action.

For these reasons and for the sake of Iran's good name? expropriation is unlikely. Nevertheless, it would be wise to build in a physical safeguard and deterrent. This is investigated in the following paragraphs.

Self-destruct and Disabling Mechanisms

Centrifuges, by the very nature of having a rapidly rotating core, contain enough energy to destroy or permanently disable them. In fact, each one contains almost the equivalent of a stick of dynamite. That energy can be harnessed to destroy either the entire centrifuge or, less dramatically, crucial parts such as the bottom bearing that are hard to manufacture and represent the primary technological barrier to their spread. Alternatively, it is possible to non-destructively disable them so that it would take a considerable period to restore them for operation. (Annex II goes into further detail of these mechanisms.) This period of time when the centrifuges were inoperable would allow either diplomatic moves to punish Iran for expropriating the facility or an air strike to destroy it since it would be built above ground for safety reasons.

Both of these options, the self-destruction or the disabling options, could be based on embedding an encrypted electronic-key circuit inside each centrifuge's motor. This circuit, when used as a disabling mechanism, would require that the centrifuge receive a periodic message allowing it to continue operation. That message would have an encrypted authentication code associated with it that would prevent it from being forged; a technology that has been well developed by the electronic banking industry. Similarly, this same circuit could be used to destroy the centrifuge by reversing the phases of two of the three power lines. The degree of destruction this would cause depends on the details of the centrifuge but it could range from destruction of the bottom bearing—a crucial and difficult to reproduce piece of technology—to the destruction of the entire central rotor.

The Risks of a Clandestine Weapons Facility

In theory, the Iranians could enter into a multilateral enrichment facility in Natanz, as we propose, and then build secret enrichment-related plants elsewhere in the country. They could do this, of course, with or without a multilateral facility in Iran. In other words, it is an option under any scheme. For example, they could build a secret facility despite a promise to the West to suspend their programme for a limited period or even to forgo it altogether. Or they could build a secret facility while pretending to ship all their UF_6 to Russia for enrichment there. And if they were allowed to have a pilot or experimental plant under national control, this would further facilitate a secret installation.

In comparison with these possibilities, the risks of a clandestine facility under our scheme appear minimal. To enter into an agreement providing for intense control and inspection within

Iran at the same time as building clandestine facilities in the country would be spectacularly stupid. Our proposal has inherent mechanisms for detecting covert facilities that would be hard, if not impossible, for other regimes to match. As UNSCOM and UNMOVIC found in Iraq, familiarity with key scientific personnel can contribute substantially to understanding all the relevant activities in a country's programme. Western technicians would work with their Iranian counterparts 24-hours per day, seven days a week and would not only understand their skills and competences but would be aware of their comings and goings. This familiarity could be a major source not only of reassurance that Iran was not misbehaving at the multilateral facilities but also for detecting any clandestine enrichment plants in Iran. (See the Appendix II for additional discussion of this point.) In addition, of course, IAEA inspectors would be stationed permanently in Iran with full rights under the Additional Protocol and also under further agreed transparency measures.

A stronger deterrent is hard to imagine. To evade its effects, the Iranians would almost certainly need a duplicate set of scientists and technicians, one set for the overt facilities at Esfahan and Natanz and a second set to build and operate more or less identical facilities elsewhere. Moreover, they would have to keep the two sets separate and refuse official positions to those in the secret set.

Cleaning the Slate

While our scheme is as effective a guarantee as can be devised against the establishment of new clandestine facilities, it does not totally assure the international community that such facilities are not already in existence. After all, the Iranians ran a clandestine operation for eighteen years and several other countries have done so as well. All the same it is unlikely that the Iranians were running two clandestine operations in parallel simultaneously nor would they have risked starting a new one while they were negotiating with the EU-3 (from September 2003 to December 2005 inclusive) and observing the IAEA Additional Protocol. Nevertheless, their history of lies and evasions, compounded when they were found out by further lies and evasions, has more or less destroyed their credibility in the West. Not only their word but also their intentions are doubted. The IAEA has repeatedly sought answers from them on some relatively simple questions and again and again has been ignored or fobbed off. After some three years of failure to respond to the IAEA on some questions, it is evident that the Iranians find full disclosure embarrassing. The international community can only suppose that it is a case of no smoke without fire. And it is upsetting that the Iranians seem to take lightly the fact that they continue to be non-compliant with the IAEA regulations. This destroys international respect for Iran and makes it hard to take their negotiators seriously. Whatever the cause of the embarrassment, it is in Iranian interests to come clean.

A clean slate will encourage the international community to begin again to trust Iran and will remove a serious burden from the Iranian negotiators. Obviously, the best course would be simply to tell the IAEA the truth. If, however, the Iranians cannot bring themselves to do this, there is another way in which the truth can be conveyed to the international community. This is what might be called the "Swedish Buddhist" method. It is modeled on the agreement between the British Government and the Irish Republican Army (IRA) whereby a French Canadian general trusted by both sides, dealt separately with each and assured the British that what the IRA said about the disposal of its weapons was true.

In the present case, the Iranians might find a neutral trusted personality—the Swedish Buddhist—show him the missing material and convince him of the true answers to the IAEA questions. He would then try to get the West to agree (but without showing them the evidence) that if the Iranians presented those answers to the IAEA, the West would encourage the Board of Governors to note the situation, reprimand the Iranians, recall the file from the Security Council and announce that the slate had been wiped clean.

The Risk of Western Withdrawal

As the West is concerned to protect against Iranian violations of the treaty, so Iran seeks protection against politically inspired Western violations. In effect, this means protection against procrastination or wrecking withdrawal. Both risks should be taken care of formally in the terms of the treaty.

In addition, the risk of deliberate Western delay can be guarded against by incorporating a timetable in a memorandum of understanding spelling out how the general provisions of the treaty are to be implemented in practice. For the reasons already given, the West will be keen to introduce non-Iranian centrifuges as quickly as possible in order to phase out the Iranian P-1s. It seems likely that in the first stage of the enterprise any deliberate delay would not come from the West but from the Iranian side. In later stages, the risks are more evenly balanced and it will not be feasible to lay down a precise timetable since global demand for LEU is inherently unpredictable. It will not even be feasible to predict with confidence the extent of the Iranian demand in any given year. That will depend upon decisions of the Iranian government and upon how they go about building or contracting for their ambitious reactor programme. Considering the large investments involved and its commercial basis, the holding company will no doubt act prudently. As explained above, the enrichment facilities will be built in stages related to the expansion of the opportunities. With those considerations in mind, a timetable for say the first seven years of the enterprise could specify, for example, legally binding provisions obliging the Western partners to ensure a minimum number of centrifuges working and a minimum level of investment linked to minimum Iranian commitments.

The same sort of considerations effectively precludes a risk that the Western partners will withdraw leaving the Iranian programme in a shambles. A Western withdrawal other than for prolonged commercial failure would undercut the dominant political reasons which induced those countries to invest large amounts in a difficult enterprise in a foreign country. Under the terms of the scheme above, the entirety of the Iranian enrichment-related facilities (including the P-1 centrifuges) leased by the holding company would automatically revert to Iranian control. In addition, the Iranians would enjoy the benefits of skills acquired during the years of the operation and of improvements made to the fixed facilities. Thus the risks to the Iranians of participating in the enterprise would be no greater and arguably smaller than those accepted by the Western partners.

The Way Forward

Current Western tactics, we have argued, are failing. Although (as with any political situation) it is not yet absolutely certain that they will fail, the probabilities are high. Time, as we have explained, is against the West. The Iranians have got the machines and the technology; save for the last engineering tricks – and these they will learn probably this year. When they do, Iran will still be five or perhaps even ten years away from actually making a bomb. And, in the right circumstances, the Iranians might not, even then, do it.

Accordingly, it is tactically unwise to stake the Western position on forcing Iran to do what it has sworn not to do. In all likelihood, this hands Mr. Ahmedinejad a "victory". Better to modify course and make a virtue of necessity by accepting that the Iranians should have their existing machines and their technology (comparatively modest on the global scale) so long as they do not make a nuclear bomb. Given a sensible modification of tactics, there is still time and a chance to secure this top priority.

Of possible modifications, the Forden-Thomson plan best meets on a permanent basis the bottom line on both sides: no nuclear weapons in Iranian hands yet enrichment on Iranian soil. Informally the Iranians have been positive. Their Foreign Minister has said publicly more than once that Iran favors multilateral participation in its nuclear programme. Nothing indicates that the West has asked him to elucidate. We should grasp this olive branch.

If Iran rejects the Forden-Thomson proposal, we have probably gained friends in Tehran and lost nothing. If it accepts, we have a deal likely to stick because agreed to voluntarily.

But the obstinacy of politicians suggests continued deadlock until it is too late. If that happens, is it the end of attempts to resolve the problem through negotiation and compromise? Probably, though as a long shot, we could try a general Middle Eastern bargain tying up all the loose ends. It would be fiendishly difficult to negotiate and perhaps impossible without a political genius on the scale of say Bismarck. But that is another story.

Appendix 1

Multilateralism in Non-Proliferation

Multilateral control of the means to make nuclear weapons is an idea almost as old as the nuclear age itself but hitherto it has had little success. The Acheson-Lilienthal Report of 1946 recommended an "Atomic Development Authority" with a global monopoly of control over all the processes that could lead to a nuclear weapon. Under the title of the Baruch Plan it became official U.S. policy but was soon suffocated by mutual Cold War suspicions.

In the following quarter century, some agreements, for example, the Test Ban Treaty (1963), the Latin America Nuclear Free Zone Treaty (1967) and SALT I (1972), sought to control weapons while others, mainly Eisenhower's well meaning but naïve Atoms for Peace (1955) promoted the spread of nuclear knowledge and materials for beneficial purposes. These two types of agreement, each admirable in its way, are essentially inconsistent, one limiting weapons, the other in effect promoting the means to make them. This inconsistency is at the heart of our present predicament and in the first place, of the Iranian crisis.

From the beginning it was well known that the machines, the technology and the material they produce, which gives us electricity and medical treatment, will do just as well, after some extra work, for weapons. Low Enriched Uranium (LEU) for civil purposes can fairly easily be turned into Highly Enriched Uranium (HEU) for bombs. Political leaders at the time understood that they could not rid themselves completely of weapons nor hold back humanity's drive for electricity. Accordingly, they crafted a political framework intended to keep the military and civilian uses of nuclear energy safely in balance: no spread of weapons combined with widespread civilian use of nuclear energy. The resulting framework was called the Non-Proliferation Treaty (NPT), signed in 1968 and entered into force two years later. So important was and is the NPT that remarkably every country in the world adhered to it save three, India, Israel and Pakistan. Later, North Korea resigned. These four holdouts all ran clandestine programmes and made nuclear weapons, thereby seriously complicating efforts to control weapons globally.

The NPT, now often described as "flawed", was the best bargain that could then be made to prevent proliferation of weapons while encouraging the spread of civil uses of nuclear energy. It did not do away with the potential inconsistency of the two objectives but it created a regime that encouraged governments to make choices that avoided forcing the potential to become actual. Eventually, however, a few governments began to make choices that had the opposite effect and this process has put the non-proliferation regime in jeopardy. This is not the place to analyse the bad choices and the unfortunate effects produced but it is important to realise that the blame is widely shared: some is due to the "hold-outs" undermining the bargain made by the rest of the international community, some to governments turning a blind eye to dangerous illegal activities, above all Pakistan and the A.Q. Khan black market, some to cheating by non-nuclear weapon states (NNWS) of which Iran and North Korea are currently the main examples, some to the nuclear weapon states (NWS), especially Russia and the U.S. who have fallen dismally short of carrying out their obligations under the NPT to reduce (ultimately to nothing) their dangerously huge nuclear arsenals and some to all the states, which irrespective of their rhetoric, have failed to give top priority to the cause of non-proliferation. Of these, the most important as well as the most influential, is the U.S. under the Bush administration.

For the sake of the future, it is important also to understand why the non-proliferation regime was so much more effective for a quarter century or so than many experts expected. First, the treaty was a negotiated bargain by which all parties derived benefits and assumed responsibilities. Second, an effective international expert body, the International Atomic Energy Agency (IAEA), monitored the legitimate activities of the participants. Third, another inter-governmental body created in the mid 1970's, the Nuclear Suppliers Group (NSG), operated agreed guidelines which bound commercial competitors to adhere to NPT and IAEA rules. These three institutions together formed the core of a regime, which worked well so long as governments behaved as they had undertaken to do.

This regime is damaged but not broken. Since no realistic prospect exists of starting afresh with a better one, there is no sensible alternative to repairing the damage and where possible introducing improvements. Such repairs cannot be done by the institutions themselves; only the governments can amend their behavior so that a fair balance is re-created. Multilateralism, we contend, can make a significant contribution to helping the governments do this and thus reinvigorate the non-proliferation regime. Mohammed ElBaradei, Director General of the IAEA has commended the multilateral concept for the last several years and an expert group appointed by him in which twenty-five countries were represented produced a useful report in February 2005. The report has attracted little attention and the conspicuous lack of enthusiasm by major governments seems designed to bury the concept without fuss.

Interment without examination is unjustified and shortsighted. We recommend serious open discussion of the issues raised by this important report. If, as seems possible, the production of electricity through nuclear energy returns to the expansionist path of the early 1970's, fresh risks of proliferation will quickly arise. Conceivably, they could be handled through the mechanisms of the existing global market, but that is doubtful. The existing market enshrines a monopoly position for the current small numbers of producers. Much of the world does not regard this or the rest of the status quo as fair, a point that in itself calls for fresh thinking and this burden of unfairness may cause the already damaged non-proliferation regime to perform inadequately or worse.

Given this prospect, it is obviously relevant, in our estimation, to see whether the balance of fairness can be redressed through multilateralisation of critical facilities, especially enrichment and reprocessing plants. They are the two most critical facilities. Enrichment creates fuel for electricity-producing reactors but unfortunately, if further enriched produces weapons grade uranium for a bomb. Reprocessing of spent fuel from a reactor can extract plutonium usable in a nuclear bomb. This brings us back to the potential inconsistency in limiting nuclear weapons while promoting nuclear energy but this is inherent in the political life of the international community. We argue in putting forward the Forden-Thomson plan (described above) that multilateralisation can effectively remove or at any rate greatly reduce the risk that civil facilities will be used for military purposes.

Multilateralisation – not just in the case of Iran– can support non-proliferation by providing a secure long- term source of reactor fuel irrespective of political quarrels, thus removing the apparent need for national enrichment or reprocessing facilities. It can be introduced step by step. It can be applied to a single stage of the full fuel cycle or to two or more at the same time. Commercial considerations can be applied and the business structure can be varied. The plants can be designed to facilitate the IAEA's monitoring tasks. The concept exploits national interests while adding a dash of international idealism. In short, multilateralism emerges as a useful and flexible policy.

Guaranteed Fuel Supplies

Many other countries besides Iran consider that under the NPT they have rights that are threatened by Western policies including the relatively recent policy of preventing any more countries from acquiring enrichment or reprocessing facilities. For this policy to become acceptable, countries must be satisfied they have a credible guarantee of buying at market rates as much fuel as they want, free of all political considerations. The only condition should be that the purchasers must be members of the NPT in good standing and accepting full scope safeguards and the Additional Protocol.

Recent experience of the way countries neglect or deny their obligations mean that few are content to accept merely verbal assurances from existing suppliers. They want a well-funded and well-founded scheme run by a multilateral organisation, probably the IAEA. This , as Mohammed ElBaradei has urged requires international discussions followed by action. We see the Forden-Thomson plan as a contribution to the discussion and a means of setting up an IAEA virtual fuel bank.

Appendix II

Detecting and Deterring Covert Enrichment Facilities

The problem of detecting and deterring covert enrichment facilities in Iran is common to all the proposed schemes for settling the Iranian nuclear crisis. Unfortunately, there are significant technical barriers to detecting such facilities. For instance, conceptual plans for using wide area environmental sampling (WAES) techniques—basically instituting a permanent chain of air and water sampling stations through a suspect country to pickup particles containing small amounts of enriched uranium—have highlighted how small are the annual amounts of uranium that might be released. An IAEA report estimates that a centrifuge enrichment facility would release at most one gram of uranium per year[3] and possibly much less. One independent estimate[4] of what such a network in Iran might look like suggested 400 stations would be needed with samples collected twice a week. And to get the number down to that "manageable" size, the author had to increase the spacing between stations to ten times the spacing of the optimal network.

Even slightly enriched uranium, if diverted to a covert weapons programme, would considerably facilitate its operation. This greatly reduces the chance that a covert enrichment facility would be detected. To illustrate, the enrichment facility needed to take uranium already enriched to 5% up to weapons grade uranium could be less than one fifth the size of a facility that started with natural uranium. Not only does this allow placing the enrichment plant in a much smaller building, such as an urban warehouse, but it also greatly eases the problems associated with preventing the accidental release of uranium hexafluoride (UF_6). For instance, one of the most likely mechanisms for releasing UF_6 is from the regular changing of feed cylinders. By using LEU, a covert facility would need to change these cylinders much less often since much less feed stock would be required to produce the same amount of HEU.

Given these difficulties in detecting covert enrichment facilities, are there any other mechanisms that might be put in place to increase the probability of detecting undeclared facilities? Yes; one based on the experience gained in inspecting and monitoring Iraqi WMD programmes. Through their frequent inspections in Iraq, weapons inspectors got to know who was important and capable so that when those people moved to other facilities red flags were raised, especially when several with complementary weapons production skills were present. The Forden-Thomson proposal has this mechanism built into it, only to a much greater extent than was used in Iraq.

Iranian technicians and scientists working at the joint facility would, almost by definition, become the local experts on enrichment. Western technicians would be working side-by-side with the Iranian technicians and scientists and would come to know their skills and capabilities. Furthermore, Western bookkeepers would, through their normal business activities, know who was taking time off and how often. Key workers, both Iranian and Western, would have to leave an address where they could be found and a contact phone number when they were on vacation. This would be required in any case so that they could be contacted in case of emergency and they

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[3] International Atomic Energy Agency, IAEA Use of Wide Area Environmental Sampling in the Detection of Undeclared Nuclear Activities, STR-321, August 27, 1999, p. 7.
[4] Garry Dillon, "Wide Area Environmental Sampling in Iran", The Nonproliferation Policy Education Center. p. 5

were needed back at the plant. However, it would act as an additional safeguard since the information could also be used to spot the movement patterns of key employees.

Western managers and bookkeepers would also know who came to replace broken P-1 centrifuges during the early phases of operation, before the more capable non-Iranian centrifuges replaced the less economical Iranian machines. This information could be used to follow centrifuge development work outside of the joint facility.

It is, of course, possible that Iran would set up covert enrichment and conversion facilities with no contact with their technicians and scientists working in the joint facility. However, they would almost certainly have to do it without the key scientists and technicians already working at the Natanz pilot plant enrichment facility. If some of those key workers did not join the joint facility, it would raise too many red flags about a possible covert facility. Thus, any new covert facility would have to start from scratch and without much of the information and skills they have so painfully and expensively—both in money and in political baggage—learned since February 2006.

Appendix III

Centrifuge Self-Destruct and Disabling Mechanisms

It is understandable that many would feel uncomfortable about installing a massive enrichment facility, using some of the world's most capable centrifuges, in Iran. They would naturally worry about Iran expropriating them for weapons production. While we believe that if Iran agreed to this joint facility, there would be little risk that they intended to nationalize it; doing so would provoke the wrath of some of the world's most powerful military powers and uniting the world in condemning its actions. Nevertheless, there are technical measures that can be taken to reassure the world that this facility would never be used for military purposes.

We believe that both safe and reliable self-destruct and disabling mechanisms[5] can be built into each and every centrifuge in the joint enrichment facility. Both of these mechanisms can be accomplished without explosive charges or other crude forms of destruction that would represent a risk to workers during their normal activities. The destructive power is inherent in a spinning centrifuge rotor, which has almost the same magnitude of energy per kilogram as a stick of dynamite. In fact, one of the important design problems that had to be worked out early in the development of centrifuges was a way of ensuring that shrapnel from a "crashed" centrifuge did not destroy nearby centrifuges and start a domino effect of destruction.

The details of both of these mechanisms will depend on the details of the centrifuge on which they are installed. In general, however, all centrifuges share a common design feature: the motor that spins the centrifuge rotor is fastened to the bottom of the stationary outer casing and is "potted" in place.[6] It is just this common design feature that we propose to make use of in both types of mechanisms by placing an encrypted electronic-key circuit inside the motor. (See Figure 1 below.) If Iran wanted to remove these key circuits they would have to disassemble the centrifuge, dissolve the epoxy surrounding the motor, remove the key circuit, repot the motor, and reassemble the centrifuge. While this is theoretically possible, Iran would have to develop the procedure—having never seen the insides of the centrifuge before—and then repeat the process thousands of times; once for each centrifuge. This could take a considerable amount of time, time that could be used for responding to Iran's actions. Of course, if a self-destruct command had been issued to the key circuit before the centrifuge stopped spinning, the centrifuge would be completely destroyed.

A Disabling Mechanism

There are several ways of implementing a disabling mechanism. In one, the encrypted key circuit could require a periodic digital signal just to keep functioning. Thus, for instance, an employee designated by the non-Iranian partners in the joint venture might be required to send a

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[5] We thank Mr. Julian Whichello for suggesting the disabling mechanism and for very helpful discussions on implementing both the self-destruct and disabling mechanisms.

[6] "Potting" involves embedding the motor, in this case, in a thick matrix of epoxy. While this epoxy can be dissolved, exposing the motor so that it can be modified or repaired, it takes a considerable amount of time to do so.

code to each centrifuge once an hour otherwise the key circuit would shut down the power going into each centrifuge. (This is not as tedious as it might appear since a central computer could relay the different codes required for each centrifuge.) The enabling code is sent together with a message authentication code to assure that a forged signal is not being sent. Encrypting such authentication codes is now well known from electronic banking applications.

Alternatively, a designated operator could send a disabling code to each and every centrifuge that would permanently open the power circuit and prevent any centrifuge from receiving the power needed to keep its motor turning. This later method, however, has the disadvantage that it could be foiled by preventing a single command from being sent, perhaps by cutting the signal wires or blocking the employee from performing his duty.

A Self-Destruct Mechanism

The same electronic-key circuit used to disable the centrifuges could also be used to destroy them. Instead of merely interrupting the incoming power, the circuit could reverse the order of two of the three input power "phases."[7] When that happens, the induction magnet spinning the centrifuge would loose its ability to systematically turn the rotor and would cause it either to crash catastrophically against the outer casing or to destroy the main bearing that the centrifuge sits on. A catastrophic crash would clearly render the centrifuge inoperable but could represent a potential safety hazard to workers inside the cascade hall. (Modern centrifuges are designed to contain any shrapnel or fragments that might be created during a crash but it still might be dangerous to have 50,000 of them crash all at once. More detailed knowledge about the designs of centrifuges than is publicly available is needed before a definite answer on worker safety can be given.) It is also possible that this reversing of phases could be done in a way as to assure that only the rotor's critical bottom bearing is destroyed. This bearing is so critical to the centrifuge's operation, and is so technologically sophisticated, that if destroyed the centrifuge is rendered permanently inoperable.

No centrifuge manufactured today has had either a self-destruct or a disabling mechanism built into it and so no matter what solution is found, there will have to be a development programme. However, we feel confident that both of the mechanisms discussed here can be effectively adapted for existing centrifuge designs and that they will withstand attempts to circumvent them.

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[7] In order to have as uniform a power level as possible, centrifuge motors are run with three input electronic phases as opposed to the more widely known single phase circuits used in most houses. While the single-phase wires in most American homes have one wire held at ground and the other oscillates between minus 120 volts and plus 120 volts, a three-phase system delivers power more equally on three separate wires.

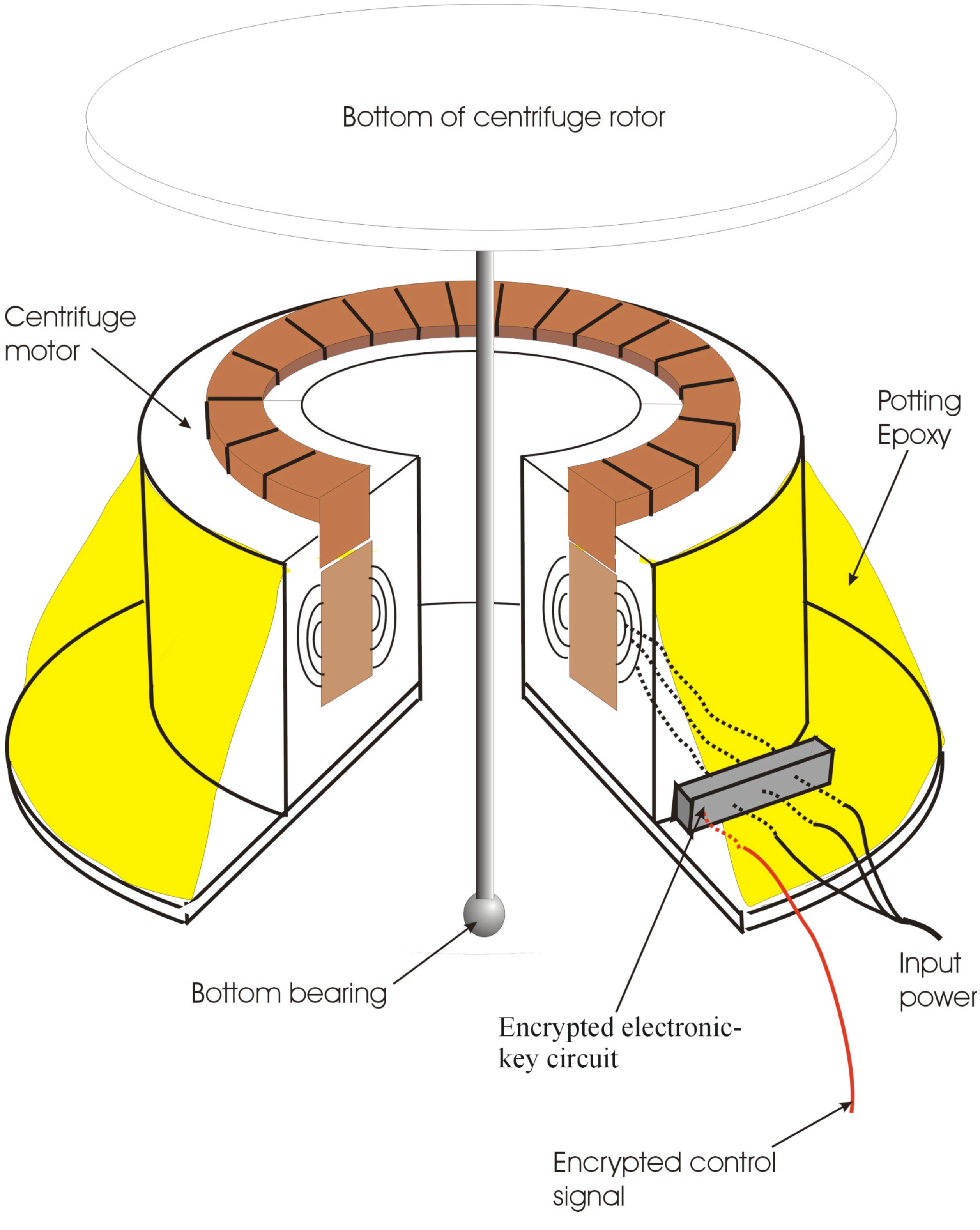

Figure 1. A sketch of a centrifuge motor with an encrypted electronic-key circuit embedded in its power train.