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The Critical Vulnerabilities of Civilian Nuclear Operations

The exploitation for peaceful purposes of nuclear knowledge and nuclear technology is inevitably connected to the exploitation of the same phenomena for military purposes. Moreover, many of the key processes that are at the heart of the civilian nuclear industry (particularly, enrichment and reprocessing of spent fuel) are at the heart of a weapons production programme. If the problem is not to be disposed of by outlawing nuclear activities for any purpose, then the critical vulnerabilities of peaceful operations need to be identified and measures need to be adopted that offer the greatest assurance that such operations are not misused to produce weapons of any kind. In the light of the enormous positive potential of nuclear power in a world threatened with climate change, as well as the benefits of nuclear materials in medicine and industry, it will be taken that the abolition option is not in the interest of humanity, even if it were viable. To the contrary, it is assumed that nuclear operations will continue to expand in scale and, particularly expand to more countries. The need then is to understand the full range of vulnerabilities and identify the widest range of responses and safeguards that may be employed.

The obvious key danger is that fresh states acquire the capability to produce weapons grade fissile material and then either covertly employ this technology to make weapons, or, at some point, in the future may decide to do so in defiance of their undertakings to that point ('breakout'). An associated danger is that states that have the capability (and perhaps a covert programme) may provide knowledge or material (including fissile material) to other states, or even to non-state actors (and, again, in defiance of specific undertakings). There is a third general vulnerability and that is that states having such programmes and the associated stocks of material, may fail to adequately protect already made-up weapons, weapons-grade fissile material, or, more generally, radioactive material that might be the basis of radioactive dispersal devices. Of course, these latter dangers apply also to the existing nuclear weapon states (both official and unofficial), although in relation to weapons and weapon-grade material it might be presumed that states with long experience of nuclear weapon production might have evolved more sophisticated systems to protect these things. Some of these vulnerabilities are specifically related to particular processes (like enrichment and reprocessing, as noted above), others relate to more general aspects of the nuclear industry and attach to the science and the materials that underlie both civilian and military operations. The discussion begins with these non-specific vulnerabilities.

Non-Specific Vulnerabilities

States that have any significant nuclear activity, even if it is only a research reactor, or a small power reactor, or even a nuclear laboratory, acquire a general familiarity with things nuclear and a facility for handling nuclear material. As operations grow, with more reactors and, perhaps, the development of ancillary activities, they will

develop a cadre of experts and accumulate nuclear material of various kinds. They will also develop relevant non-nuclear technology such as machine tools for precision engineering. At whatever stage it may be, this kind of development represents a non-specific vulnerability. States that have made any progress along this path are in a better position to start a nuclear weapons programme than those that haven't. States, such as Japan or Germany, that have the full range of capabilities, have everything they would need to make nuclear weapons, should they wish to so; it is only a matter of how long it would take. The principal of bureaucratic prudence suggests that they will also have the plans. The scenario is easy to describe. The Minister comes into the bureaucrat's office and says, 'We have decided to make nuclear weapons. How can it be done?' The bureaucrat envisages two possibilities. He may say to the Minister, 'I'm sorry, I have no idea. We haven't thought about it.' Or he may reach for the bottom drawer in his desk and pull out a file and say, 'This is what you need to do'. It is very clear to this writer that the perceptive bureaucrat would want to be in a position to make the second response, rather than the first.

This is not to suggest that either of the states mentioned as examples above began their civilian nuclear power programmes with the idea of developing nuclear weapons, or even that they developed nuclear power in order to acquire general expertise against the possibility that they might want to pursue nuclear weapons ambitions at some later stage. In the case of Japan it is plausible to believe that the development of nuclear power was a response to long-time energy supply anxieties, exacerbated by the oil crises of the early 1970s. There have been other cases that were clearly different. The British programme to build nuclear power stations in the late 1940s and early fifties was said at the time to be a civilian programme directed at the production of much needed electrical power. In fact, the driver was military. The purpose of the reactors was to produce plutonium for nuclear weapons. This was a pattern that was repeated in the case of India and (to take another example from the writer's own part of the world) Australia (though in this case the programme was aborted at an early stage).[1] At the present time, there is a serious question about the purposes of the nuclear programme of Iran. These are said by that country to be entirely peaceful and related to a developing civilian nuclear power programme.[2] On the other hand, Iran's only civilian nuclear power plant is not yet completed (although it is expected to go critical for the first time in 2005). To be building enrichment and reprocessing capability at this stage seems premature and scarcely economic, especially since the party constructing the nuclear power plant (Russia) has also offered to supply the fuel and to take away spent fuel. Iran has also recently confessed[3] to having discussed with a potential supplier the acquisition of technologies necessary for the production of nuclear weapons as long ago as 1987. Some of these were not dual use technologies but processes, such as uranium metal casting, specific to weapon fabrication.

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[1] The Australian programme was centred on the construction of a series of plutonium production reactors, the first of which was to be built at Jarvis Bay in New South Wales. See Wayne Reynolds, *Australia's Bid for the Atomic Bomb*, Carlton, Victoria, Melbourne University Press, 2000.

[2] This claim is set out in some detail in a speech by the Iranian Deputy Foreign Minister (Dr Gholamali Khoshroo) to the Committee on Foreign Affairs of the European Parliament on 23 November 2004 (text distributed by the Iranian Embassy in Wellington).

[3] New York Times, 28 February 2005.

Dealing with the risk

The moral here is plain. Judgements about proliferation risk, and upon appropriate safeguards, must be made on the basis of actions and capabilities not on the basis of intentions, stated or implied. Specific technologies, such as enrichment and reprocessing, imply specific capabilities which require appropriate responses (to be discussed further below). The non-specific risks that arise from general possession of nuclear material and technology, just have to be accepted. Something between these two is represented by what happened in regard to Taiwan and South Korea during 2004. In both countries, evidence had been found or disclosed of earlier experimentation with sensitive technologies[4]. In the Korean case, there had been experimentation (in 2000) with laser technology that had resulted in the production of a few milligrams of enriched uranium. This had not been reported to the IAEA, or the Korean Government at the time but had been revealed in the context of Korea's acceptance of the additional protocols.[5] In the Taiwan case, rumours of plutonium separation experiments in the 1980s resurfaced following a newspaper editorial exploring the virtues of a nuclear arsenal to deter Chinese use of force against the island.[6] There are separable issues here. It needs to be noted that the activities in question are ended (in one case nearly 20 years ago) and that as far as South Korea was concerned the matter was freely acknowledged, and that South Korea is now bound to the additional protocol regime. In the light of this, it is important not to overreact and inhibit the impulse to transparency. The words of Professor Eun Cheol Lee (of Seoul National University) in reference to the South Korean experiments are also of interest. He talks of 'some curious researchers' and, incidentally, claims that what was done was not at the time subject to compulsory reporting.[7] Enthusiastic scientists are going to be curious and they are going to want to satisfy that curiosity. On the other hand, other commentators point out that the chosen enrichment method (laser separation) is so expensive that it is hard to believe that this 'curiosity' was able to be indulged without some official support[8]. Either way, the incident points up the general non-specific vulnerability that attaches to nuclear activity, however peaceful its ostensible purpose. Obviously, there are general precautions that can be taken in the context of a comprehensive safeguards system (and these seem to have been effective in the Taiwan and South Korea cases) but the non-specific vulnerability will remain.

Specific vulnerabilities of the civilian nuclear fuel cycle

These may be at the front end or the back end of the nuclear fuel cycle and they may relate to sensitive material or sensitive processing capability. At the front end they mainly attach to the process of enrichment and prior uranium hexafluoride manufacture.

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[4] Of course, these are by no means the only states to have been suspected of this and the recently uncovered activities of Pakistani nuclear scientist, A.Q. Khan, suggest that there might be quite a few parties who have been interested in this sort of experimentation. (See, for example, William Broad and David Sanger, 'As Nuclear Secrets Emerge in Khan Inquiry, More Are Suspected', *New York Times*, 26 December 2004.)

[5] IAEA Press Release 2004/08 (http://www.iaea.org/NewsCenter)

[6] 'Taiwan May Have Experimented With Atomic Bomb Ingredient', *New York Times*, October 14, 2004.

[7] *TCNC Newsletter*, September/October 2004, Page 3

[8] In November 2004 the IAEA announced that it would be sending a team of investigators to Korea to make further inquiries.

At the back end proliferation anxieties centre on the accumulation of plutonium in spent fuel and on the existence of plant capable of reprocessing spent fuel. In both cases there is the capacity to covertly produce weapons grade material and thus the possibility that nuclear weapons are made or that material or technology is passed on to third parties who may themselves produce weapons. There is also the danger that states that have some level of nuclear activity may covertly develop the proliferation-sensitive technologies. The traditional way of dealing with this problem has been the IAEA safeguards regime which follows on from the almost universal adherence by states of the world to the 1968 Nuclear Non-Proliferation Treaty. Under this, parties to the treaty lay their nuclear activities open to monitoring and inspection so that it can be verified that they are not engaged in proscribed activities.

Safeguards

One answer to present concerns about proliferation is to further strengthen the safeguards regime. This would involve a renewed effort to get the 40 or so states that are not yet in compliance with their treaty obligations to deposit the appropriate documents and make the appropriate arrangements. It would also involve getting all those states that have, or are acquiring, sensitive technologies to sign up for the additional protocols and, as the IAEA Secretary General said in September 2004, not taking 'no' for an answer.

It is undoubtedly true that full compliance from all parties would provide a high degree of assurance, not only in regard to enrichment and reprocessing activities but also in the difficult area of illicit transfers of material and technology; but there are a number of obvious problems with this as the sole solution. With the likely expansion of capability (for existing players) and the very likely extension of nuclear power activities to fresh states, the demand for IAEA monitoring capacity is going to increase enormously, perhaps unacceptably so, if there is a proportional increase of new entrants into the more sensitive technologies. This will place a particular strain if there are widespread and persistent efforts to cheat on the system. In such cases additional measures of surveillance are likely to be required in addition to the protocol regime, to ensure compliance. 'This would include short notice access to go anywhere, and interview anyone, at anytime without restrictions and to allow agency inspectors to use their own equipment.'[9]

Problems

There is some debate about how well such a system can work. On the one hand:

> The Iraq experience has demonstrated that inspections – while requiring time and patience – can be effective even when the country under inspection is providing less than active cooperation.[10]

On the other: 'sanctions have not proven to be a workable solution, and in many cases simply serve as a catalyst for clandestine nuclear programmes'.[11] A glance at the footnotes here will show that this is the same speaker (IAEA Director General Mohamed

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[9] Pierre Goldschmidt, IAEA Deputy Director General, 22 June 2004 (http://www.iaea.org/NewsCenter/)

[10] Address by IAEA Director General, Mohamed ElBaradei, to Pugwash Conference in Seoul, 7 October 2004. (http://www.iaea.org/NewsCenter/)

[11] IAEA Director General, Mohamed ElBaradei, opening international expert group meeting on nuclear fuel cycle, 10 September 2004. (http://www.iaea.org/NewsCenter/)

ElBaradei) in speeches less than a month apart. Of course, he may have been thinking of different cases and there are clearly many variables here but it is surely evident that the safeguards system is an invitation for the unscrupulous to play games with the international community. The IAEA has been fooled in the past and it is likely to be fooled again. It certainly seems that in the case of Iraq a combination of persistent sanctions and a comprehensive inspection regime over many years produced a situation in which that country was unable to actively pursue its nuclear ambitions. On the other hand, it needs to be remembered that this was only confirmed *after* the 2003 invasion and the fall of Saddam Hussein and that before the invasion most experts were still speaking of doubts and unresolved questions. It also needs to be noted that, at almost the same time, it emerged that Libya had been pursuing a nuclear weapons programme that was undetected by the safeguards system.

Breakout

There is yet another factor. Even the additional protocol regime cannot guard against 'breakout'. A state which has a substantial enrichment facility could simply repudiate its commitments, remove monitoring equipment and refuse further visits from IAEA inspectors. It could then adjust the mode of operation of the facility so that instead of producing (say) 4% uranium 235, it produced 90+% for weapon manufacture[12]. In the case of a typical centrifugal cascade system this might take a couple of weeks. There would presumably be no shortage of the uranium hexafluoride feedstock (although this is another sensitive technology subject to safeguard). Similar considerations would apply in the case of states that had a reactor that was capable of producing weapons grade plutonium (one that could be refuelled without shutting down and thus capable of permitting short burnups of the nuclear fuel) and/or reprocessing technology that would permit the separation of plutonium, thus produced.[13] The only restraint on the further development of a nuclear weapons programme based on either of these pathways would then be only world opinion. This is the same force that must oblige states not in compliance with their NPT obligations to become so. The crucial question is, to what extent can we rely upon this? Clearly for some states that already have a full range of capabilities (like Germany or Japan), the esteem of other states is very important to them so that dishonest practice, or the open repudiation of solemn undertakings would have a high price. The same may not apply to what have sometimes been called 'pariah' states; states that are already in bad odour for other reasons (Myanmar and North Korea spring to mind as examples of this case). More generally, there is a need to face the realities of world politics. Issues like this are not determined by international bodies on a strict objective assessment of what even-handed justice and fairness would require. They are also determined on the basis of interest and advantage. The line-up of major players in relation to the ongoing Iran saga, illustrates this very well. China's support for Iran's position is easily defended on the basis of Iran's (albeit sometimes tardy) acceptance of

[12] Covert alteration *whilst under full safeguards* is rendered problematic by the possibility of short notice inspection. It could be further guarded against by remote monitoring of process lines, as suggested by Arian Pregenzer of Sandia National Laboratories in a paper prepared for an international meeting in China (and privately provided to the present author).

[13] The Canadian CANDU reactor, which also has the advantage of working on unenriched fuel, is very relevant here.

IAEA demands but it is also very understandable in the light of China's acute need for oil and gas to support its rapidly growing economy.

NPT Anomalies

There is also the vexed problem of the few NPT standout states that already have nuclear weapons (Israel, India and Pakistan). As matters presently stand they cannot be admitted to the NPT as nuclear weapon states, and they cannot be admitted as non-nuclear weapon states unless they give up their weapons (which in their present security circumstances they are very unlikely to do). The downside of this is that these states cannot be embraced in the IAEA safeguards regime and be full parties in, for example, nuclear export control measures. In a 2004 article in the *Bulletin of the Atomic Scientists* Cohen and Graham suggest that this might be rectified by establishing a form of associate membership of the NPT through a 'free standing agreement or protocol'.[14] Whether this is a politically viable proposal, the fact remains that the anomalous situation of these states is a weakness in global efforts to control proliferation and will remain so until it is rectified. A tentative conclusion at this point is that safeguards, even enhanced, may not be enough. It is thus essential to consider other ways of dealing with the proliferation problem.

Restricted Access to Sensitive Technologies

An obvious alternative which may also deal with some of the problems identified above is to establish a pattern of international cooperation which would control access to particularly sensitive technologies. This end may be achieved by the cooperative establishment, for this purpose, of internationally owned and operated facilities, or through the licensing of particular existing providers (or both). In either case, the essence of the proposal is that beyond these two categories, the establishment or operation of sensitive nuclear technologies would not be permitted and suppliers of relevant technology would be forbidden to supply services other than to authorised operators.[15] Such a regime would have a number of other virtues beyond proliferation control. By taking advantages of economies of scale, it should be able to supply enrichment, reprocessing, or spent fuel storage more cheaply than could be provided by national operations, particularly in the case of smaller players and newer entrants to nuclear operations. Indeed, such a scheme must offer substantial financial inducements to parties that were not permitted to have their own facilities to compensate them for opportunities thus forgone. As far as the backend of the fuel cycle is concerned, international cooperation could also provide for more optimal environments for repository construction. Concentrating on a smaller number of internationally monitored facilities would also simplify and reduce the work of the IAEA safeguards inspectorate.

The simplest way of approaching such a regime would be to internationalise existing facilities, supposing that the countries involved were willing. Britain, France and Russia already have substantial reprocessing capability which they might be persuaded to open to a wider range of customers with the caveat that certain monitoring

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[14] Avner Cohen & Thomas Graham Jr, 'An NPT for non-members', *Bulletin of the Atomic Scientists*, May/June 2004, pages 40-44.

[15] This is the central thrust of the February 2005 International Expert Group report, 'Multilateral Approaches to the Nuclear Fuel Cycle' (MNAs).

mechanisms were put in place. Similarly, the United States and China have plans for spent fuel/high level waste repository construction, which in the case of the US are quite far advanced. It may be that they could be persuaded to expand on present plans to take material from overseas. A consideration that lies behind these suggestions is, of course, that these five states are the five 'official' nuclear weapon states. The fact that spent fuel goes to any one of them for reprocessing or long term sequestration is thus not a direct proliferation risk. For the most part these countries are already flush with weapons grade material. In the case of the first three, they also have substantial MOX fabrication capability. If this latter consideration was thought important, enrichment and fuel fabrication activity could also be limited in the same way. All five NWS have the relevant plant. So of course, do many non-NWS and this would be the core of the most obvious and cogent objection to the proposal. It would be an egregious restraint of trade and a clear interference in the sovereign rights of a state. (Further general objections to any form of internationalised monopoly of parts of the nuclear fuel cycle will be considered together below.)

Approved Suppliers

The proposal for international cooperation on the nuclear fuel cycle may be broadened in two ways. The range of approved suppliers of sensitive nuclear services could be widened beyond the five NWS to a range of existing providers, with a proven record of operation and with the additional protocol regime already in place. Apart from those already named, this would include, for example Japan and Germany. In the case of the latter there is already in existence a deep underground repository for high-level waste that is ready to go (at Gorlaben). Staying in Europe, Finland also has well-advanced plans for a similar repository. Front end facilities, particularly, are widely available around the world. The problem would be to determine where, if anywhere, the cut-off is to be made. The weakest position would be to accept that all present facilities could be, in principal, accepted as approved international facilities. On the plus side, such a designation would require acceptance of the full slate of safeguards (perhaps with some additional measures to provide for the 'international' component). On the other side, such a regime would have enormous implications for the IAEA inspectorate. Again, why should existing capabilities be favoured over those that are being built or planned? It seems obvious that the wider the range of capabilities that is accepted, the weaker would be the counter-proliferation potential of the scheme. The crucial question here is, what are the prospects for international agreement along these lines?

Purpose-built cooperative facilities

There is another way to look at the notion of establishing international facilities and that is to plan and construct entirely new facilities, employing the most advanced and safest systems, and to situate these facilities in the most appropriate places. This was the concept advanced (in relation to spent fuel storage) by Dunn and Carey in 1998[16] and then taken up as a commercial proposition by Pangea Resources. Pangea surveyed the whole globe for suitable sites on the basis of highly plausible criteria and then came

[16] Lewis A Dunn and Stephen Carey, 'Internationalising Spent Fuel Storage: Concepts, Issues and Options', McLean, Virginia, Science Applications International Corporation, 1998.

down in favour of a site in Western Australia[17]. The project had an unfortunate start in that it was leaked to antinuclear interests before it could be officially announced. The company eventually went into voluntary hibernation after several years of attempting to explain what was proposed and what its value might be to the Australian economy. The more recent difficulties that the Australian government has had in getting agreement for the site of a modest low and intermediate waste national repository, anywhere on the continent, suggest that the possibilities for rational public debate on such matters in Australia may not have improved. More generally, as long as nuclear activities are seen as an imposition on a community and not an opportunity, it is going to be difficult to convince such communities that they should accommodate them. This is going to be particularly true in the case of countries that do not have nuclear capabilities of their own. This suggests that if new international facilities are to be built they will be built in countries that already have such an industry. Such countries will also be likely to have available the skilled labour force and the support industries.[18]

Restraint on Trade

There are two aspects to the international cooperation project. One is persuading states to service international needs and, perhaps, build additional plant. With the possible exception of accepting foreign waste for long term storage (where simplistic arguments about taking other people's rubbish are apt to seem persuasive) there may not be too much difficulty with this, although issues of safe transportation are bound to be raised. It also has to be noted that *any* proposal for international cooperation will entail more movement of nuclear material and that may provoke those states (like the writer's own), without significant industrial nuclear activity but with a carefully cultivated capacity for nuclear phobia. Much more significant than this, though, is the difficulty of persuading the international community (and particularly the states that are affected) that access to certain technologies must be restricted to only *some* of those states that have or might have a nuclear power industry. Not only might this be seen as a restraint of trade and an interference with sovereign rights (as noted above) but it may also appear as a repudiation of article IV(1) of the Nuclear Non-Proliferation Treaty regarding the 'inalienable right of all parties … to develop research, production and use of nuclear energy for peaceful purposes without discrimination'. Similarly, suggestions that enrichment and reprocessing plants should be limited to those states that presently possess them and that the Nuclear Suppliers Group should 'refuse to supply enrichment and reprocessing equipment and technologies to any state that does not already have full-scale, functioning enrichment and reprocessing plants' would seem to conflict with the article IV(2) right to 'the fullest possible exchange of equipment, materials and scientific and technological information for the peaceful uses of nuclear energy'. More particularly, states that did not have (say) their own enrichment and fuel fabrication

[17] Other suitable sites (chosen on the basis of geology, climate and landform) were identified in Argentina, Namibia and Northwest China. The last of these is of particular interest, since it is the site also chosen by the Chinese government for a national repository. This fact is what lay behind the suggestion, above, of China as a possible location for an internationally monitored facility.

[18] The February 2005 IAEA report (footnote 15, above) notes that in the case of some sensitive technologies (e.g. reprocessing) the demand is such that there would be no need for the establishment of MNAs for some time.

capability might see themselves to be in a weakened position.[19] They might fear that their essential supplies of fuel might be cut-off, or that continuation of supply could be used as a diplomatic lever. As IAEA Director General, Mohamed ElBaradei, emphasised in an address to a Pugwash meeting in October 2004, any scheme for the multilateral control of the 'sensitive parts of the nuclear fuel cycle' must also guarantee the reliability of supply to legitimate would-be users.[20]

These considerations suggest that there must be a multiplicity of service suppliers. This would also ensure price competition which should mean that the cost of these various services would be significantly less than it would be if the customer were to do it on his own (quite apart from a subsidy system that might be necessary to induce acceptance). The issue as far as fairness is concerned is simply that these limited cooperative arrangements 'would further entrench the discrimination against non-nuclear-weapon states' by apparently entrenching the privileges of NWS, who, in the eyes of many, are already failing to live up to their obligations under NPT.

There is another side to all this and that is that many of the major players are already significantly dependent on overseas suppliers, even for crucial services. For example both South Korea and Taiwan have a substantial nuclear power generation industry without any enrichment capability of their own. Again, the establishment of cooperative international waste facilities could be seen as an enormous boon for states having difficulty (for whatever reason) in finding suitable repository sites.

Special Uses

Any arrangement for multilateral control of enrichment technology will also have to take account of civilian but high enrichment uses. These include highly enriched fuels for research reactors and for marine propulsion systems. In both cases enrichments have historically been as high as 90% (i.e. they are weapons grade without further enhancement) and even where this is not so (nuclear submarines have more typically used fuels of 20-45% enrichment) a potential proliferator having access to such material is given a very substantial head-start in the production of weapons grade material. Already some effort is being made to convert research reactors that operate on highly enriched fuels to operate at lower enrichments. This needs to be accelerated. The case of nuclear submarine fuel is different. Here, higher enrichments are linked to crucial operating desiderata. There is also the military security aspect. It may be quite unrealistic to expect that a state would accept that fuel for its naval forces had to be sourced from an international provider. At the moment this is academic as far as nuclear proliferation is concerned since all present operators of nuclear submarines are also nuclear weapon states but this isn't necessarily a situation that can be assumed to continue. It is conceivable that a state might judge that the development of a nuclear submarine fleet was in its security interest and might then claim the right for a national enrichment capability to provide fuel for that fleet. There is another possibility: trends in the cost of oil may reverse the economic disadvantage that has inhibited the development of civilian nuclear propulsion. If this were to happen there would be a demand for

[19] These sentiments were expressed in the *Newsletter* of the Republic of Korea Technology Centre for Nuclear Control (May/June 2004, page 3).

[20] http://www.iaea.org/NewsCenter/News/2004/globalsecurity.html

special fuels and this would constitute a significant vulnerability if there were not a general acceptance that any such fuels would only be supplied by specialist facilities under international control.

The Impact of Technological Development

The argument to this point has concerned institutional control with regard to established technologies but there are other technologies (actual or conceivable) that could transform the proliferation vulnerability situation both positively and negatively. On the positive side there is some potential for reducing the possibilities for diversion by minimising, or eliminating altogether, the stage in conventional (PUREX) reprocessing, at which separated plutonium is accumulated. In France separated plutonium is produced in La Hague and then transported several hundred kilometres to Marcoule where it is incorporated into MOX fuel. All other things being equal, this is a more vulnerable situation than that which exists at the THORP plant in the United Kingdom, where the separated plutonium passes straight on through the wall to the MOX fabrication plant.

There is also the possibility of re-'contaminating' separated plutonium with some of the relatively short-lived isotopes removed earlier in the process, so as to make the material unsuitable for weapons production but still viable as reactor fuel. Of course, the cost here would be that you would have a material that was more dangerous (through its higher radioactivity) to the process workers who have to handle it (though no more dangerous than spent fuel, presumably). Also relevant here would be the fast reactor plus pyro-processing technology, developed by the Argonne National Laboratory, in which the spent fuel is never separated from the other transuranics and in which reprocessing is also done on site.

In relation to the sensitive process of uranium enrichment, there are both positive and negative possibilities. The present dominant enrichment methods are the older gaseous diffusion technique and the newer centrifugal system. Typically these entail large plants, which are big users of energy and, thus, are activities that it is not easy to conceal (this is particularly true of gaseous diffusion technology). This fact makes a monitoring and safeguards regime easier to operate, although it does not guard against breakout. As far as this possibility is concerned, it may be that investigations could be undertaken to devise a system of engineered barriers which would prevent covert modification (of the kind envisaged earlier) and make alteration of the plant extremely difficult and time-consuming, even in a breakout situation. The latter case would also provide a longer period during which negotiations could proceed to prevent the intended fissile material production from going ahead.

Another highly significant technology to consider is laser separation. In theory this could provide an alternative enrichment technique which is less energy intensive and which allows separation in a single pass, as opposed to the multiple passes involved in gaseous diffusion or centrifugal methods. Separation technologies based on laser activation may permit smaller scale operation and may be less energy intensive and thus easier to conceal. In these respects, laser technology may present a particular proliferation challenge, despite the fact that many of the major players (France, United States, Japan) appear to have abandoned development in this area on grounds of 'economic feasibility' (and, perhaps, also because of its proliferation implications?). On the other hand, Russia seems to have supplied AVLIS (Atomic Vapour Laser Isotope

Separation) technology to Iran (and, perhaps, to others). The fact that it is uneconomic is, of course, of no significance to a party determined on nuclear weapon production.[21] More speculatively, it may be that other laser separation techniques may be developed that might (say) enable the separation of plutonium isotopes, so that high burn-up fuels containing as little as 60% plutonium-239 may be converted into a more weapons-suitable material by enrichment[22] This sort of possibility would also have the potential to defeat some of the anti-proliferation suggestions discussed above (for example, recontamination).

Conclusion

There is a general conclusion to be drawn from all this: technological developments together with a determination to succeed on the part of a would-be proliferator will always have the potential to defeat the most careful of counter-proliferation measures. Holding the line here (preventing the acquisition of nuclear weapons by further states) will require a modicum of good faith as well as an elaborate system of safeguards and a determination by the international community to insist on the specific adherence by all parties to their commitments under the Nuclear Non-proliferation Treaty. Failing this, it is hard to see how unilateral action by parties that see themselves as particularly threatened, can be ruled out — and that is a most uncomfortable conclusion.

As far as restricting the sensitive technologies is concerned, it is interesting to note that the IAEA International Expert Group is effectively proposing a Grand Bargain under which Nuclear Weapon States and non-NPT states would agree to give up their rights to operate reprocessing and enrichment plants to produce nuclear explosive material and in return Non Nuclear Weapon States would agree to a limitation in their rights to have certain sensitive technologies under national control. Under this arrangement, multilateral facilities would be the norm.[23]

End-note on Iran's Nuclear Programme

The present situation of Iran illustrates a particularly difficult set of problems as far as non-proliferation is concerned. In the first place, it has to be recognised that, under international law, Iran has a perfect right to whatever 'peaceful' nuclear technology it believes it needs and that the international community has no right to attempt to prevent the development by Iraq of such technology. Apart from anything else, these 'rights' are specifically proclaimed in the NPT, to which Iran and almost all other countries in the world are parties. Provided that Iran binds itself to all the appropriate safeguards and fully cooperates with the associated monitoring and inspection programme there are, on the face of it, no grounds to deny any technology that Iran believes it needs.

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[21] DEBKAfile (28 August 2003) reports that AVLIS technology has been installed at Nantaz and, underground, at Moallen Kalayeh in the Albroz Mountains 40Km north of Tehran.

[22] It is understood that some nuclear weapon-design experts claim that even the isotopic mix resulting from high burn-up in the common style of light-water reactor can be used in a nuclear explosive device. In the view of this writer this claim is based on a number of very problematic assumptions. It is also noted that no would-be proliferator has thus far actually tried to go this way.

[23] 'Multilateral Approaches to the Nuclear Fuel Cycle, IAEA, February 2005, page 12 (paragraph 39)

On the other hand, there are substantial grounds for Iran to consider self-denial in the matter of the most sensitive technologies, at least for the time being.[24] Its neighbours and, indeed, the world community have good grounds for concern. At the present stage of its nuclear development, Iran does not *need* enrichment, fuel fabrication and reprocessing technologies. The government and official spokesman may insist that their intentions are entirely peaceful but there are other voices and other actions. Iran is devoting increasing amounts of money to its medium and long range missile programme and this programme makes most sense if the intended payloads are nuclear, rather than conventional. Also, Dr Hassan Abasi, theoretician of Revolutionary Guards Intelligence and adviser to Iranian Leader, Ali Khamenei has been quoted as saying:

> We have a strategy drawn up for the destruction of Anglo-Saxon civilisation and for the uprooting of the Americans and the English. Our missiles are now ready to strike … at their cities and their installations.[25]

In the light of this, it is understandable that neighbours (including Israel), as well as the wider western world, continue to be anxious. That anxiety could be much relieved by a policy of voluntary restraint on the part of Iran and such a policy would have little cost (apart from a perceived loss of face), given that Iran's nuclear programme is 'strictly and exclusively energy-oriented'[26]. It also might be that Iran could determine that the preservation of the NPT was in its interest.

Given Iran's clear and repeated repudiation of any nuclear weapon ambitions, the crucial question is: what would be the disadvantage to Iran of deciding not to go further with its present development of sensitive technology? As noted earlier in the general discussion, it could certainly point to uncertainties in fuel supplies and some vulnerability in the matter of cost. Again, as noted, there are ways of dealing with this that could offer security and cost advantage. This is where the focus of discussion between Iran and the international community ought to be.

The disadvantage that could not be offset would be the one that arose from Iran's incapacity to develop nuclear weapons (having relinquished the means), if it at some point in the future it chose to do so. In this way it would lose the potential deterrent effect of possessing such an arsenal. It is a moot question how much of a loss this would really be, in terms of the security of Iran. On the one hand, it might seem that an (even minimally) nuclear armed Iran would be invulnerable to the sort of regime change that has recently been imposed on Afghanistan and Iraq. On the other hand, a plausible deterrence posture would seem to require an indisputable capability to strike with unacceptable consequences at any party that struck it. This might apply generally to neighbouring states (except Israel) at an early stage but it would not apply to the United States for a very long time. In the interim, Iran might seem to have increased its vulnerability to pre-emptive strike. Having regard to the political/moral/tactical difficulties of such an undertaking, the likelihood of this is small but, perhaps, not negligibly so. From a security point of view, therefore, it represents a palpable disvalue.

If Iran did not agree to forgo these sensitive technologies and went ahead with enrichment and reprocessing, other questions would arise. Given that Iran could not be

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[24] There are precedents for this. The Republic of Korea does not have enrichment or reprocessing capability, notwithstanding a very substantial nuclear power industry with some 18 operating reactors.

[25] MEMRI *Inquiry and Analysis*, Number 181- Iran, page 3.

[26] Khoshroo, page 1 (see footnote 2)

persuaded, what would be the prospects of urging similar restraints on others, either in the context of a general plan for cooperative but restrictive development of such technologies, or as another one-off? 'Small', one would have thought[27].

What would be the plan in the case of Iran or any other nuclear aspirant state in the event that full safeguards were not agreed, or full access was not maintained, or that illegal activities were detected? How likely is an agreement on referral to the Security Council and the adoption of sanctions, and how likely is it that such sanctions as were adopted would be effective? If the answer to these latter questions is, 'not very', we have a problem.

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[27] This, of course, is not academic. At present Egypt, Indonesia, Turkey and Vietnam are proposing to build nuclear power reactors. Given that, why should they not insist on their 'right' to develop the associated, sensitive technologies?