Proceedings of
MIT's Workshop on Multinational Enrichment Facilities

Monday, October 20, 2008

James Goodby and Geoffrey Forden

Contents

Introduction

The prospect of a “renaissance” in nuclear energy coupled with the spread of dual-use technologies, has increased interest in finding new ways to promote nuclear energy while maintaining strong barriers to proliferation. Many feel that some form of multinational arrangement should be the way forward. In fact, as Tariq Rauf and Zoryana Vovchok pointed out in the March 2008 issue of the IAEA Bulletin, there are at least twelve such proposals coming from a wide spectrum of countries and organizations.

This workshop is intended to explore some of these ideas as well as look at existing models of international nuclear collaboration. As can be seen, the application of these models in various regions of the world was considered as well as economic, monitoring and verification, and broader disarmament aspects. We believe that this workshop comes at an auspicious time: we are in the run up to a very important NPT review conference in 2010 as well as critical meetings of the Nuclear Suppliers Group that the new administration will have to address very soon after taking office.

MIT Workshop on Internationalizing Uranium Enrichment Facilities

Dates: October 20-21, 2008

Monday, October 20, 2008

8:15 – 8:45 AM	Breakfast
8:45 – 9:00 AM	Opening remarks with Goodby and Forden
9:00 – 10:20 AM	Session One: What problems does internationalizing the fuel cycle address? **Discussion Leader: Tariq Rauf** 1. Matt Bunn 2. Laura Holgate 3. Larry Scheinman Discussion: 20 minutes
10:20 – 10:30 AM	Coffee Break
10:30 – 11:45 AM	Session Two; Economic Analysis: economies of scale **Discussion Leader: Charles Forsberg** 1. Geoffrey Rothwell 2. Steve Goldberg 3. Thomas Wood Discussion: 20 minutes
11:45 – 1:05 PM	Session Three (part 1): Models of Multinational Enrichment Facilities: Existing Industrial Models **Discussion Leader: Myron Kratzer** 1. Alan Hanson- AREVA 2. Mark Marano- GE-Hitachi 3. James Timbie—USEC Discussion: 20 minutes
1:05 – 2:00 PM	Lunch
2:00 – 3:45 PM	Session Three (part 2): Models of Multinational Enrichment Facilities: New Concepts **Discussion Leader: Pierre Goldschmidt** 1. Diakov/Podvig—Russia's plans for Angarsk

2. Carol Kessler—International Fuel Services Center
3. John Thomson—Iran as a Pioneer Case for Multilateral Enrichment Centers
4. Chaim Braun—Fuel assurances for Iran

Discussion: 30 minutes

3:45 – 4:00 PM Coffee Break

4:00 – 5:30 PM Session Four:
Discussion Leader: Marvin Miller
1. Houston Wood
2. Brian Boyer
3. Geoffrey Forden

Discussion: 30 minutes

6:30 – 8:30 PM Reception & dinner at the Marriott Hotel

8:30 PM END OF DAY ONE

Tuesday, October 21, 2008

8:30 – 9:00 AM Breakfast

9:00 – 10:45 AM Session Five: International Frameworks—Legal Structures, NSG, etc.
Discussion Leader: Thomson
1. Fred McGoldrick
2. Daryl Kimball
3. Yuri Yudin
4. Jeffrey Bedell

Discussion: 30 minutes

10:45 – 11:00 AM Coffee Break

11:00 – 1:00 PM Session Six: Responding to needs in: Asia/Pacific, Middle East, Africa, South America, North America?
Discussion Leader: Mark Hibbs
1. Chaim Braun—India/Pakistan
2. Carlos Feu Alvim—South America
3. Larry Scheinman—Japan
4. Fiona Simpson—Middle East

	Discussion: 30 minutes
1:00 – 2:00 PM	Lunch
2:00 – 3:15 PM	Session Seven: Relationship to nuclear disarmament and a diplomatic solution to accomplish multinationalization of fuel cycle **Discussion Leader: Steve Fetter** 1. John Steinbruner 2. Paul Meyer Discussion: 30 minutes
3:15 – 3:30 PM	Coffee Break
3:30 – 4:30 PM	Session Eight: Wrap up and conclusions **Discussion Leader: James Goodby**
4:30 PM	END OF WORKSHOP

Summary of Talks

Summary
MIT's Workshop on Multinational Enrichment Facilities

Monday, October 20, 2008

Session One: What problems does internationalizing the fuel cycle address?

Tariq Rauf told us that the many IAEA Member States, particularly those from the NOM/G-77, are suspicious of being deprived of their "inalienable right" to develop nuclear energy for peaceful purposes as enshrined in Article IV of the NPT. He traced this reaction in part to President Bush's speech at NDU in February 2004 that proposed limiting enrichment and reprocessing to those States that already have these technologies at a mature level. He added that many IAEA Member States are opposed to creating a new discrimination within the NPT -- that of technology-holders and technology-recipients -- in the context of nuclear fuel cycle options, and that such States strongly support a non-discriminatory and equitable approach.

Matt Bunn said that while the commercial market is doing well at providing reliable supplies of nuclear fuel, countries refuse to give away rights they consider they have to develop their own fuel cycle services. He suggested that offering some help on the back end of the fuel cycle had great potential and that a lease-take back system had the makings of an attractive incentive to relieve any desires for indigenous fuel cycle services.

Laura Holgate described five reasons underlying national decisions to acquire domestic enrichment facilities: security of fuel supply, commercial interests in selling enriched uranium, technical prestige (or "nuclear nationalism"), a desire to develop nuclear weapons, or to create a weapons "hedge" or "virtual" program. She saw the problem as how to meet the first three while exposing the last two. She thought it was not obvious that an international structure is inherently superior to other means, although three or four countries running a plant might be less inclined to pick fights with suppliers or consumers. She urged attention to specific circumstances under which benefits could occur.

Larry Scheinman, speaking through Marvin Miller, emphasized that advocacy and promotion of multilateral facilities needs to be considered in a broader context than just how to manage the fuel cycle, in particular the nature and extent of progress being made (or not) on nuclear disarmament to which many in the non-aligned are particularly attentive and maintain expectations of forward movement especially as they see the NPT as a bargain involving give and take on all sides. This relates as well to Article IV of the NPT that speaks of the "inalienable right to develop research, production and use of nuclear energy for peaceful purposes without discrimination and in conformity with articles I and II of this Treaty." Efforts to interpret this provision as excluding sensitive nuclear technologies and of limiting the right to pursue them to a small number of countries is widely, and in some cases, vigorously disputed. The option of limiting

enrichment needs to be addressed in terms of opportunity and advantage, not in terms of denial – hence the relevance of exploring the possibility of partnering in multinational enterprises with a technology holder in which investing partners share in decision making and profits and have priority access to product but agree not to "compete with themselves" by developing competitive national capabilities. The alternative of a two-tiered world based on denial and discrimination is not viable in the longer run.

Session Two: Economic Analysis of Multinational Enrichment Centers.

Charles Forsberg presented an analysis showing that the capital costs of reactors were by far the biggest expense in civil nuclear power programs and the largest component in the cost of electricity from nuclear power plants. The cost of enrichment services and spent fuel disposal is a small fraction of the cost of electricity. However, the capital costs of enrichment facilities and spent fuel repositories are high. There are very large economics of scale for enrichment facilities and spent fuel repositories and large incentives for these types of facilities to service large numbers of reactors. Large nuclear programs tended to favor owning fuel cycle facilities. Major uranium suppliers have an advantage in determining the rules and may have strong incentives to build enrichment plants to maximize the revenue and jobs. Finally, he pointed out how inefficient uranium enrichment is. Because uranium enrichment processes are inefficient, there are strong financial incentives to develop new enrichment processes and the potential for break-throughs that might radically alter the characteristics of uranium enrichment.

Geoffrey Rothwell also discussed economies of scale, mentioning that in the case of MOX fabrication there were increasing returns on scale. Smaller facilities were way up in the cost curve. He mentioned that although USEC was heavily subsidized, it might fail. Speaking of incentives to refrain from building fuel cycle faculties, he mentioned lower prices for nuclear fuel.

Thomas Wood drew attention to the pubic good of nonproliferation versus the private good of technology supply. He mentioned the costs of concealment of nuclear activities. The lack of a carbon footprint also was a public good and this was a separate issue from economics of scale. He also stressed the value of dealing with the back end of the fuel cycle.

Steve Goldberg discussed a three topics: (1) an enhanced leasing arrangement, multilateral in nature, whose acronym is TRUST, that would support new nuclear consumer countries being supplied economically competitive nuclear fuel and disposition services; (2) large financial transactions that would both support a multinational enrichment capability and would be essentially "off-budget" transactions from the Federal budget perspective; and (3) in-fashion deals for financing new nuclear projects that are trending toward public-private partnerships. Based on his experience in privatizing USEC, he suggested that the assets that were the basis for brokering the HEU agreement could be utilized in facilitating the establishment of a multinational enrichment facility. Regarding the last point, more research is needed on the ownership and contractual framework underpinning USEC, keeping in mind the foreign ownership

constraints imposed by Section 193(f) of the USEC Privatization Act.

Session Three (part 1): Models of Multinational Enrichment Facilities: Existing Industrial Models

Myron Kratzer said that supply concerns had not existed in his experience. Long-term contracts have worked quite well. He then described the organization and functioning of URENCO.

Alan Hanson agreed with the other speakers that the backend of the fuel cycle could be attractive if the practicalities could be worked out. The enrichment part might be too small of a sector to be interesting. He agreed that the bottom-up approach was the right way to proceed. He thought that AREVA would be open to multinational ownership of facilities because, among other things, this would provide access to capital.

Sam Shakir discussed black box protection of technology, pointing out that the AREVA model works for some countries but not for others. He said that the Georges Besse facility in France was moving to multinational ownership. He thought the same model might be followed at AREVA's Eagle Rock facility in the United States.

Jim Timbie described USEC's evolution from a government enterprise to a private company. USEC produces 5.5-6 million SWU annually at its 50-year-old Paducah gaseous diffusion plant and imports 5.5 million SWU from Russia under the HEU Agreement. USEC sells 10-12 million SWU per year, about equal to total U.S. demand, but sells most of the Paducah production to Asia, so nearly all of the enrichment actually used by U.S. utilities is supplied by Russia and Europe. This distortion of the market is a price we pay for the nonproliferation benefits of the HEU Agreement. Approval by the USG of loan guarantees to USEC would be essential for that company to complete development and deployment of advanced centrifuge technology. (A brief discussion ensued on criteria for blackbox practices.)

Session Three (part 2): Models of Multinational Enrichment Facilities: New Concepts

Peter Goldschmidt favored long-term generic export licenses in a common fuel procurement agency for small utilities. He explained why he did not see multinational enrichment facilities as responding to current needs.

Pavel Podvig described arrangements at Angarsk international nuclear fuel center. He thought it could be a good testing ground for safeguards in such facilities.

Carol Kessler described the IAEA's possible roles in the assured nuclear fuel supply proposals presented to the IAEA Special Session on this in September 2006. The IAEA

roles range from applying safeguards to owning the low enriched uranium in a reserve and managing its allocation. The roles are all authorized in the IAEA statute with the exception of predicting the successful operation of the international fuel market. The IAEA will increase customer assurance in the reliability of supply the more it is engaged. But the IAEA does not seem well-suited to own or operate a facility. The IAEA's role should be balanced with the nonproliferation benefits gained, as it remains important to conserve IAEA resources for those activities with greatest nonproliferation benefit.

John Thomson stressed the difficulties facing the nonproliferation regime. Security of supply was not the most important factor. An increasing number of countries take a very different view of the whole enterprise than we in the room do. He then described the Forden-Thomson generalized multilateral idea. He rejected the notion that this would help countries develop indigenous nuclear weapons capabilities. Citing the Iran case, he thought we were well past the time when we could continue profitably on the present course.

Chaim Braun described his proposed modification of the Forden-Thomson model that would build on current Iranian centrifuge technology at the early phases of engagement with Iran, before importation of advanced western centrifuges could, or should, be considered. He stressed the need to maintain low enriched Uranium in Iran only in the form of fabricated fuel assemblies for Bushehr and follow on Iranian reactors. To that purpose he suggested internationalizing the conversion/fabrication complex in Esfahan, along similar lines to the multi-lateral management of the Iranian enrichment plant in Natanz. He thought, as one option, that AREVA or URENCO could manage the enrichment facility while the Russians could manage fuel conversion and fabrication. Chaim suggested that the Forden-Thomson model could be implemented as follow-on program, once successful internationalization of the Iranian fuel cycle industry was demonstrated based on his early engagement model.

Jim Timbie explained why the US administration had favored modest steps to provide assurance of reliable supply that would improve the current situation rather than the more ambitious multilateral enrichment facilities that were the subject of the workshop. He thought the existing commercial market meets the demand quite well and underscored the enormous expense of building facilities that would compete with established large companies with advanced proprietary technology developed over decades. He also pointed out that regardless of ownership structure, multilateral facilities would face the same legal and regulatory constraints on exports of nuclear materials imposed by governments where they are located, and therefore would not be in a position to make unqualified commitments to supply enriched uranium under all circumstances.

Session Four: Improving Proliferation Barriers for Multinational Enrichment Centers

Regarding safeguards, **Marvin Miller** discussed laser enrichment technologies and its proliferation potential.

Houston Wood pointed to the small number of enrichment cascades required to build bombs as opposed to the large number it takes to supply reactors with fuel. He emphasized the need for people on the ground to find clandestine facilities.

Bryan Boyer described the basis for IAEA safeguards at gas centrifuge enrichment plants. He stated the goals of IAEA safeguards at these facilities and the challenges of safeguarding such bulk material handling facilities. He noted that it is very difficult for the IAEA to detect undeclared feed and undeclared products under the safeguards regime formulated by the Hexapartite Safeguards Project during the 1980's. He then discussed how IAEA safeguards are done at the URENCO facilities and briefly described improvements in the safeguards approach and technology to handle better verifying undeclared feed and undeclared products .

Geoff Forden concluded the day with a discussion of safeguards in the Forden-Thomson plan. He stressed that AQ Khan was the symptom, not the cause of the current problem. The supply-side approach no longer worked. We are in a new technological environment where precision engineering is widespread. We need to get the developed and developing countries working together.

Tuesday, October 21

Session Five: International Frameworks—Legal Structures, NSG, etc.

John Thomson said that the US has now changed its laws to accommodate the US-India deal, which will have some ill effects. The agreement shows what happens when nonproliferation is not given first priority. Indian foreign policy cannot be bought: it will be exactly what it would have been without the deal. As to giving up rights to the fuel cycle, developing countries will not give up rights at least legally. The P5 will have to be more adroit to get even a "maybe" from developing countries to forego the nuclear fuel cycle. Problems of the NSG include the fact that it does not include countries like Singapore, Malaysia, and Iran, countries that manufacture relevant equipment. Such countries might well refuse an invitation to join. They represent the dominance of the big powers and prefer to retain freedom of action. The crucial point is that multilateralism is one way to get wider acceptance of nonproliferation. The US will have to embark on ratification of the CTBT and the FM CT will have to be pursued seriously, in order to have a successful 2010 Review Conference.

Fred McGoldrick said that existing NSG guidelines call for restraint in the transfer of enrichment technology and encourage supplier involvement or multinational participation as an alternative to national plants. The language of denial and renunciation contained in the Bush 2004 nonproliferation proposal on fuel assurance was damaging and motivated countries to assert their rights to enrichment technology. The <?xml:namespace prefix = st1 ns = "urn:schemas-microsoft-com:office:smarttags" />U.S. proposals to change the NSG guidelines have not been accepted and the NSG is now engaged in a debate on the merits of requiring black-boxing of enrichment transfers. The US could help promote

norm of multinational enrichment by proposing the NSG adopt a statement of principles on security of supply and an offer to multi-lateralize US enrichment facilities. These efforts could be advanced in the run-up to the NPT review conference.

Daryl Kimball said that lessons from the NSG decision of September 6 on India will undermine the NSG and the nonproliferation system as a whole. He then discussed the circumstances surrounding that event. He urged that the United States and other nuclear suppliers adopt more stringent guidelines on the transfer of enrichment and reprocessing technology along the lines of the "criteria-based" proposal that was discussed at the NSG's May 2008 meeting.

Jeffrey Bedell associated himself with McGoldrick's views regarding the NSG, and stated that the NSG is not treaty based and is an informal arrangement and therefore may not be the best forum to mandate enrichment plant MNAs as a new norm. He noted the NSG is not supposed to promote or inhibit legitimate commercial trade, but rather is primarily an export control group for proliferation controls. In this context enrichment plant MNAs could be useful, but should preferably serve to minimize technology transfer. He then reviewed the MNA and blackbox options discussed in the first days session. He thought the Angarsk system might be the best, since this model seemed to afford the best technology protection. As regards the Forden-Thomson and Braun plans for Iran, he expressed concern that this would enable Iran to build replicate facilities. He saw a technology transfer issue here. "Black boxes" are not a perfect solution everywhere, and also may be less applicable for other enrichment processes. In the ensuing discussion McGoldrick said that he thought the problem was not urgent but that careful thought and consultation should be useful for a new normative framework for the fuel cycle. The United States would have to accept the same norms it was asking other countries to accept. Thomson advised that we should try not to be too stuck on the ideal solution but try to get the concept into people's heads.

Session Six: Responding to needs in: Asia/Pacific, Middle East, Africa, South America, North America.

Mark Hibbs said that we may be reaching a consensus that multilateralism will not take place overnight. As regards Canada and Australia, uranium enrichment as well as the back end of the fuel cycle would be an interesting possibility for cooperation. There are, however, obstacles in both countries. Neither country is likely to accept spent fuel. As regards China, this is a real possibility for operation. It might be willing to take on a role in low enrichment uranium fuel provision. The Asian region could support a regional uranium facility, involving the ROK, but supplying Europe might be more likely. Japan is not a candidate for multilateral facilities. Tokyo was looking for US leadership. The participation by the US would be necessary because of security concerns. All the smaller countries of Asia are looking at nuclear power. Vendors will probably come in to sell fuel cycle services.

Chaim Braun spoke about India and Pakistan, first describing the Indian plan for major nuclear power build-up. He characterized the Indian plan for installing forty ALWRs by

2020 as "irrational exuberance." He thought that smaller capacity would ultimately become operational by that time. India has a small centrifuge program for Naval and research reactors. Pakistan's power program is much smaller. Currently, reactor and fuel cycle plans are driven to some extent by military requirements. Pakistan is working toward separation to two nuclear programs, one civilian, and one military, similar to the Indian plan. It would not justify a large international enrichment plant based on need, for several decades. It would make sense eventually for India to build an enrichment facility for itself given its nuclear build-up plans. Ten to twenty GW of operating ALWRs would justify an enrichment facility, in the 2020-2030 time frame or later. Imported enrichment technology on black-box model could be obtained from Rosatom, Areva, or Urenco. Low enriched Uranium would be provided under IAEA safeguards to similarly safeguarded ALWRS. The Indian enrichment plant could be constructed to partially serve the requirements of an 'extended' region including South Asia and beyond.

Carlos Feu Alvim described the Economic and Energy Organization. If the motivation for building a fuel cycle is nuclear proliferation, it can be solved in a regional framework. Thus Argentina-Brazil cooperation was created. The Carter restrictions convinced Brazil that it must rely on its own nuclear fuel capacity. Venezuela and Chile can be considered for the future. However, technology would not be shared. The host country would be the country that has the technology. After all, the Brazilian Navy doesn't even want to share technology with the Brazilian civilian nuclear industry. No sense of urgency is felt and will not be unless there are restrictions on fuel supply. Regional or bilateral mechanisms can be more secure than larger groupings. But the Additional Protocol reduces the role of regions and is not felt to be helpful in the region.

Fiona Simpson described the current nuclear status of several Middle Eastern countries. Demand for energy is growing, leading to ambitious goals for nuclear power. In the short-term, it may be more practical to locate an enrichment facility outside the region. Leasing and take-back are attractive and should be given greater consideration as both a non-proliferation measure and as a benefit for states with new and revived nuclear programs, such as are envisioned in the Middle East. No state in the region, however, has publicly expressed interest in obtaining a complete domestic fuel cycle, except Iran, although many states remain concerned in principle regarding the possible erosion of their rights under the NPT. Recent suggestions regarding joint activities on other parts of the fuel cycle, or creating a joint company for the purchase of fuel, would be interesting in the Middle East.

Ambassador Gumbi shared South Africa's preliminary views regarding internationalizing the nuclear fuel cycle. As much as this is work in progress he stated that disparity between states that have nuclear technology and those that do not should be eliminated. The world must avoid creating new cartels. There should be no presumption that new technologies are safer in the hands of some countries but not in others. The IAEA should be involved in all such endeavors.

Session Seven: Relationship between multinationalization of the fuel cycle and nuclear disarmament.

Steve Fetter observed that we need to keep the problem in a broader framework, arguing that nuclear disarmament would encourage multilateral arrangements for enrichment.

John Steinbruner described the background to the current discussion. For many countries the unique military capabilities possessed by the United States are both the principal source of threat and the only source of reliable protection. The US must convey global reassurances if it is to legitimize its military advantage. It is a better strategy for those countries threatened by the US to get security assurances rather than nuclear weapons. The six party agreement with North Korea is a good model for Iran, but would probably require some provision allowing Iran to continue limited enrichment activities under robust IAEA scrutiny with international control of the product. Alternatively, participation in a state-of-the-art enrichment plant with international management might be an attractive option. In general, internationalizing the nuclear fuel cycle has a better chance of working in a broader program of security accommodations.

Session Eight: Wrap up and conclusions

Ambassador James Goodby saw a splitting of the audience into two groups. For those who saw the nonproliferation crisis as fairly limited in scope, fuel supplies assurances rather than multinationalizing facilities, would be the main tool to deal with concerns about equity. Others felt that the only way to prevent proliferation and further strengthen the NPT were for developed countries to get more involved in the nuclear programs of developing countries. Several methods were presented and discussed. Some participants were dubious about the security of multilateral enrichment facilities and whether interest among consumer nations really existed.

On the economic side, there was agreement that economies of scale are clearly present as regards enrichment and spent fuel reprocessing. Cost and pricing policies also could be used to provide incentives for nations to forego enrichment facilities. The problem is to allocate costs of enrichment to assure efficiencies, equity, and nonproliferation.

Cost considerations argued in favor of leasing arrangements instead of sales, several argued. In this connection, it was generally agreed that the backend of the fuel cycle would offer considerable incentives for nations to accept lease-take back arrangements instead of buying fuel. Some questioned whether the "nuclear renaissance" would take off on the scale once envisioned, given the financial complications present today.

As regards further steps in the NSG, there was general agreement that criteria should continue to be pursued to clarify export procedures in the aftermath of the US-India deal. The "black box" idea should be further discussed. However it was recognized that the NSG had a limited mandate and the pursuit of broader goals, such as promotion of multilateral enrichment facilities, should be carried on elsewhere, probably in the context of the preparation for the NPT Review Conference.

The possibility of regional approaches was discussed from the point of view of their own special advantages, in contrast to the methods of global organizations. Since proliferation problems often arise in a regional context, perhaps regional solution should be given more emphasis. Prohibitions of nuclear weapons should require controls over enrichment and reprocessing. Internationalizing of uranium enrichment facilities should be the *quid pro quo*.

As to multilateral uranium enrichment facilities, the participants in the conference from AREVA and GE Hitachi expressed the opinion that the companies would welcome additional shareholders from the international community. This model was not seen as a true multilateral facility, however, although it does convey advantages to the ownership. Some participants expressed the opinion that USEC might be ready for foreign participation and ownership, recognizing that this would require consultation with the U.S. Congress.

As regards new models for cooperation in this area, the Iranian case was the most thoroughly discussed. Two different versions were presented and defended. Critics doubt that Iran could be expected to act in good faith even if it accepted the idea. Angarsk, on the other hand, was seen as an interesting model, possibly one that could be emulated elsewhere. China might be interested in becoming a supplier of LEU along Angarsk line, but possibly not on a regional basis. Some view this as a promising option. Japan was perceived as unlikely to be interested in multilateral approaches.

Jim Timbie suggested that, as an alternative to the development of assurance mechanisms acceptable to the NAM and the G77 and approved by the IAEA Board of Governors, a conceptually different approach would be to proceed one-by-one. For any country that desires assurance of reliable fuel supply, the USG is prepared to negotiate a bilateral 123 agreement for cooperation or a trilateral project and supply agreement with that country and the IAEA. With that legal basis in place, if a supply disruption should occur, we could move quickly to supply enriched uranium. The USG is moving this direction, with 123 agreements already in place or under negotiation with a number of countries considering nuclear energy, and we encourage other suppliers to do the same. This approach avoids questions about rights and provides assurances to those that want them.

Presentations

Uranium Enrichment: Its Place In the Nuclear Fuel Cycle

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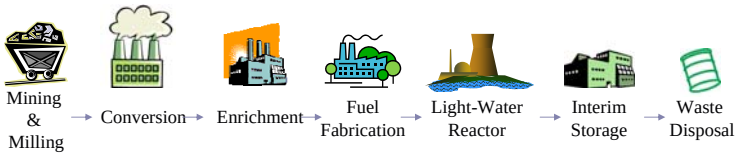
October 20-21, 2008

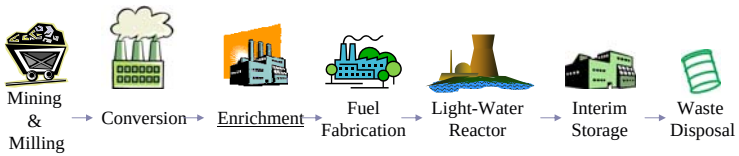
MIT Center for Advanced Nuclear Energy Systems

Traditional Once-Through Fuel Cycle



Enrichment: Natural Uranium (0.7% ^{235}U) →
Enriched Uranium (3-5% ^{235}U for Power Reactors)
+ Depleted Uranium (typically ~0.3% ^{235}U)

Nuclear Electricity Cost Components By Fuel Cycle Step [mills/kw(e)]



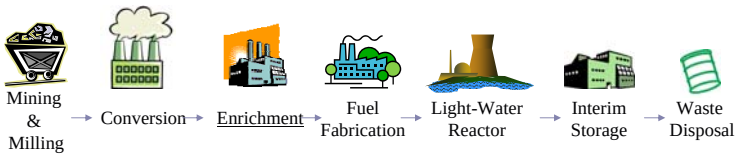
1.3	0.2	1.9*	0.6	35.8**	0.3	1.0

The Capital Costs of the Reactor Drive Nuclear Electricity Costs

Representative costs subject to multiple assumptions--from literature. *Includes 0.2 mills/kw(e) for depleted uranium management. **Includes 9.9 mills for plant operations.

Three Fuel-Cycle Steps Have Capital-Intensive Facilities

Large Economics-of-Scale with Incentives for Large Facilities to Produce Fuel For Multiple Reactors



$	$	$$$	$	$$$	$	$$$

Relative Single-Facility Capital Costs—Different Fuel Cycle Facilities Have Different Throughputs

Strong Economic Incentives for Large Enrichment and Repository Facilities to Minimize Fuel Cycle Costs

Caveats and Notes

- Not all reactors require enrichment for long-term operations
  - Candu Reactors (today)
  - Advanced concepts such as once-through breeder reactors (future)
- Some countries have major incentives to develop enrichment technologies
  - Large nuclear programs with any doubts about suppliers
  - Major uranium suppliers (Canada, Australia, etc.) to enhance value of natural resources
- Enrichment is a very inefficient process—potential for major breakthroughs
  - Centrifuge uses 5% electricity of gaseous diffusion
  - Centrifuge efficiency near 10^{-4} (very low)

Conclusions

- Economics can support or hurt nonproliferation strategies
- Two fuel cycle operations have large economics of scale where there are significant incentives for large facilities that meet the needs of many nuclear reactors
  - Uranium enrichment
  - Repositories
- Economics is a strong driver of utility and national behavior

Biography

Dr. Charles Forsberg is the Executive Director of the Massachusetts Institute of Technology Nuclear Fuel Cycle Study. Before joining MIT, he was a Corporate Fellow at Oak Ridge National Laboratory. He is a Fellow of the American Nuclear Society, and recipient of the 2005 Robert E. Wilson Award from the American Institute of Chemical Engineers for outstanding chemical engineering contributions to nuclear energy, including his work in hydrogen production, nuclear-renewable energy futures, and various fuel cycles. He received the American Nuclear Society special award for innovative nuclear reactor design. Dr. Forsberg earned his bachelor's degree in chemical engineering from the University of Minnesota and his doctorate in Nuclear Engineering from MIT. His doctorate work was on uranium enrichment and he has worked on both gaseous diffusion and gas centrifuge enrichment projects. He has been awarded 10 patents and has published over 200 papers.

Scale Economies in the International Uranium Enrichment Industry

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20 October 2008
"Workshop on Internationalizing Uranium Enrichment Facilities"
Massachusetts Institute of Technology

Economies of Scale: Defining Increasing, Constant, and Decreasing Returns to Scale

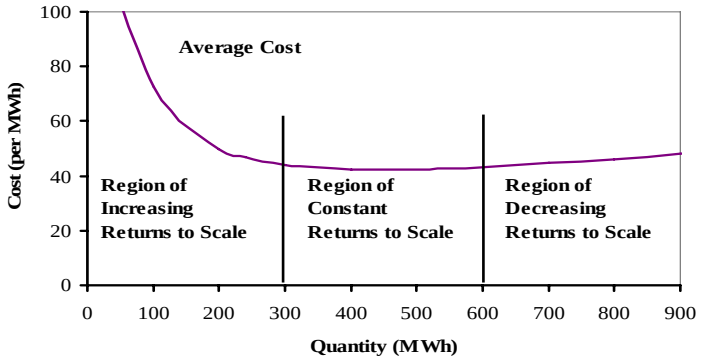
(1) **Increasing Returns to Scale** imply that an increase in size increases cost less than proportionally, e.g., a 10% increase in size yields less than a 10% increase in cost

(2) **Constant Returns to Scale** imply that an increase in size increases cost proportionally, e.g., a 10% increase in size yields the same proportional increase in cost

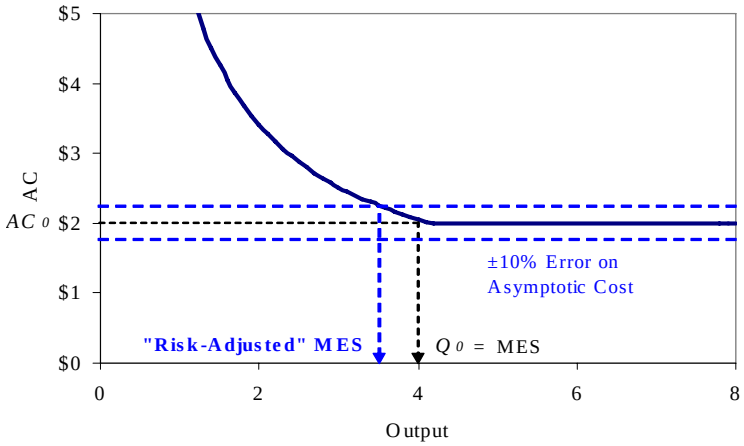
(3) **Decreasing Returns to Scale** imply that an increase in size increases cost more than proportionally, e.g., a 10% increase in size yields more than a 10% increase in cost

Defining Economies of Scale: Generic Example
Average Cost = ($5,000 / Q) + $20 + ($0.25 · Q)

from Rothwell and Gomez, ***Electricity Economics,*** 2003



Determining the Minimum Efficient Scale ("Risk-Adjusted" MES)



Why do Economies of Scale matter?

In industries with increasing returns to scale, larger firms can increase output, thus decrease cost, and undercut the price charged by smaller firms, forcing them out of the industry

The larger firms can exercise market power to set price. Generally, in these industries either

(1) an oligopoly of the remaining firms exercise some power to increase their profits (e.g., OPEC), or

(2) near monopoly develops where the dominate firm sets the market price to maximize its profits.

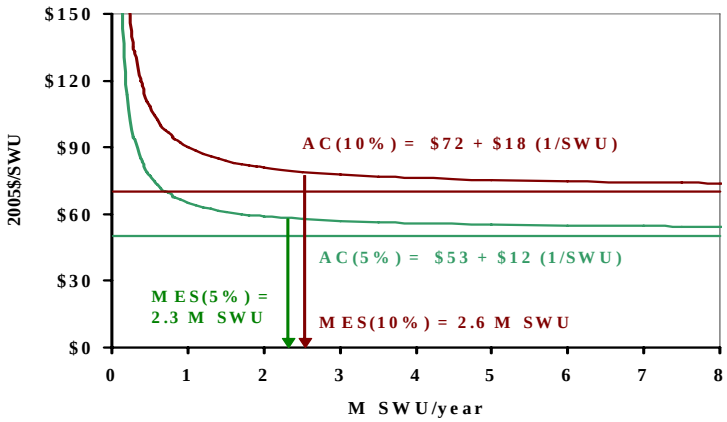
Economies of Scale in the Front-End of the LWR Nuclear Fuel Cycle?

(1) In uranium mining and milling, assume the price of uranium is approximately equal to the long-run cost of production (consistent with a competitive market)

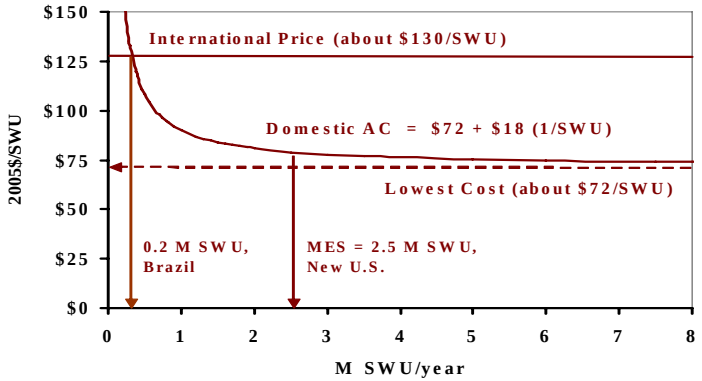
(2) In uranium enrichment, Rothwell and Braun (2008) show there are increasing returns to scale: how does this influence economies of scale in the front end of the light water reactor fuel cycle?

(3) In fuel fabrication, assume constant returns to scale in low-enriched uranium and increasing returns to scale in MOX fabrication; see Rothwell (2008)

Proposed Cost Structure of Centrifuge Enrichment: see Rothwell and Braun, "The Cost Structure of International Uranium Enrichment Service Supply" (2008).

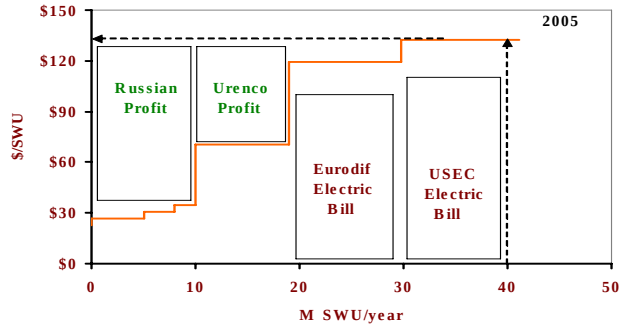


As the price of enrichment rises, smaller plants become economic: Brazil's at 200,000 SWU/yr



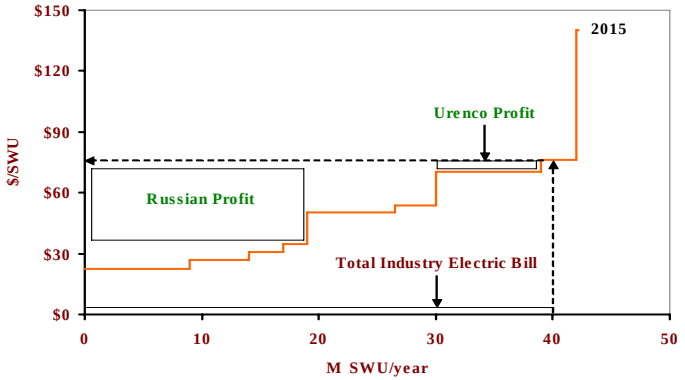
SWU Prices in 2005:

Prices were high, and profits were being made by centrifuge enrichers! Price set by the marginal producers at about $135



SWU Prices in 2015:

In a competitive market, the market price would cover the highest cost ("marginal") centrifuge producer, e.g., at less than $100/SWU (in 2005$)

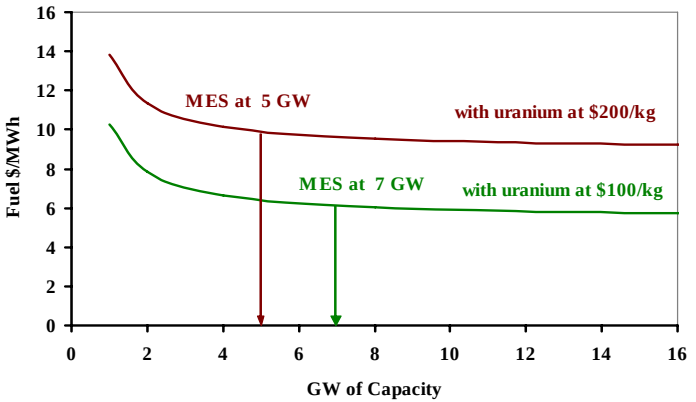


Further, with high uranium prices, the price of enrichment is only 1/4th of the total cost of fuel

Cost ($M/year)	Uranium plus Conversion		Enrichment		Fuel Fab		Total ($M)	Average Fuel Cost
	$40.21	+	$14.30	+	$6.07	=	$60.58	$7.67 /MWh
% of Total	66%		24%		10%		100%	
Prices	$206 /kg		$130 /SWU		$250 /kg			
Quantities	195,196 kg		110,000 SWU		24,265 kg			7,900 GWh
Quantities	724 kg		408 SWU		90 kg			
	FEED 0.71% feed assay	→	**ENRICHMENT** 0.3% tails assay	→	**PRODUCT** 4% product assay	→	**ELECTRICTY** 1,000 MW 90% Capacity Factor	
			TAILS					

http://www.wise-uranium.org/nfcue.html

What is the cost structure of total fuel costs?



Which States have fuel cycle facilities?

	Enrichment + Fuel Fab		LEU Fuel Fab Only		Neither	
	USA	Germany	Korea	Spain	Ukraine	
>5	France	China	Canada	Belgium	Taiwan	
GW	Japan	UK	Sweden			
	Russia	India				
	Brazil				Armenia	Mexico
<5	Pakistan		Argentina		Bulgaria	Romania
GW	Iran	(No Fab)			Czech	Slovakia
	Netherlands	(No Fab)			Finland	Slovenia
	S. Africa	(by 2017)			Hungary	Suisse
					Lithuania	

Which States have Uranium Reserves?

	Percent of the Top 10's Uranium Reserves	GW of Nuclear	Enrichment
Australia	24%	0	NO
Canada	22%	12.6	NO
Kazakhstan	13%	0	NO
South Africa	10%	1.8	NO
Namibia	6%	0	NO
Niger	6%	0	NO
Uzbekistan	6%	0	NO
USA	5%	99.3	YES
Brazil	5%	1.9	YES
Russia	4%	21.7	YES

Primary Contradiction: Enrichers can leverage Political Barriers to Entry into Market Power in the Enrichment Market

(1) There are international political barriers to entry into enrichment services, e.g., through NPT enforcement

(2) Enrichment services have been privatized in most of the nuclear weapons states: France, Russia, UK, and US

(3) Private enrichers can leverage political barriers of entry into market power over price, leading to inefficiency in the enrichment market and encouraging new entry

Can We have Private Enrichment and Non Proliferation?

(1) Political barriers to entry protect private enrichers from competition leading to inefficiency and prices greater than production cost

(2) Current policy does not address the enrichment market pricing problem: high SWU price encourages new entry!

(3) Further, as uranium prices increase, enrichment becomes a smaller percentage of the total cost, and more countries (particularly, those with large uranium resources) have an incentive to develop enrichment facilities to make their own fuel

Possible Market Failure in International Enrichment Services

Some market intervention might be necessary to assure
(1) a near competitive price, discouraging entry, and
(2) sufficient capacity in nuclear weapons states to meet all future international enrichment demand

Possible Solutions:

(1) international rate-of-return regulation?

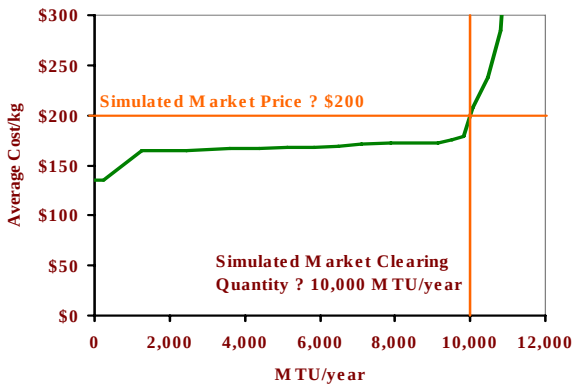
(2) cooperatively owned enrichment centers?

(3) weapons states subsidization of enrichment capital costs so that the SWU price would be equal to variable (marginal) cost of production?

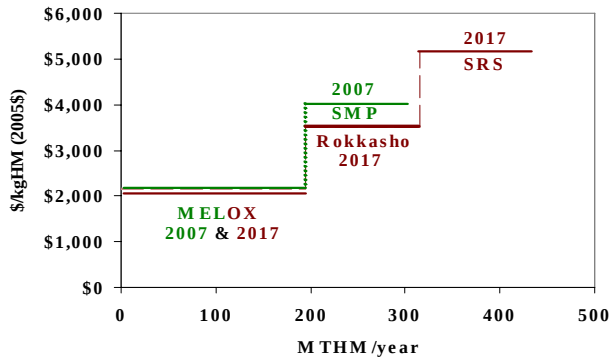
More Slides on Cost Structures and Markets

from Rothwell, "Economics of Scale and Barriers to Entry in the International Light Water Reactor Fuel Fabrication Industry," submitted to *Energy Economics* (June 2008).

Low Enriched Uranium: International Supply (not including hardware costs)



Mixed Uranium and Plutonium Oxide: International Supply, 2007 and 2017



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Office of Science
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Financial/Budgetary Components

presented at
Economic Analysis: Economies of Scale

MIT Workshop on Internationalizing Uranium Enrichment Facilities

by:

Stephen M. Goldberg
Special Assistant to the Director
Argonne National Laboratory

October 20, 2008

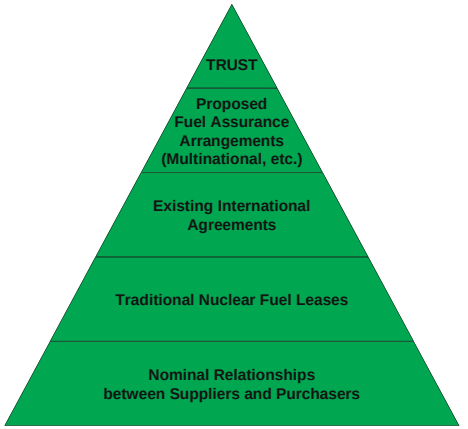
Topics

- Terms for Reliable Uranium Services Transactions through Leasing
- Budgetary Treatment of Enrichment Deals
- In-Fashion Deals
- Overall Response: Create a Self-sustaining and Efficient Enterprise

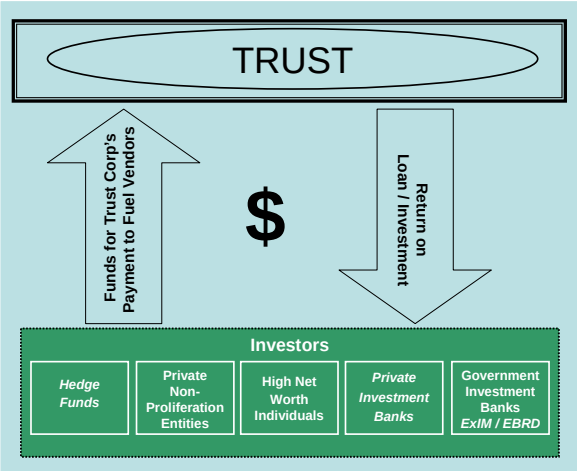
Current Issues Facing Utilities in Emerging Nuclear Energy Countries

- Without sophisticated risk management tools, these utilities would be sensitive to price spikes and/or market imbalances
- Managing market risks has historically been accomplished by inventory – expensive for these utilities to dedicate capital to maintain inventory
- Loan rate for uranium has risen significantly – close to the peak of 1974
- Cost of borrowing for such utilities in the developing world is significant – could be as high as 17 percent

Bridge to Multinational Arrangements

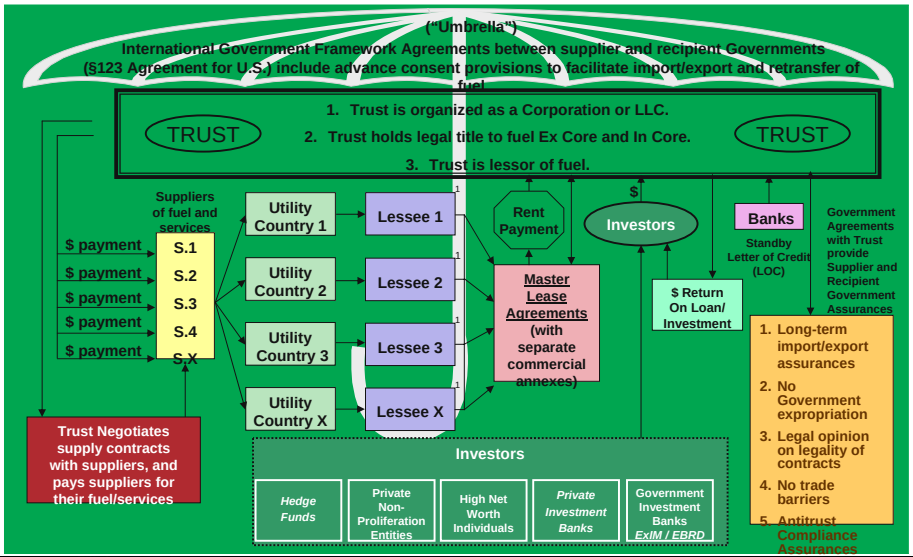


Terms for Reliable Uranium Service Transactions ("TRUST")
TRUST for Emerging Nuclear Power Programs Business Case



- TRUST's cost of capital is significantly lower than the cost for utilities in emerging nuclear energy countries; also risk management strategies, such as multinational guarantees, are essential to reduce the cost of financing.

Terms for Reliable Uranium Service Transactions ("TRUST")
TRUST for Emerging Nuclear Power Programs



Budgetary Benefits

- Establishment of TRUST would not be subject to "availability of funds clause"
- Excellent model – the 1993 HEU agreement between the USG and the Russian Federation – accomplished in a budget neutral fashion

Financial/Budget Deals

- G-G HEU deal – backed by supply contracts – off-budget – 20 years and stable (multinational as well) – 0.5 -0.75B/Yr
- U.S. HEU stockpile deals – less than 0.1 B
  - Barter deals
  - RFP deals
  - All on budget
- Deals of the future – essential ingredients

The *Let Us Beat Swords into Plowshares* statue at United Nations Headquarters, New York.

In Fashion Deals

- Emerging demand market – significant and partnering – by 2030, projected to be 20-30% of the SWU market
- Emerging markets – BOO or BOT deals
- Large vendors such as AREVA – lock-up of full-service and use indigenous resources as assets – e.g., monetize uranium deposits
- International development banks
  - Must be partners to any BOO/BOT deals
  - Would be encouraged by a robust nonproliferation regime, that includes multinational enrichment support

Overall Response: Create a Self-sustaining and Efficient Enterprise

- How are multinational enrichment centers affected by economies of scale?
  - Economies of scale are critical.
- What are the costs of entry into the enrichment market?
  - Key driver is a credible fuel leasing arrangement and appropriate financing.
- How would new suppliers affect the current market?
  - New market
- What are the economic motivations for creating new multinational enrichment centers?
  - Pure financial play with no hit to the Federal Budget
  - Guarantee of long-term leases
- What are the pros and cons of investment in new enrichment facilities vs. other methods of assuring reliable supply?
  - Key driver: secondary uranium market; G-G agreement
- How would lease arrangements work? (How should the capital requirement be translated into leasing rates?)
  - L-T agreements
- What are the important non-economic factors in weighing a decision to create new multinational enrichment centers?

Enrichment Economics
in the context of assured fuel initiatives

20 October 2007
"Workshop on Internationalizing Uranium Enrichment Facilities"
Massachusetts Institute of Technology

Tom Wood
Pacific Northwest National Laboratory
Thomas.wood@pnl.gov 509-531-8355

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Outline

- Starting point - technology, cost curves, and market organization – a normative summary
- Factors typically *not accounted for* in cost curves
- "Publicness" of fuel cycle products
- Reactor owner's perspective - enrichment and *fuel* assurance
- Summary of recent GNEP RNFS working group survey

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What we want from the fuel services sector

- Low costs for enrichment and fuel
  - *Implies sufficient incentive to insure investment in efficient plants or – government subsidy/intervention in building new plants*
- Functional markets for fuel and fuel services
- "Assured" (reliable) supply of fuel to responsible reactor owners
- "proliferation resistance" – i.e.
  - "Market discipline" - to refuse fuel to irresponsible reactor owners
  - Fewer rather than more enrichment plants
    - *Implies high costs for prospective owners/operators of small plants*
  - Fewer rather than more countries in which plants are located
  - Compliance with safeguards, export controls, etc.

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Some cost factors typically *unaccounted* for

- Costs of concealment for indigenous programs
  - Physical concealment of facilities
  - Cost of "cover" activities
- Increased uncertainty of supply due to technical risk
  - Decades of development and trial operations required for operational enrichment plants slows down the nuclear program and reduces its economic viability
- Opportunity costs of scarce capital
  - Other critical energy sectors may be starved for financial and human capital – market prices can understate this cost
- Costs of advanced safeguards
  - (TBD but probably also subject to scale economies)

Some of these costs apply only to covert programs – but all are imposed on prospective builders of small (<MES) plants by the non-proliferation regime

While these factors are hard to estimate, the case of Iran suggests that real costs could easily be several times costs estimated from "economy of scale" curves for small plants

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Natanz Gas Centrifuge Uranium Enrichment Complex

Photos from LANL

- Dummy structures to prevent detection and identification
- Concealed underground, hardened, well defended

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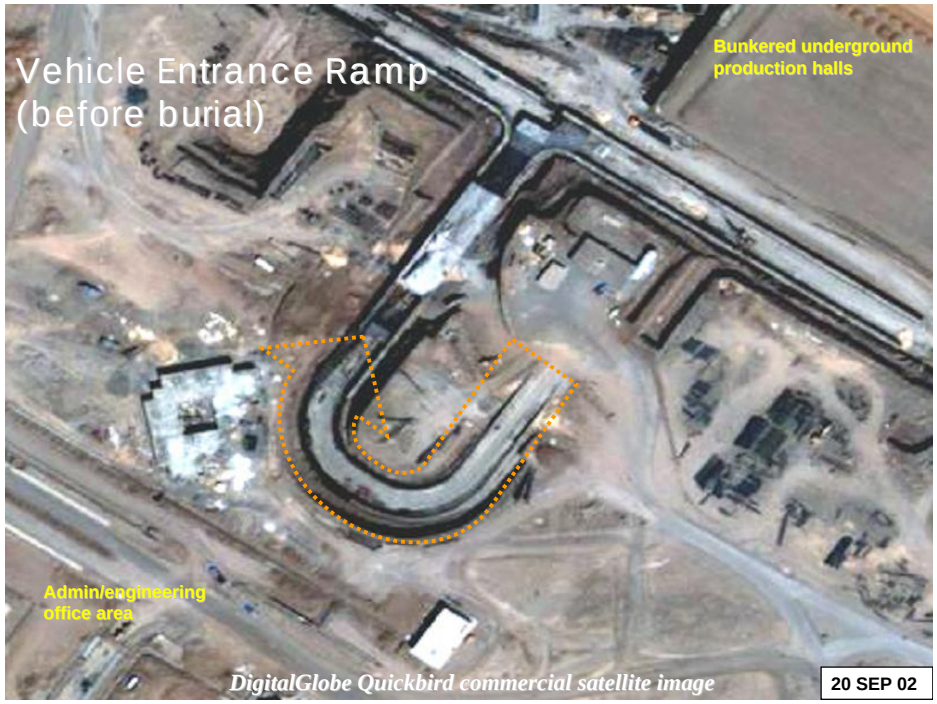

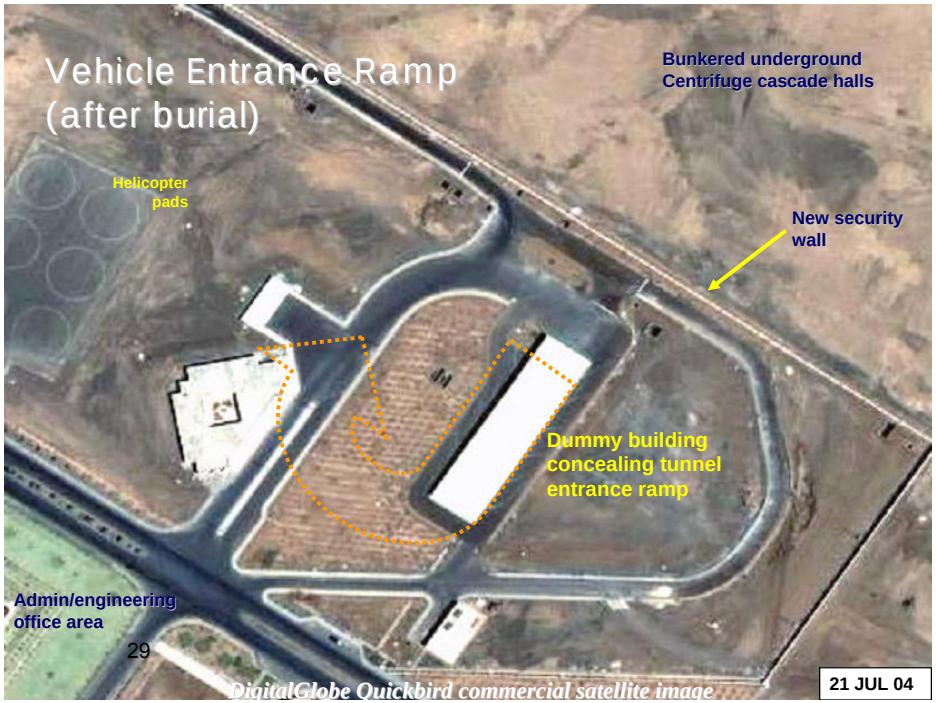

"Publicness" of fuel cycle products

- Public goods (bads) often under (over) produced under laisser-faire market organization
- Climate change benefits of nuclear power are public goods
- Proliferation risks associated with new nuclear facilities are public bads

Under (over) investment in nuclear power can be addressed by:

[1] internalizing externalities via such mechanisms as carbon taxes
[2] direct government intervention to increase production of key products and services

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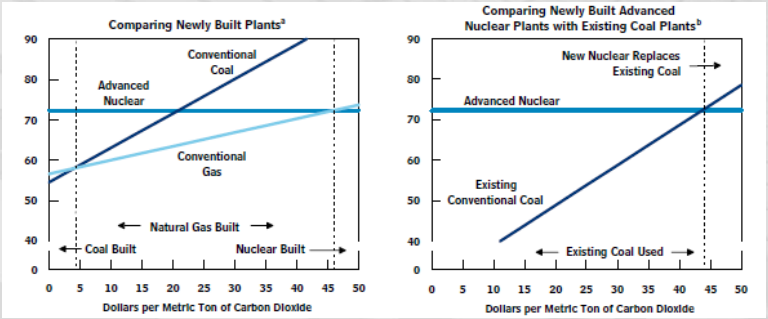
Sensitivity of electricity costs to carbon price

Source – CBO 2008



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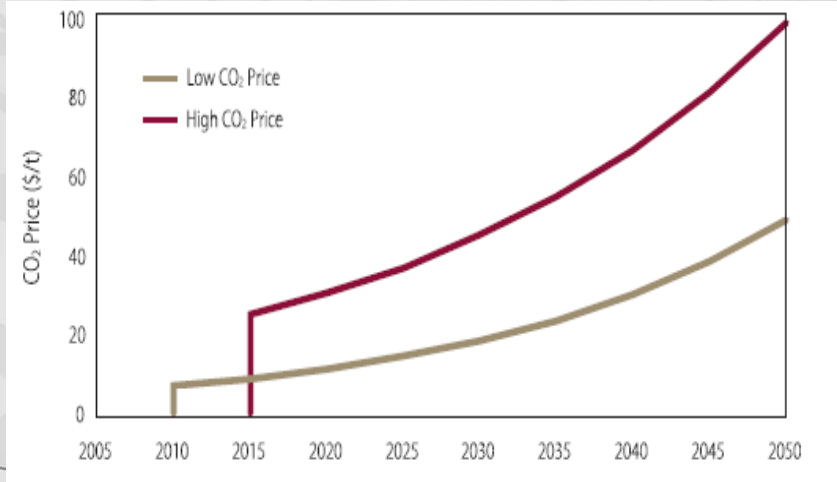
Envelope for CO_2 Prices

Source - MIT 2005



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Public good "content" of enrichment

- A single 3M SWU/year plant supplies roughly 20 GWe (LWR)
- Assume 90% capacity factor – gives 157680 GWH/yr
- Assume coal power displaced – gives 1.51 E8 MT CO_2 per year avoided emissions
- At $40 per MT, "carbon emission avoidance" benefit is $6 billion/year
  - Compare to
    - Market value of SWU produced at $100/SWU - $300 million/year
    - Interim storage cost of fuel at $10/kg per year - $7 million/year
    - Disposal cost of fuel at 2 mills per KWH - $315 million per year

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Reactor Operator's Perspective

- What matters are the cost and quality of fuel and the certainty with which it is supplied *(indifferent between high cost small enrichment plants and efficient large plants generating economic rent for their owners)*
- Commodity nature of SWU and LEU facilitate competition relative to the fuel fabrication sector
- Specialized fuel designs (dependent on proprietary technology) have significant productivity benefits
- Significant exposure to economic loss from fuel supply failures
  - Delayed delivery
  - Technical failures

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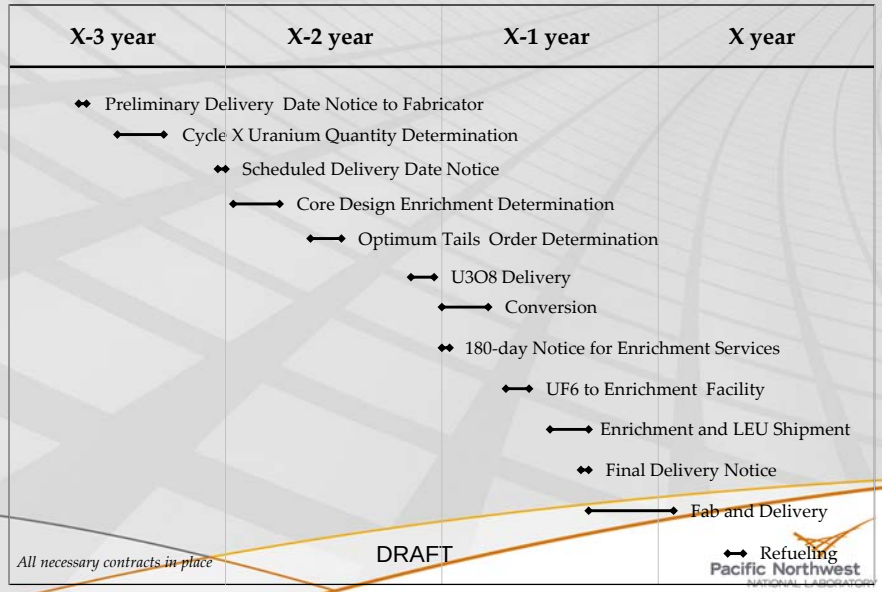
Typical Nuclear Fuel Manufacture Timeline



All necessary contracts in place

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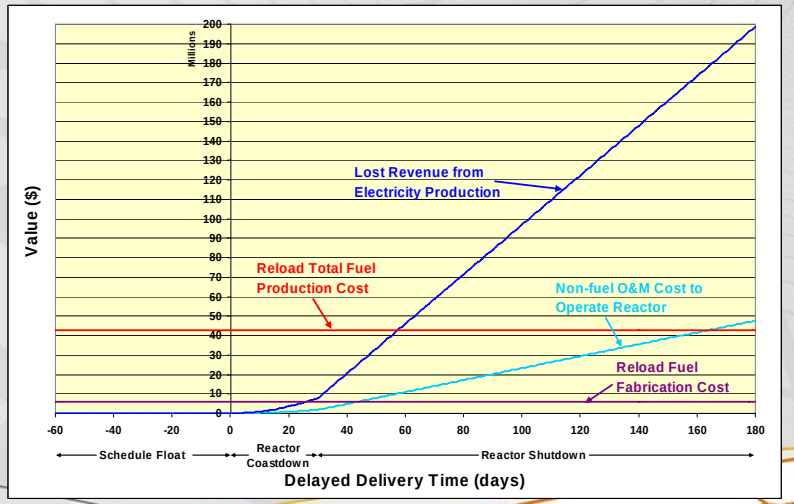
Cost of Fuel Delivery Delay (LWR)



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The back end is important

- Mixed market/government paradigm
  - Private goods
  - National public goods
  - Global public goods
- Spans fuel transition from asset to liability (?)
- Without resolution, hinders nuclear renaissance
- The default option (indefinite at-reactor storage) poses problems
  - Risk tolerance beyond operating reactor life?
  - Constrained availability of reprocessing feedstock
  - Proliferation risk from simple reprocessing technologies

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GNEP RNFS WG Survey Objectives

Understand each State's legal, regulatory, and policy framework concerning Reliable Nuclear Fuel Services

Identify common positions and areas of disagreement to focus discussion

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Summary of Response Status

Received responses from 11 states:

- Australia
- Bulgaria
- France
- Japan
- Poland
- Romania
- Russia
- Slovenia
- South Korea
- United Kingdom
- United States

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RESPONSES –

What does RNFS mean to you?

- Primacy and importance of market mechanisms
- Definition includes fuel supply and spent-fuel take-back
- Two states mention quality requirements for supply on an appropriate timescale and at *competitive prices*
- *Only US and one other country mentioned any motivation for RNFS in non-proliferation policy – others saw it as an economic issue.*
- One state has plans to close its cycle through other countries reprocessing programs; supports fuel leasing and wants to bean active player
- Implicit agreement but limited mention of need for specific government intervention and measures (e.g., fuel bank)

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Summary – GNEP Survey

Good agreement that the market is functioning well to provide generally reliable nuclear fuel services. Less agreement on those cases in which the market may need to be supplemented or reinforced.

- Almost all countries responding see this issue strictly in terms of economics - supply chain reliability for their reactors, or access to markets for their fuel service products, rather than as an instrument of non-proliferation policy.
- Most focused more on the front-end than back-end in their definitions.

Differing views on major challenges being faced

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International Uranium Enrichment Center

Anatoli Diakov
Center for Arms Control Studies
Moscow Institute of Physics and Technology

Initiative by the President of the Russian Federation St.Petersburg, EurAsEC Summit, 25 January 2006

The President of the Russian Federation Vladimir Putin proposed the creation a network of international centers providing nuclear fuel cycle cervices

«A prototype of a global infrastructure is required, that would enable us to ensure equal access to atomic energy to all the interested parties. I would like to stress, that the requirements of the nuclear non-proliferation regime should be fully met. A network of international centers providing nuclear fuel cycle services, including uranium enrichment, placed under the IAEA control and ensuring non-discriminatory access, should be the key element of such an infrastructure.»

Initiative by the President of the Russian Federation

Objectives of the initiative :

- **Increasing the role of nuclear energy in ensuring global energy security**
- **Developing global nuclear energy infrastructure via establishing a network of international nuclear fuel cycle centers**
- **Providing non-discriminatory and guaranteed access to products and services of nuclear fuel cycle to the States developing nuclear power**
- **Strengthening the non-proliferation regime**

Basic principles of the IUEC

- **Non-discriminatory (equal) membership terms for all interested States.**
- **Guaranteed access of the IUEC member States to enriched uranium product and/or SWU.**
- **The IUEC works based on the principles of market economy.**
- **Transparency of the IUEC activities is ensured through the application of the IAEA safeguards to the Center's nuclear material.**

Basic principles of the IUEC (cont-ed)

- **Access of foreign members to the Russian uranium enrichment technology is prohibited.**
- **The IUEC is established step by step, as the number of members increases.**
- **Authorized companies of new member countries are joining JSC IUEC on the basis of separate intergovernmental agreements (Notes) between RF and country.**

JSC IUEC is open for participation by all NPT member states which meet nuclear non-proliferation requirements and share the objectives the Center is intended to achieve

The Basic Principles of the Intergovernmental Agreement

- **Main objectives and terms for JSC IUEC activities;**
- **Executive government bodies and authorized companies;**
- **Form of incorporation and location of JSC IUEC;**
- **Basic requirements to member countries, whose companies would like to become JSC IUEC shareholders (full compliance with the NPT obligations);**
- **Prohibition against foreign shareholders' accessing Russian uranium enrichment technology;**
- **Application of the IAEA safeguards to JSC IUEC nuclear materials.**

Establishment of the IUEC

ROSATOM announces at the 50-th session of the IAEA General Conference the establishment of IUEC on the premises of Angarsk Electrolysis Chemical Complex (AECC).

September 2006

The Republic of Kazakhstan decides to join the Russian Initiative to Establish the IUEC.

October 2006

The Russian Federation sends a Verbal Note to the IAEA to include the AECC into the list of Russian facilities, that could be placed under the IAEA Safeguards.

January 2007

Intergovernmental Agreement between the Russian Federation and the Republic of Kazakhstan establishing the JSC IUEC is signed.

August 3, 2007

JSC IUEC is registered as a legal entity.

September 5, 2007

Establishment of the IUEC (cont-ed)

The Government of the Russian Federation decides to include the JSC IUEC in the list of Russian facilities, that could be placed under the IAEA Safeguards *in the framework of the Safeguards Agreement between the Russian Federation and the IAEA - INFCIRC/327.*

November 27, 2007

The Government of the Republic of Armenia decides that JSC Armenian NPP joins JSC IUEC. ***November 29, 2007***

The Republic of Armenia joins JSC IUEC through exchange of Notes.

February 2008

Potential Participants of the IUEC: Ukraine, Bulgaria, Belgium

Why Angarsk Electrolysis Chemical Complex (AECC)

- **The relative simplicity of placement under the IAEA safeguard**
- **The presence of the conversion plant**
- **The absence of centrifuge design and production facilities**
- **Availability of underloaded enrichment capacities as well as an infrastructure for further development:**

  Current capacity : – 2,8 Mln SWU/year

  Planned capacity: year 2013 – 5,2 Mln SWU/year

  year 2015 – 9.2 Mln SWU/year

The principles of the JSC IUEC operation

- **The carent share distribution in the registered capital of IUEC is :**
  - **JSC TENEX - 80%**
  - **JSC NAC Kazatomprom - 10%**
  - **(JSC Armenian NPP - Medzamor - 10%)**
- **Redistribution of shares in the JSC IUEC registered capital in the case of joining new members by reducing JSC TENEX share as follows:**
  - **JSC TENEX - 51%**
  - **JSC "NAC Kazatomprom" - 10%**
  - **New member countries - 39%**
- **Distribution of profits is proportional to share.**
- **JSC IUEC concludes contracts with Federal State Unitary Enterprise AECC for EUP/SWU.**

IAEA's Role in Proposed Assured Nuclear Fuel Supply Arrangements

Carol Kessler
Pacific Northwest Center for Global Security
October 20, 2008
MIT Workshop on Internationalizing Uranium Enrichment Facilities

IAEA Role

- Study evaluated 8 of 13 proposals presented to IAEA
- Range of IAEA roles from owning and/or managing nuclear material or nuclear facilities to broker for arrangements between suppliers and customers
- Statute allows all these roles for IAEA, but do they make sense for IAEA and its overall mission and credibility?
- What are budget implications for IAEA and where would funds come from? Do budget outlays and consequent reduction in other activities balance nonproliferation benefits gained from reliable fuel supply (RFS)?

Potential IAEA Roles

Simplest and Most Direct Roles for IAEA

- Safeguard material in question.
- Establish nonproliferation criteria for releasing material from fuel reserve or bank with BOG approval
- Certify consumer full compliance with nonproliferation obligations
- Virtual reserves of LEU or uranium - establish arrangements with suppliers for release of material upon IAEA request

More Difficult Role

- IAEA owns material - establish agreement with host state concerning respective responsibilities on: physical protection, safety and liability, and export; apply safeguards to IAEA-owned material

Models for Assured Nuclear Fuel Supply Arrangements

- I: Commercial suppliers back-up: customers depend on international fuel market as first source of supply; IAEA decides if eligible for emergency fuel supply from supplier based on nonproliferation criteria
- II: LEU reserve: IAEA owned or not; IAEA determines release of material to customer based on nonproliferation criteria
- III: Multilateral investment facility: partners are assured nuclear fuel supply
- IV: Full multilateralization of fuel cycle activities- all supply multilateral

Possible Model I - World Nuclear Association

- Three tiered system: 1) International market, 2) Emergency or backup collective guarantee of supply by enrichers in equal shares, 3) reserve of material derived from former weapons HEU would be better for market, reserve subject to IAEA control.
- IAEA role: 1) Enter agreement with suppliers for emergency supply in tier 2; 2) Determine if customer eligible for emergency supply; 3) Apply safeguards; 4) Determine customer eligibility for third tier supply using criteria on nonproliferation; no IAEA ownership of HEU, but under its control; 5) Use IAEA Statute provision to request release of material from nuclear weapons state reserve
- Issues: Does IAEA or Board of Governors (BOG) decide on nonproliferation criteria and standards to meet criteria? Can suppliers add requirements such as consent rights if supply under Tier 2 or 3? If IAEA "controls" material in Tier 2 or 3, can it require supply when supplier state does not agree customer is eligible?

Model 1: Six Supplier Proposal

- France, Germany, Netherlands, Russian Federation, United Kingdom, United States
- Six enrichers back each other up if customer is eligible on nonproliferation grounds
- Customer must meet conditions for supply: 1) Comprehensive Safeguards Agreement (INFCIRC153) and Additional Protocol in force; 2) no exceptional safeguards implementation issues with IAEA; 3) adheres to accepted international safety standards; 4) adheres to the Convention on Physical Protection of Nuclear Material and Nuclear Facilities; 5) uses international market to obtain fuel supplies; and 6) commits to forgo sensitive fuel cycle facilities.
- Issues: Can IAEA decide that consumer has met eligibility criteria?

Model I: Standby Arrangement System for AFS (Six Suppliers +)

- Japanese proposal to "prevent nuclear fuel market failure"
- Expands assurance to cover all front end fuel cycle facilities: uranium mining and milling, storage, conversion, enrichment and fuel fabrication
- Member States notify IAEA annually of capacity in five front end nuclear fuel cycle facilities according to three levels of readiness to supply: 1) possesses commercial capability, but not yet exporting; 2) export on commercial basis and willing to cooperate on emergency supply, and 3) maintains reserves for export on short notice.
- IAEA role: conclude bilateral standby arrangements with States, administer database, collect information annually from suppliers, keep track of potential demand from consumers including projections of future needs, monitor situation in international uranium market, and prepare annual report on adequacy of fuel supply market based on data.
- IAEA would not possess or store any nuclear materials.

Standby Arrangements (cont)

- Issues: Will private sector fuel cycle facilities provide requested information to IAEA?
- Is some of data requested commercially sensitive?
- Can or should IAEA have capability to analyze data and judge adequacy of international nuclear fuel market?
- Or should it buy services of some entity and charge Member states for services?

Model I: UK Enrichment Bonds

- Voluntary scheme; Bond involves agreement among group of supplier states, customer and IAEA; supplier government(s) guarantee, subject to international law and nonproliferation commitments as assessed by IAEA, national enrichers supply eligible customers.
- Bonds address national export approval issue. Idea is supplier state guarantees export approval to increase customer's confidence in reliable and timely supply, i.e., "prior consent for export" assurances, conditions for export.
- May require Congressional or parliamentary approval
- IAEA role: determine if customer meets bonded supply requirements; facilitates supply as third party in agreements on supply; apply safeguards
- Issues: Will supplier countries offer prior export consent? How do private industry suppliers work under arrangement? Can IAEA determine eligibility to satisfaction of supplier state? Need BOG involvement as in previous arrangements?

Model I: Extraterritorial Enrichment Facility

- Construct and operate one or more multilateral commercial enrichment plants on **extraterritorial land**; location in stable country; host country cedes administrative and sovereign rights over land
- Facility state of art; owned and managed on commercial basis; no technology transfer to partners
- Delivery of supplies on commercial basis, but facility operates at less than full capacity to put aside product or alter flow of orders to meet IAEA requests for eligible customers
- Supply of materials subject to "flag rights" and treated as such by IAEA
- IAEA role: determine who meets eligibility criteria; sole control over access to material; regulates facility instead of State; applies safeguards
- Eligibility criteria developed by IAEA and approved by BOG to help Agency enforce supply.

Extraterritorial Enrichment Facility

- Issues: Will operator accept full liability for plant or will require liability protection from multilateral contributors?
- If accident with transboundary consequences, what is host country's liability?
- Would private companies accept economic risk associated with unpredictable assured supply requests and invest in building and operating such plant?
- Will governments be only investors because can balance nonproliferation benefits with potential reduced profits?
- Will private company engage if given some additional incentives? What?
- Can IAEA "regulate" facility?

Possible Model II - Nuclear Threat Initiative LEU Reserve

- LEU stockpile - improve reliability of assured nuclear fuel supply; provides "reliable access to a nuclear fuel reserve "under impartial IAEA control"
- LEU stockpile "owned and managed by IAEA" and made "available as last resort" for nations with "no indigenous enrichment facilities" and "in full compliance with nonproliferation obligations."
- Reserve should not affect international fuel market
- Storage and transfer of nuclear material new role for Agency despite being foreseen in Statute
- Agreement needed among suppliers, customers and IAEA to set prices, pay Agency costs, assure customers of receipt when eligible, among other issues.
- IAEA suggests $150 million for LEU = one reactor core is minimum size for reserve

NTI LEU Reserve (cont)

- Issues: Does IAEA own and manage facility even though no experience? Or only own LEU and host country manages facility? Could host accept receipt of reserve material and account for to IAEA?
- How export controls applied to LEU as moves from supplier to fuel reserve? and from reserve to fuel fabrication facility, and then to customer?
- Is LEU facility subject to laws and regulations of host state?
- IAEA owns material so need to apply safeguards? Allowed for in IAEA Statute, but perceived conflict of interest? or concern IAEA cut costs and skip safeguards on facility.

Possible Model III - Angarsk International Uranium Enrichment Center

- LEU and enrichment services to contributors subject to government-to-government founding agreement.
- Two types of contributors – those who provide uranium and those who contribute funds to get enrichment services.
- All have government-to-government agreement with Russia.
- Russia considering set aside of 1-2 reactor loads of LEU for broader assurance of supply
- Angarsk under Russian laws and regulations; enrichment technology not shared.
- Russia may offer facility for safeguards under voluntary offer
- Russia stated "regulatory basis will be developed in the sphere of export control such that the shipment of material out of the country at the request of the Agency is guaranteed."

Angarsk (cont)

- Members of Angarsk "chiefly from States not developing uranium enrichment capabilities on their territory" according to Russian announcement
- Angarsk operates under joint advisory committee; IAEA expected as member.
- IAEA role advisory in IUEC operations; safeguard facility (or LEU?) if selected; identify eligible customers for reserve; Terms of "eligibility" for LEU approved by BOG.
- Issues: How will the Advisory Committee work? What IAEA provide advice on? What will safeguards apply to? Will Russia create LEU store for broader assured supply purposes?

Possible Model IV - Austrian Multilateralization of Nuclear Fuel Cycle

- Two-track mechanism. First, optimize international transparency beyond IAEA safeguards; states declare all nuclear facilities, plans for development, all nuclear material activities and transactions to IAEA.
- Second, place all nuclear fuel transactions under auspices of international "nuclear fuel bank" so states that need access to sensitive nuclear technologies have it through multinational process.
- IAEA role: to elaborate mechanism
- Issues: assumes level of confidence among States in information supply and cooperation currently not achievable.

Table 1. Issues on IAEA's Role in Assured Nuclear Fuel Supply Arrangements

Proposal/ Issue	IAEA Liability	BOG Role	IAEA Budget implica-tions	IAEA owns mat	Safe-guards	Strengthens NP Regime	Strengthens IAEA
WNA	no	yes	yes	no	yes	yes	yes
Six Suppliers	no	yes	small	no	yes	yes	yes
Standby	yes*	yes	significant	no	yes	yes	Not clear
NTI	yes	yes	yes	yes	yes	yes	yes
Angarsk	no	yes	yes	no	yes?	yes	no
Extraterri-torial	no	yes	yes	no	yes	yes	Not clear
Enrichment Bonds	no	not clear	yes	no	yes	yes	yes
Multilat Info Sharing	yes	yes	large	maybe	yes	yes	yes

*** IAEA will have liability for its judgment on fuel market viability**

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Conclusions

- IAEA has authority in Statute to do what requested
- Need BOG to agree on exactly what constitutes "nonproliferation obligations", compliance and to approve compliance measures if want IAEA eligibility conclusions supported
- Ownership of nuclear material new for IAEA, but taking title to material not undue burden on Agency and may increase confidence in AFS
- Nonetheless, Agency's safeguarding own material is sensitive
- IAEA is ill-suited to build and/or manage LEU reserve or providing assessment of international fuel market for Member states.
- Budget implications for IAEA need to be balanced with nonproliferation benefit, e.g., not clear with Japanese and Austrian proposals that balance is favorable for IAEA

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Fuel Assurances for Iran

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Presentation at the MIT Workshop on

Internationalizing Uranium Enrichment

Cambridge, MA
October 20-21, 2008

Principles of Future Proposals re. Iranian Uranium Enrichment

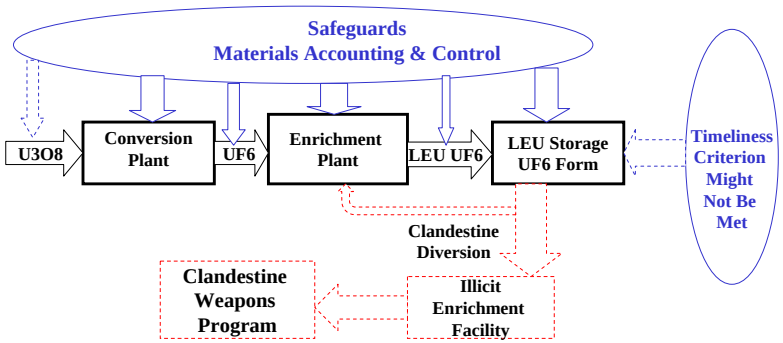
- **Future proposals related to resolution of Iranian enrichment conflict should be embedded in more general negotiations of outstanding security & economic cooperation between Iran & Western countries**
- **Enrichment resolution could be labeled 'Nuclear Third Way' in line with Iranian thinking**
- **Enrichment conflict resolution should stress:**
  - **Recognition of current Iranian progress in enrichment. Some enrichment activity in Iran seems unavoidable**
  - **Internationalizing Iranian enrichment activities to improve transparency**
  - **Capping Iranian centrifuges technology development**
  - **Future low enriched Uranium (LEU) stockpiling in Iran only in form of fabricated fuel assemblies (for specific NPPs)**

Materials Accounting, Timeliness Criterion Applied to Centrifuges Enrichment Plants

- **UF6 input, output, materials accounting flows to & from conversion plant & enrichment plant now used to determine that no UF6 has been diverted for illicit re-enrichment purpose**
- **Given centrifuges separation characteristics, IAEA timeliness criterion, LEU in UF6 form can be clandestinely fed again into enrichment cascade or into separate illicit cascade, enriched to HEU level, before IAEA notice, even with smart tags on UF6 containers. Such operation certainly possible in case of open breakout from NPT regime**
- **In order to improve likelihood of timely detection it might be preferable to keep LEU output from enrichment plant not in UF6 form but convert it to UO2 form, or preferably to fabricated fuel assemblies form**
- **Easier to account for smaller number of fabricated assemblies**

Safeguarding LEU from Diversion to Clandestine Enrichment

- **Safeguarding Against Clandestine Diversion**



Commercial Constraints on International Enrichment Technology Offer to Iran

- **Importation of external centrifuges technology to Iran requires payment for centrifuges, enrichment plant, to technology provider:**
  - **Enrichment Technology Corporation (ETC) in case of Urenco or Areva enrichment plants**
  - **Rosatom (Techsnabexport) for Russian enrichment plant**

  Who will pay? - Not ETC or Rosatom!
- **Operation of centrifuges plant (at least initially) will require expatriate personnel from enrichment technology corporations. Who will pay their salaries, country uplifts?**
- **It should be recognized that black-box centrifuges supply implies no local machines maintenance. This will reduce operating costs**

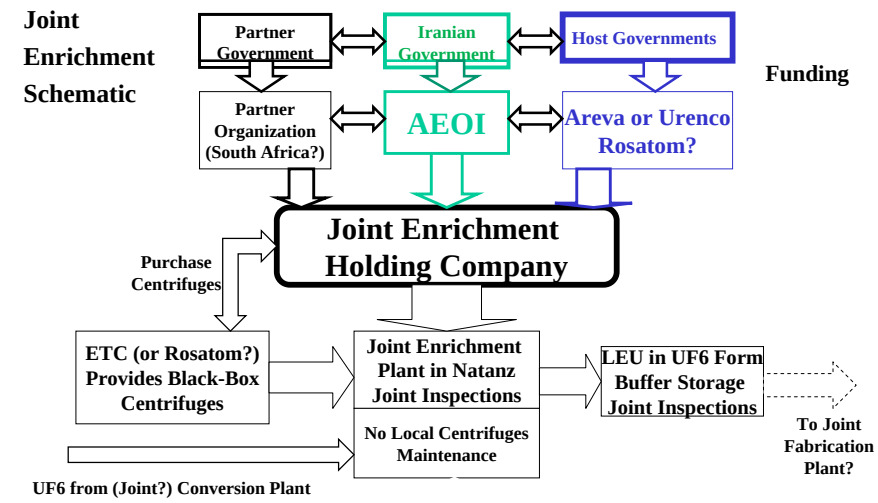
Commercial Constraints on International Enrichment Technology Offer to Iran (Cont.)

- **Payment for foreign enrichment technology & personnel will come from host countries, Iranian Government, in proportion to ownership stake. Detailed agreement on direct payments distribution, payments in kind, liability protection including third-party liability, local services, will have to be worked out**
- **Parallel agreement related to disposition of existing Iranian enrichment plant in Natanz & support infrastructure, as imported plants are installed, will also have to be negotiated. Should termination of Iranian enrichment be agreed to, who will pay plant decommissioning cost? Will foreign government be asked to contribute?**
- **Similar agreements will have to made regarding future operation or disposition of Iranian conversion plant and fuel fabrication plant in Esfahan. Who will pay?**

Governance Issues Related to International Enrichment Technology Offer to Iran

- **Imported centrifuges offer to Iran will likely be made on black box basis (Requirement for ETC centrifuges supply). Iran & enrichment corporation will jointly contract with ETC or Russian supplier to provide centrifuges, to be installed by international partner. Will Iran accept?**
- **Commercial operation of joint enrichment plant will be distributed on a 50:50 basis per enrichment agreement. Will Iran agree to equally-shared commercial control? How will management conflicts be resolved?**
- **In practice, imported enrichment plant will operate on a two-tier black box model. Will Iran acquiesce with this concept, given its experience with the Sofidiff Corporate model?**

Possible Institutional Arrangement for Joint Enrichment in Iran



Political Constraints on International Enrichment Technology to Iran

- **Iran might require political guarantee from host governments of enrichment technology providers to not interfere in the commercial operation of imported plant in Iran, if all nonproliferation obligations undertaken by Iran are met. This would be similar to U.K. concept of 'Enrichment Bonds'. In order for such guarantee to be valid it will have to be backed up by domestic legislation in host country. Would such legislation be voted in?**
- **Imported enrichment plant would be most economically effective at sizes of about 1.0 Million SWU/Year. This corresponds to installed nuclear plants capacity of about 7,000 MWe or higher. It will take time (~ 20 Years?) for Iranian nuclear capacity to reach that level. Until that time imported plant will operate at sub-optimal smaller modular level, incurring higher per SWU costs. This will have to be accepted**

Braun Proposal for Resolving Iranian Enrichment Impasse – Complement to Thomson - Forden Proposal

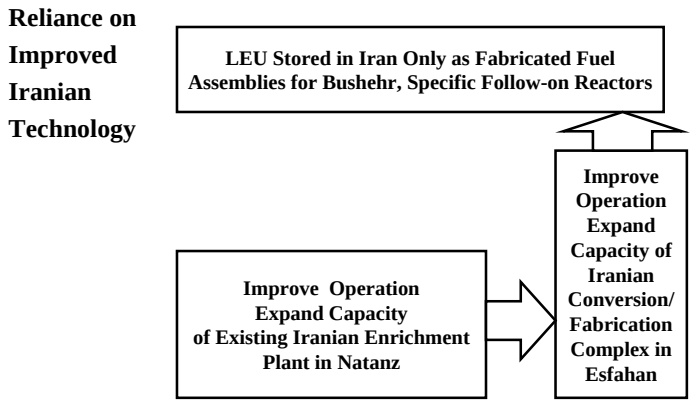
- **My own proposal (discussed next) based on:**
  - **- Braun-May Nonproliferation Review (NPR) paper of March 2006 (Enhancing Iranian enrichment)**
  - **- Insubria Center for International Security (ICIS) proposals of February 2008, provided by Maurizio Martellini of ICIS/LNCV (Fuel fabrication in Iran)**
  - **- Maleki-Bunn (KSG-STPP Program) paper of March 2006 (storage of fabricated assemblies)**
- **As discussed, my proposal could represent complement of, enhancement to, Thomson – Forden proposal, when combined as comprehensive package with phased-in steps**

Braun Proposal for Resolution of Iranian Enrichment Conflict

My suggestions for resolving Iranian enrichment conflict include:

- **International Uranium enrichment corporation (IEC for short), e.g. Urenco, take 50 percent equity stake in Iranian Uranium Enrichment Plant (UEP) in Natanz, in cooperation with Atomic Energy Organization of Iran (AEOI)**
- **IEC & AEOI will improve operation of UEP to commercial level, will provide enrichment requirements of Bushehr, future Iranian NPPs, from operation of improved, enlarged UEP & imports from IEC other plants, as required**
- **Imported SWU supplies could be provided at discount**
- **Centrifuges to operate at UEP based on Iranian technology (IR-2, IR-3). IEC will optimize operation of centrifuges cascades, entire plant layout, based on Iranian centrifuges**
- **Should excess enrichment capacity ensue for a while, IEC will sell excess product in its global markets**

Schematic of Braun Iranian Enrichment Proposals



Proposal for Resolution of Iranian Enrichment Conflict (Cont.)

- AEOI & Western international fuel fabrication corporation (IFC) will form 50:50 percents joint venture to expand Iran Uranium conversion/fabrication plant (UFP) in Esfahan to manufacture NPP's type fuel assemblies
- All LEU product from jointly operated UEP sent to UFP in Esfahan to manufacture into completed NPP fuel assemblies ready to be loaded in Iran's specific future NPPs
- All LEU stockpiles in Iran only in form of fabricated assemblies for specific Iranian NPPs, such as Bushehr, follow on reactors. Agreement to be coordinated with current Russian fuel supply agreement to Bushehr, to avoid duplication
- Two annual reloads for each NPP to be stored in Iran in assemblies form. Excess fabricated assemblies (if exist) to be stored for Iran in IFC plants outside Iran

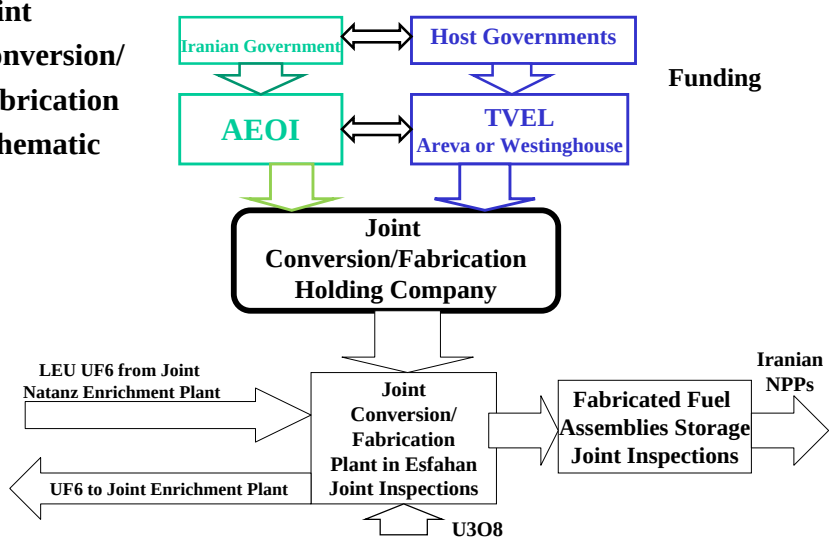
Esfahan: Uranium Conversion and Fabrication Plants

Proposal for Resolution of Iranian Enrichment Conflict (Cont. II)

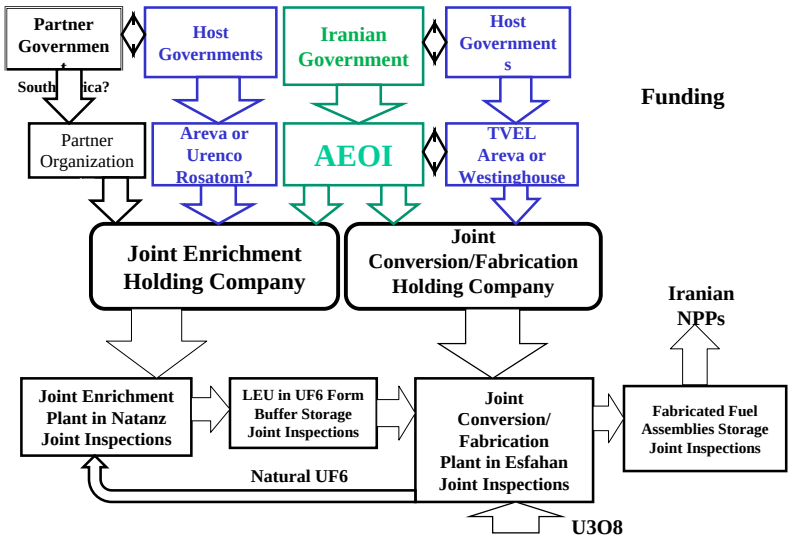
- Iran will ratify, bring into force, IAEA Additional Protocol (AP), implement it fully, answering IAEA open issues, permit IAEA to install environmental sampling system
- All Iranian NPPs, fuel cycle facilities, nuclear R&D institutes to operate under IAEA Comprehensive Safeguards Agreement (CSA) + AP. Iran volunteer transparency of nuclear operations
- Iran will sign international nuclear agreements to levels indicated in UAE White Paper on Peaceful Nuclear Energy (April 2007) or beyond
- Governments of IEC, IFC countries guarantee to Iran non-interference in commercial operations of UEP (Version of U.K. Enrichment Bonds proposal)
- Iran will consider joining regional nuclear security arrangements e.g. Weapons of Mass Destruction Free Zone (WMDFZ) in Persian Gulf only (GCC proposal, 2005), ultimately, Middle East Nuclear Weapons Free Zone (NWFZ)

Possible Institutional Arrangement for Joint Fuel Fabrication in Iran

Joint Conversion/ Fabrication Schematic



Joint Fabrication Enrichment Model in Iran



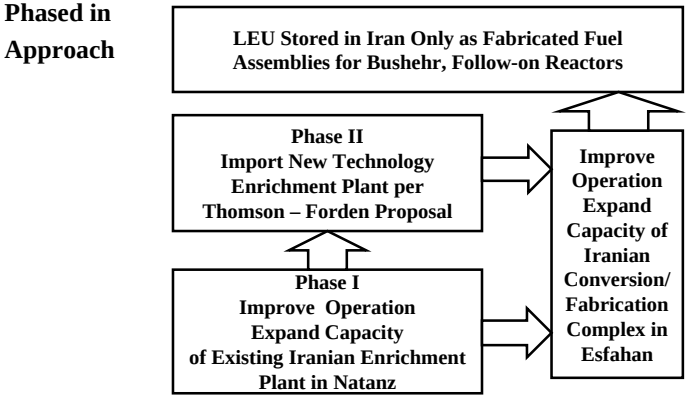
Incentives to Iran of Braun's Proposal

- Iran's right to enrich fuel for its reactors in Iran using Iranian technology will be recognized
- Pride in achievements of domestic technology will be enhanced
- No issue of black-box centrifuges, implied loss of sovereignty, since Iranian centrifuges technology will be used
- Cost of expanding enrichment capacity using domestically manufactured components, cost of fuel cycle services, in near-term lower than costs of importing foreign enrichment plants
- Iranian centrifuges manufacturing infrastructure, Natenz plant, will be maintained, enhanced. All local personnel be retained
- Efficiency of operating current Iranian enrichment plant will be improved, approaching world standards
- Similar benefits will also accrue to Iranian conversion & fabrication plants complex in Esfahan

Combined Braun + Thomson – Forden Iranian Enrichment Proposals

- Both Thomson – Forden & Braun proposals could be combined into a comprehensive fuel cycle supply package based on a phased-in approach
- First phase will include Braun proposal of enhancing operation of existing Iranian enrichment complex, converting LEU from UF6 form to Bushehr-specific fabricated fuel assemblies
- Second phase might include construction of follow-on imported technology enrichment plant in Iran, based on Thomson – Forden proposal. This phase initiated when:
  - Confidence builds in successful implementation of first phase & Iran's nonproliferation record
  - Iran's nuclear capacity increases, justifying larger enrichment plant built to world technology standard

Schematic of Braun + Thomson – Forden Iranian Enrichment Proposals



Conclusions

Iran-Specific International Arrangements for Future Enrichment Activities

- **Iran enrichment proposal unique to Iran's situation. Based on principles of:**
  - **Improved transparency, through partial international ownership**
  - **Iran ratify, implement AP, answer IAEA inquiries, consider environmental sampling**
  - **Recognition of Uranium enrichment operations inside Iran**
  - **Improve operation of Iranian centrifuges through international partnership, however:**
  - **Cap Iranian centrifuges technology development**
  - **Stockpiling Iranian LEU only in form of fabricated fuel assemblies for specific Iranian NPPs; to that purpose:**
  - **Internationalize operation of Iran's fabrication plant**

Iran-Specific International Arrangements for Future Enrichment Activities (Cont.)

  - **International partners sign 'Enrichment Bonds' type agreements not to politically interfere in operation of joint ventures if Iran meets its obligations**
  - **All partners (including Iran) agree on a variant of ABACC type safeguards on joint fuel cycle facilities in Iran**
- **Proposed arrangement might represent 'nuclear third-way' Iran seeks**
- **Proposal saves face all around –Iran keeps domestic enrichment, international partners join Iranian fuel cycle operation, greater transparency is assured, threshold for proliferation is raised**
- **To succeed, however, higher levels of trust must be established. This requires embedding enrichment arrangement in more comprehensive resolution of Iran's political-security-economic conflict with Western powers, recognition of Iran's status within Middle East**

Backup Slides

Why May Iran Want Nuclear Weapons?

- **Gain greater role in Middle East, in Islamic leadership**
- **As deterrent to U.S. aggression, U.S. influence in Gulf**
- **To counter Israel's nuclear weapons capability**
- **For domestic consumption – shore up Islamic regime**
- **To gain international prestige**
- **Hedge against Saudi Arabia, Pakistan**

Natanz Gas Centrifuge Uranium Enrichment Complex

- Covert facility in remote location: agriculture cover story
- Concealed underground, hardened, well defended
- Concealment structures to hide infrastructure

Iran – International Enrichment Plant Concept

Uranium Enrichment in Iran

- **Iran has developed a clandestine Uranium enrichment program based on Pakistani centrifuges technology, secretly provided by A.Q. Khan starting 1989. In 2007 Iran has developed (partially) indigenous centrifuges technology (IP-3)**
- **Iran insists its enrichment program is peaceful, kept in secret to prevent Western supply embargo, citing its own experience with Sofidiff Corporation, Western nuclear embargo on India, U.S. closing of the enrichment orders books in mid-1970's, general perception of unreliability of Western suppliers, willingness of Western Governments to stop supplies for political purposes**
- **Western Governments insists that Iran's nuclear program, given its clandestine nature, lack of transparency, incomplete responses to IAEA questions, development of nuclear–capable missiles, indicates latent proliferation program intent**

Uranium Enrichment in Iran (Cont.)

- **IAEA Board of Governors (BOG) voted in 2007 to transfer 'Iran's File' to UN Security Council (UNSC). UNSC passed three Resolutions {1737 (2006), 1747 (2007), 1803 (2008)}, calling on Iran to stop domestic enrichment. Iran refused to comply, claiming Resolutions are illegal**
- **Russia offered to enriched Iranian natural Uranium in Angarsk, guarantee shipment of fuel assemblies to Bushehr reactor. Offer later extended, developed into IUEC general purpose supply assurance proposal**
- **U.K., France, Germany (EU3) & U.S. offered Iran package of incentives, including Western reactors technology, guaranteed fuel supplies, membership in World Trade Organization (WTO), other economic incentives, in exchange for stoppage of domestic Iranian Uranium enrichment**
- **Iran so far refuses Western offer, insists on need for (some) domestic enrichment, for reliability of supply, prestige reasons**

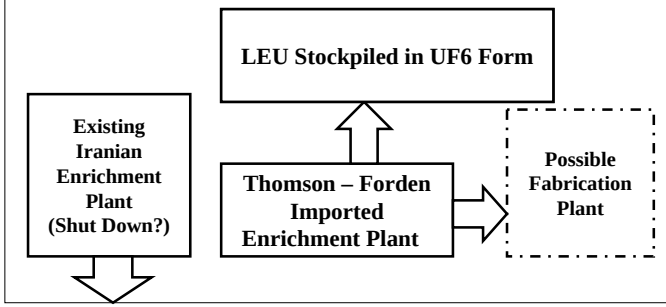
Past Proposals for Resolution of Iran Uranium Enrichment Conflict

- **Various proposals made to accommodate both Western concerns regarding Iranian proliferation intent and Iranian insistence on domestic enrichment**
- **Putin Proposal for enrichment of converted Iranian UF6 in Angarsk, fabrication of Iranian LEU to Bushehr fuel Assemblies in Novosibirsk, complementing Bushehr spent fuel disposal contracts with Iran**
- **Thomson-Forden proposal calls for construction of Urenco centrifuges plant in Iran based on best Urenco technology (TC-21 centrifuges?), possible Russian centrifuges, in exchange for termination of Iranian independent domestic enrichment program. Centrifuges to be provided with sophisticated, built-in, self-destruct mechanism in case Iran breaks out of agreement**

Schematic of Thomson – Forden Iranian Enrichment Proposal

New Enrichment Plant in Iran. Product Accumulates in Iran in UF6 Form?

Existing Iranian Enrichment Plant Phased Out?



International Enriched Uranium Plants & Supply Assurance Proposals

- **Eurodiff, Sofidiff – French based enrichment corporations. Several Countries members of commercial tier, French Corporations Cogema (Areva) controlled technology tier**
- **LES plant in U.S – Urenco controlled technology tier. Sponsoring U.S. electric utilities have no access to Urenco technology**
- **International Uranium Enrichment Center (IUEC) in Angarsk, Russia. Participating countries have access to commercial tier – decisions on disposition of enriched Uranium stockpile. Russia only have technical access to enrichment plant co-located in Angarsk**
- **German multi-lateral enrichment sanctuary proposal (MESP) envisions international enrichment plant under IAEA control operated on extra-territorial site. Enrichment corporation operator only controls access to plant technology**

Regional Two-Tier 'Black Box' Enrichment Plant Concept

- **Regional enrichment plant to be operated within a region could be built under two-tier commercial, technical, structure:**
  - **Commercial First Tier: Commercial decision-making vested in Board of Directors whose membership chosen by participating states within region, & by international technology provider, in relation to their relative investments in plant**
  - **Technology Second Tier: Enrichment technology to be provided by international enrichment corporation under 'black box' arrangement**
- **Flexible application of 'Black box' arrangements, depending on nonproliferation credentials of participating countries**
- **Participation in regional enrichment plant to be conditioned on signing, ratification of IAEA Additional Protocol**

Regional Two-Tier 'Black Box' Enrichment Center Concept (Cont.)

- **Member states fully participate in commercial operation of enrichment plant. Entitled to withdraw enriched Uranium product to meet all their NPPs requirements**
- **Regional enrichment plant operate under contract by international enrichment corporation with limited technical access & participation by member countries**
- **Enrichment plant safeguards arrangement would be based on ABACC model**
  - **Cross-national safeguarding of plant by member countries**
  - **Top tier of IAEA safeguards**
  - **Member countries sign, ratify Additional Protocol**
- **Proposed arrangement conceptually similar, updated version of, EURODIFF, SOFIDIFF, IUEC, LES corporate structures**

Conclusions Regarding Generic International Enrichment Plan

- **Future enrichment plants based on:**
  - **International or regional ownership involving regional countries & international enrichment Corporation**
  - **Two-Tier 'Black Box' arrangement (flexibly interpreted)**
  - **ABACC-type mutual safeguards with IAEA top-tier inspections**
  - **All user countries ratify, bring into force CSA + AP Agreements with IAEA**
  - **All supplier Governments sign 'Enrichment Bonds' type guarantees not to interfere in commercial enrichment operations for political purposes, pass requisite laws**
- **Concept offers best possibility for safeguarding enrichment plants while assuring fuel supplies**
  - **Ultimately depends on good will of supplier, user Governments**

Uranium Enrichment

Houston Wood, Professor

Mechanical & Aerospace Engineering
University of Virginia

Presented at MIT Workshop
October 20, 2008

Separative Work

- Enrichment of uranium is measured by separative work units (SWU) in kgU/yr.
- $\Delta U \equiv$ separative capacity of separating element (e.g. centrifuge) or cascade.
- To fuel a typical power reactor for a year requires ~125,000 SWU.
- If a single centrifuge has ΔU = 10 SWU, the cascade requires 12,500 centrifuges.

HEU Production

- To produce 25 kgU (1 SQ) enriched from natural uranium (0.72% ^{235}U) to 93% requires 5,000 SWU.
- To produce 25 kgU enriched from 3.5% ^{235}U to 93% requires 1400 SWU.
- So 72% of the work is in making 3.5% ^{235}U from natural uranium.

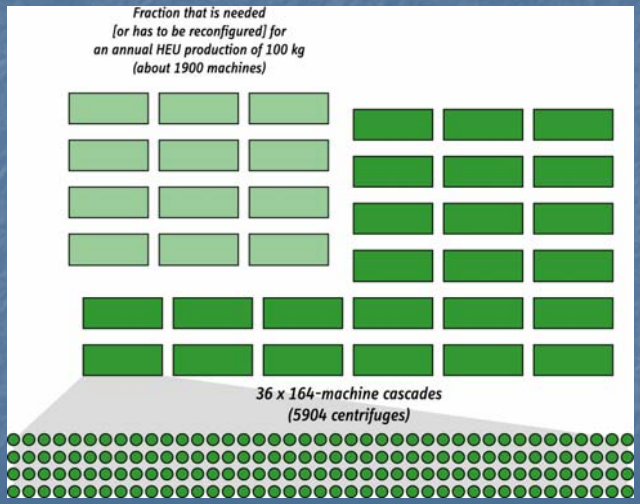
Centrifuges Required for HEU

- Consider a hypothetical centrifuge with ΔU = 10 SWU.
- To produce 1 SQ per year at 93% ^{235}U from natural U would require 500 centrifuges.
- To produce 1 SQ per year at 93% ^{235}U from 3.5% ^{235}U would require only 140 centrifuges.

P1 Centrifuge

- This is the example in September issue of **Physics Today**.
- P1 reported to have $\Delta U \sim 2.5$ SWU
- Arranged in cascades of 164 centrifuges to produce reactor grade U.
- Consider a plant with 36 of these cascades or 5904 P1 centrifuges.

Two Plants: One with 12 and one with 36 cascades of 164 P1 centrifuges



Breakout

- With natural U, the 36 cascade plant can produce about 40 kgU HEU per year with batch recycling.
- If 12 of the cascades are dedicated for LEU to HEU, 90 kgU HEU per year can be produced.
- With pre-enriched feed, 12 cascade plant can produce 90 kgU HEU per year and the 36 cascade plant 3 times that amount.

Clandestine Plants

- Difficult to detect.
- No distinguishing signs.
- ~160 W/m^2, comparable to food services.
- Process gas pipes pressure < atmospheric so little leaks into the atmosphere.

Consequences for Non-proliferation and Safeguards

- More resources needed.
- More stringent safeguard methods.
- More accurate material accountability – especially LEU.
- More Human Intelligence to detect clandestine plants.

Need to Remain Aware of Other Methods of Enrichment

- Thermal Diffusion
- Electromagnetic Isotope Separation
- Aerodynamic Separation
- Chemical and Ion Exchange
- Plasma Separation
- Laser Isotope Separation

Questions?

Comments?

The Challenge of Safeguarding Gas Centrifuge Enrichment Plants

MIT Workshop on Internationalizing Uranium Enrichment Facilities

Brian D. Boyer
Los Alamos National Laboratory
Nuclear Nonproliferation Division
October 20-21, 2008

What is Safeguards?

INFCIRC 153 Para. 28: The Safeguards Technical Objective

... the objective of safeguards is the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection. …

NOTE:

- Timeliness
- Significant Quantities
- Deterrence by Risk of Early Detection

Safeguards Concerns at LEU GCEPs

- **Production of a SQ of undeclared HEU (≥20% U-235)**
  - SQ = 25 kg U-235 contained in HEU
  - Detection within one month
  - Detection probability = *high confidence (HSP report)*
- **Diversion of a SQ of declared LEU, NU, or DU**
  - SQ = 75 kg U-235 contained in LEU
  - Detection within one year
  - Detection probability = 50%
- **Production of LEU in excess of declared amounts**
  - SQ = 75 kg U-235 contained in LEU
  - Detection within one year
  - Detection probability = 50%
- **Hexapartite Safeguards Project in 1980's addressed the issues**

A Critique - Weaknesses in Existing Model Approach

Based on Hexapartite Safeguards Project Findings

- **No significant measures specific to detecting undeclared feed**
  - **Fixed Inspections: PIV and 11 IIV – predictable: difficult to detect undeclared feed**
  - **LFUA only for process cascades – not for F/W areas**
  - **Need to be able to detect undeclared cylinders – Random Inspections**
- **LEU diversion scenarios not covered**
- **Challenge to meet detection goals for large throughput plants**
- **New, large centrifuges make it more difficult to see piping**
- **New cascade designs are less transparent than before**
- **Technology moving out from original tech holder states**
  - **New states and new technology**

Measures to Detect Undeclared HEU Production

Limited Frequency Unannounced Access - Verification Measures include:

- **Random, 2 hr notice inspections – 6-8 per year**
- **Visual observation – During LFUA**
  - Detect presence of unreported F/W equipment within cascade areas
  - Detect piping changes indicative of connecting cascades in series

- **NDA measurements on header piping**
  - Cascade Enrichment Header Monitor (CEMO)
  - Detects HEU
  - Only operates at Capenhurst (QCAX)

- **Obtaining of UF_6 samples from cascade**
  - Analyze for enrichment
  - Rare event!

- **Obtaining of environmental samples; analyze for enrichment**

Environmental Sampling (ES)

- **Potentially a very powerful technique**
- **Baseline samples need to be taken**
- **Field trials have occurred**
  - Including sampling inside cascade halls

- **Can detect increasing enrichments as cascades brought on line**
  - Peter Friend (URENCO) confirmed this statement
- **Operators did not take special measures to prevent UF_6 releases**

IAEA Measures (HSP) to Detect Diversion of Uranium Declared and Undeclared LEU Production

- **Inspection regime includes:**
  - Annual PIT/PIV
  - 11 monthly interim inspections for flow verification
  - IAEA verifies feed, product, and tails cylinders - receipts and shipments
    - OPERATOR holds feed before feeding to process
    - OPERATOR holds tails and product before shipment off-site
- **Auditing of records and reports (ICR, PIL, MBR)**
- **Verification of nuclear material quantities (flows and inventories)**
  - Measure UF6 in cylinders – sampled for **NDA, Weighing, DA**
- **Material balance evaluation**
- **Application of seals to UF_6 cylinders**
- ***New* IAEA Draft MODEL SAFEGUARDS APPROACH**
  - Uses Mailbox and Random Inspections to increase detection of undeclared feed
  - Trial completed at Gronau (URENCO) with IAEA and EURATOM

IAEA Accountancy Verification Methods

- **Three levels of defects to detect with NDA Instruments:**
  - ***Gross defect / Partial defect / Bias defect***
- **Examples in GCEPS:**
  - ***Gross defect***
    - **No U, ^{235}U present**

  - ***Partial defect***
    - **Lower ^{235}U content**
    - **Part of U missing**

  - ***Bias defect***
    - **Lower ^{235}U content bias**

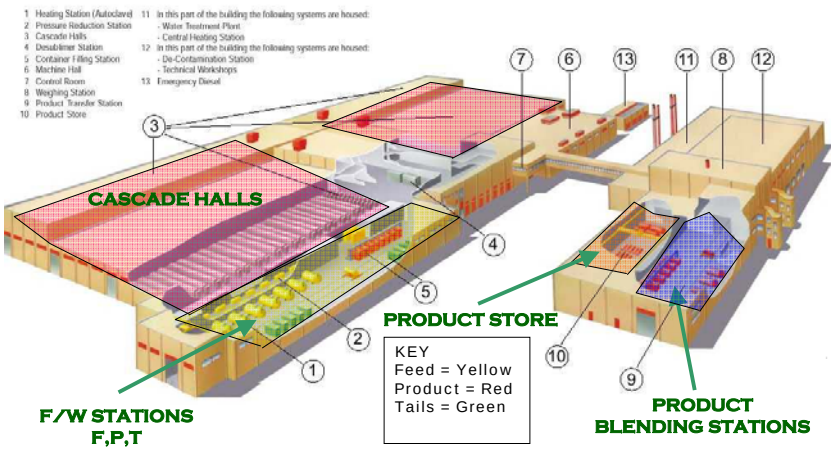
Potential Excess LEU Production Detection Improvements

Present Possibilities and Future Tech

- **Detect undeclared feed cylinders concurrent with**
  - LFUA inspections
  - Establish SNRI regime (SNRI+LFUA)
- **Full use of " Mailbox" declarations of declared cylinder operations**
- **Unattended monitoring system – Process Monitoring**
  - Enrichment measures at feed, product, and tails stations
  - Weight from load cells at feed, product, and tails stations
  - Flow and enrichment monitoring of process flows – several modes in R&D
  - Surveillance and use of RF tagging to track cylinders
- **Detect undeclared UF_6 Streams in cascade halls**
  - Enhanced inspector access inside cascade halls
  - Enhanced video surveillance inside cascade halls
  - Video/radiation monitoring of cascade hall access doors
- **Use of AP / SLA / IS to provide more transparency and confidence**

Gas Centrifuge Enrichment Plant (GCEP)

Process Areas – Where Can We Measure Flow/Enrichment?



Summary of GCEPS Safeguards

- **GCEPS safeguards – a manpower intensive endeavor**
- **Desire to close gaps on undeclared feed**
  - Operator "no one would ever divert undeclared LEU product"
  - Or would they?????
- **Mailbox and SNRI – trials at Gronau – IAEA's "1st next step"**
- **Unattended monitoring system – in development**
  - RFIDs
  - Process Monitoring – In Process vs. Accountancy Scales modes
- **Sensitive technology on several levels – state/commercial/proliferation**
- **Multinational facilities**
  - Black boxes – concept essentially will be put in place now
    - France and USA - use of ETC URENCO technology
    - Lasers – extremely sensitive and controlled technology – access by IAEA?
  - IAEA Safeguards should be required – *range of opinions*
    - Should be as rigorously applied as at present facilities
    - Safeguard as UF6 storage facility – Ignore process areas

Proliferation Barriers Inherent in Multinational Enrichment Facilities

Geoffrey Forden

MIT's Program on Science, Technology and Society

1. **The new Proliferation Environment** — the spread of precision engineering makes it imperative to increase participation in developing countries' nuclear programs.
2. **Multinational organization details** — organizational structure, implimentation timeline, cost estimates.
3. **Proliferation Barriers** — Interlocking Legal, Organizational, and Technical Barriers for **Mutual Reinforcement.**
4. **What this proposal gives the host country** — enrichment on Iranian soil, economic viability to its enrichment, participation as a founding member in a new international nonproliferation concept.

The New Proliferation Environment

Proliferation then: (When the NSG etc. were formed)

In **1984**, the West was the standard of good manufacturing:

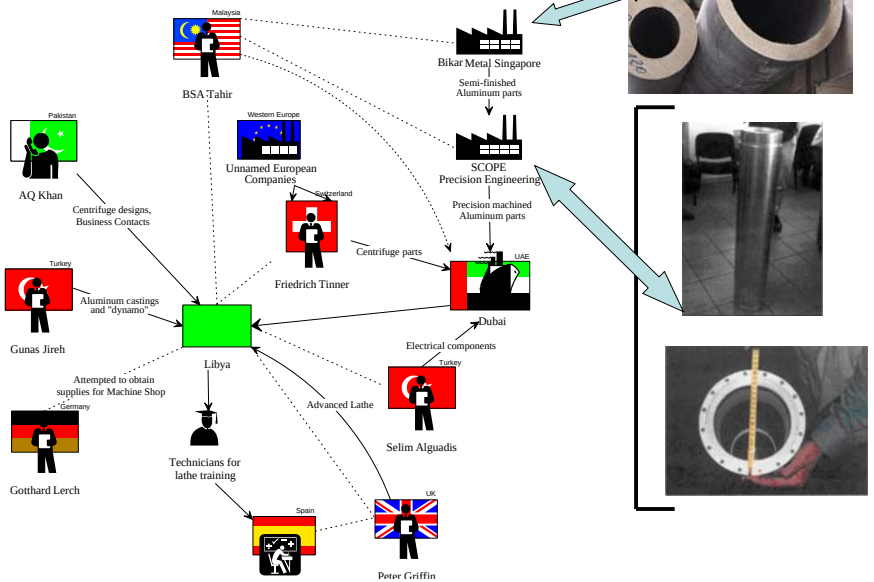
Article 25 : Origin of Supplies

The Supplier shall issue a certificate by which he confirm that the Supplies delivered under this Contract are produced or manufactured in the following Country or Countries, United States Of AMERICA, FRANCE, ITALY , WEST GERMANY, AUSTRIA, UNITED KINGDOM, SWISSZRLAND, CANADA, SWEDEN, HOLLAND.

In case another Country becomes Sub Supplier, the Supplier will inform the Customer who will have a period of Two (2) months to object. •

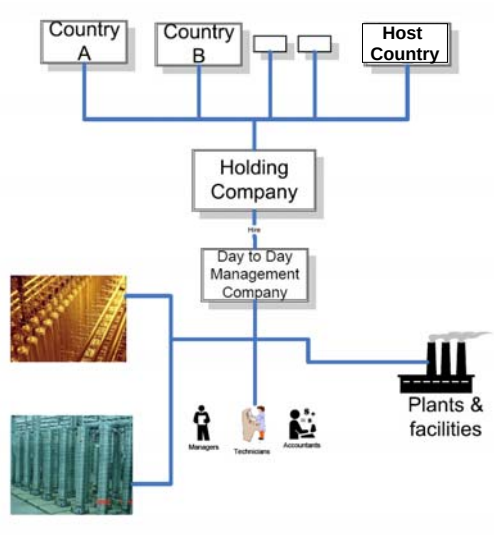
Contract for the Badr-2000 missile

Proliferation today:



Organizational Details of Multilateral Enrichment Facilities

Organizational Outline



Countries create a board of directors of a holding company; sets policy etc.

Management company **leases** centrifuges, facilities, hires employees.

Each shift will have at least one representative of each country on duty.

Eco ges.

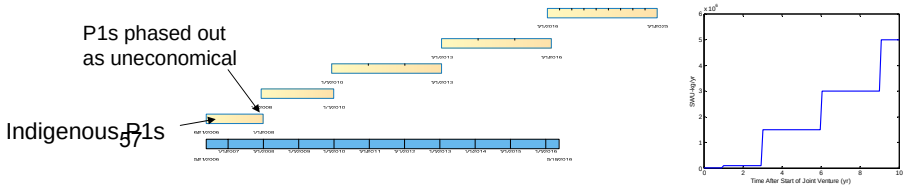
*could include Russia, South Africa, etc.

Estimating Costs

It is generally reported that an enrichment plant needs to have a 5 Million SWU-kg/yr capacity if it is going to be economically viable

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

URENCO would have the best view of TC-12 vs. TC-21s and Russia would be the best to decide between their centrifuge models.



Proliferation Barriers Details

Legal Barriers

Most Important: Partner states agree not to pursue nuclear fuel cycle activities outside Multilateral Arrangements

Precedent example: the Treaty of Almelo (which formed URENCO)

Other Important Aspects:

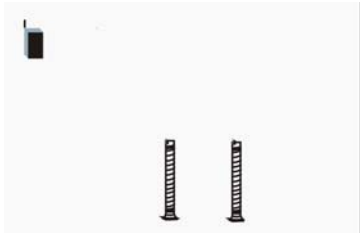
- Agreement not to transfer technology
  Precedent example: URENCO agreement with France and the US
- Agreement to identify current and former nuclear workers and allow them to be interviewed.
  Precedent example: commercial nondisclosure/noncompetition agreements
- Multilateral or bilateral agreements for new or unique safeguard measures.
  Precedent example: Japan's agreement to host IAEA inspectors on site, 24hr /day

Organizational Barriers

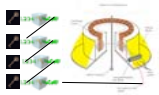
1. International Centrifuges will be removed for repair outside of the country (repaired by leaser company/country, i.e. URENCO)
2. All Technicians will only follow pre-defined (i.e. written/formalized) procedures—this is Good Manufacturing Procedure (GMP) but also prevents the transfer of know-how in either direction.
3. Each participating nation will have nationals working each shift and at all levels
   1. Plant floor technicians.
   2. Bookkeepers
   3. Managers…
4. "Social" Monitoring—international employees working 24/day, 7 days/week can gain an essential understanding of what Iranians are doing. (This is based on our experience in Iraq i.e. UNSCR 1441 List of Names.)

Technological Barriers:

- Technology safe:
  - "black boxed" centrifuges
  - "Smart tags" on centrifuges
    - Continual monitoring of position
    - Motion/acceleration sensors



- Material accountancy much greater than IAEA
  - Joint venture extending down into uranium conversion and up into fuel fabrication.



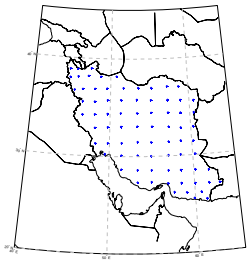
- Built in self-disablement mechanisms
- Increased mechanisms for detecting covert enrichment facilities

The Covert Enrichment Facility Problem: Technical vs. "Social" Mechanisms

It takes 1,700 P-1 centrifuges to enrich enough natural uranium to make one bomb per year.

That number can fit into almost any warehouse in Iran.

The IAEA has estimated that such a facility will release <u>less than</u> 1 gram of UF6 per year!



The optimal spacing between air samplers would be 10 km ➔ 33,000 stations!

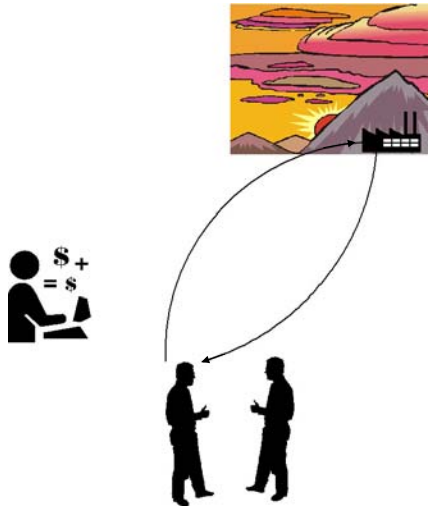
Garry Dillon arbitarily increased this spacing to 100 km ➔ ~400 stations. Because of the dust in the atmosphere they would have to be checked every 2 weeks

Increased Detection of Covert Enrichment Facilities

UNMOVIC and UNSCOM found that knowing who are the skilled workers etc. was a key monitoring tool in Iraq.

This was one of the reasons by UNSCR 1441 required Iraq to provide names of all WMD workers.

The Joint Enrichment Facility, with Western Technicians, Western Bookkeepers, and Western Managers working side-by-side with Iranian experts will provide even grater awareness.



What this gives the Host Country

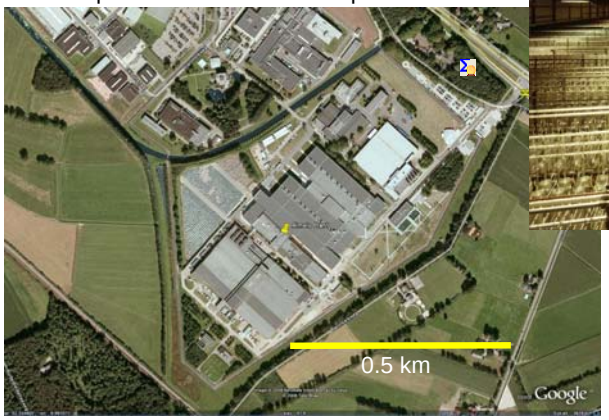
More of what they get:

- Assured nuclear fuel supply
  - Holding a sizable foreign investment in Iran
  - Gain allies (South Africa, India, if they joined) who would help ensure the facility is run
- They can become an important world supplier of nuclear fuel
- They can work with Westerners on state-of-the-art nuclear technology.
- They can tell their people that they are participating as founding members of an important new nonproliferation initative.

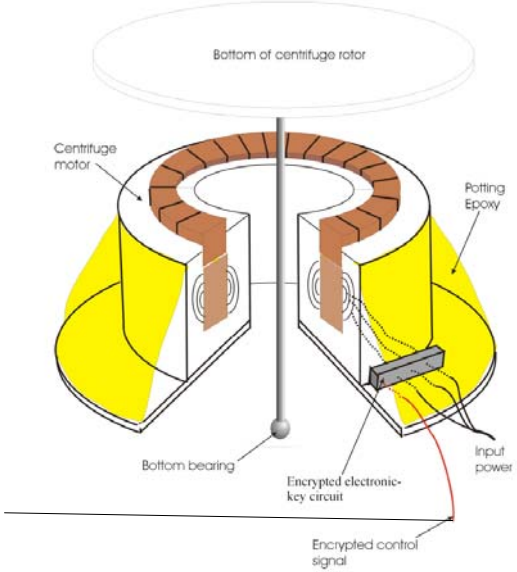
Details of Preventing Nationalization

To protect worker safety, the new centrifuge plant would have to be installed above ground

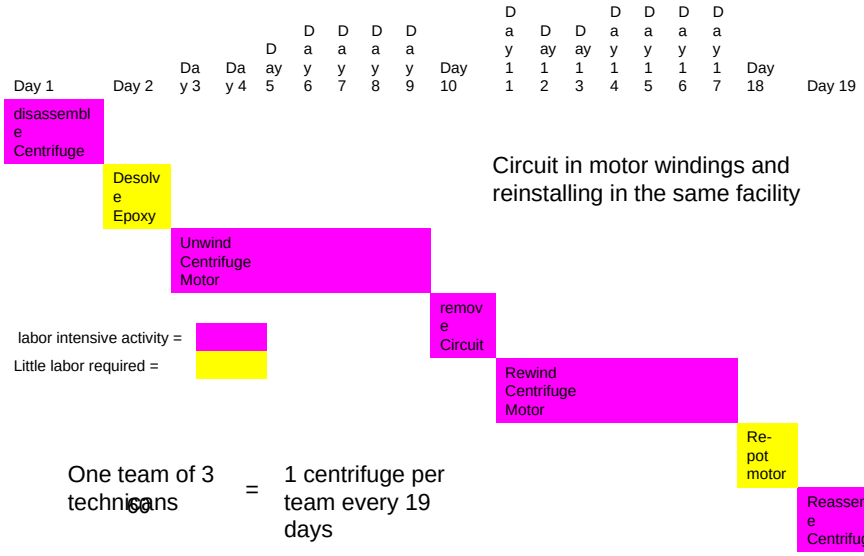
Plant designers much consider a catastrophic loss of UF6 into the plant.



Disabling mechanisms: details could be considered later.



Estimating Cheating Times



Circuit in motor windings and reinstalling in the same facility

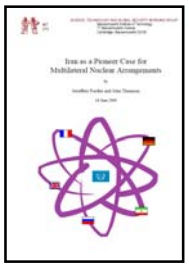
One team of 3 technicians

=

1 centrifuge per team every 19 days

More Details on the Forden-Thomson Proposal can be found on our website:

http://mit.edu/stgs/irancrisis.html



Models of Multinational Enrichment Facilities – New Concepts

Iran as a Pioneer Case for Multilateral Enrichment Centers

John Thomson

Geoff Forden and I usually share presentations on this topic but since he has nobly undertaken the burden of organizing the workshop, I am on my own today. However, we remain partners and if I falter I will depend upon Geoff for support.

We have put two papers on the Workshop's website: our proposal on Iran in its latest version dated 24 May 2007 and our paper on "Multilateralism as a Dual – use Technique: Encouraging Nuclear Energy and Avoiding Proliferation" published in March 2008 by the Stanley Foundation. Hard copies of both are available.

Rather than repeat the detail of the generalized scheme set out in our Stanley Foundation paper, I will pick out a few key points for multilateralizing nuclear fuel centers – not just enrichment facilities – irrespective of whether they are based on taking over existing national facilities or whether they are new facilities intended to be multilaterally owned and operated from the beginning.

First, we recommend that the necessary basic agreements should be between governments and should take the binding form of a treaty. This secures the greatest authority and clarity possible and also avoids situations in which governments claim, genuinely or not, that they didn't know what was happening or that they lacked the legal right to prevent abuses in the private sector.

Perhaps this is already accepted as a general principle since URENCO is based on the Treaty of Almelo and the US agreed to the Treaty of London (1992) as the basis for an American private company buying centrifuges from URENCO.

Second, we recommend that the multilateral business should be run on commercial lines. This creates a substantial common interest for the shareholders and gives management a clear and measurable objective. It also orientates operations clearly towards civil and away from military considerations. Flouting commercial considerations would signal potential danger. But markets cannot be safely predicted years ahead so in any event the multilateral facility would expect normally to supply the fuel for all the reactors in the partner countries.

Third, to reconcile government responsibilities with commercial operations we recommend a two tier structure. Main lines of policy and relations with governments would belong to a Board of Directors representing all qualified participants. Day to day operations and commercial and technical advice to the Board would be the business of a management company. To this all partners would contribute personnel but not necessarily in relation to their shareholding.

Fourth, the treaty would amongst other things, provide that

- Each participant would undertake not to engage in the relevant activity, enrichment for example, except through the multilateral consortium; but this would not apply to a participant who was already engaged in that activity; thus, for example, a URENCO government could be a partner without affecting its URENCO business;
- That no single partner irrespective of its share holding could override the wishes of the others;
- That if and when it was agreed to wind up the enterprise the equipment would return to its supplier;
- That costs and profits would be shared by the partners on the basis of the number of shares held.

All that I have said about structure is intended to be helpful to countries wondering how to embark on a civil nuclear program or to increase an existing small one while retaining some degree of national control and securing fuel free of political conditions. That in itself is a justification for multilateralization at a time when many countries are thinking about including nuclear power in their energy mix. However, for all countries, multilateralization is crucially a device to avoid proliferation.

I will speak briefly about the technical contributions of multilateralization to non-proliferation and then turn to the crucial political issues.

Multilateral facilities will have one or perhaps two more layers of IAEA inspections than national facilities. Besides the standard comprehensive safeguards the Additional Protocol will be mandatory and beyond that there will be special inspections tailored to the particular circumstances, probably involving resident inspectors.

By its nature, multilateralism automatically creates a unique form of intrusive inspections. The foreign professionals will live and work with their opposite numbers from the host country. This observation, informal but constant, makes it virtually impossible for the host country to run a clandestine operation without detection. In this respect, multilateral facilities are far superior to national ones.

Some people worry that technologically backward partners would learn from working with technically advanced machines and personnel. Up to a point this is true: they would learn about the day to day running of a modern facility – just what is needed if we have a major nuclear renaissance – but that is not to say they would be able to duplicate that facility in secret. The more advanced the technology they seek to copy, the harder it is.

The issue, however, is not what they might learn but rather whether multilateralization would incline a partner in such an enterprise to make weapons and then help them to do it. On both the questions, inclinations and capability the answer is "No". Multilateralism, as I have said, makes it virtually impossible to run a secret program. So if a country is determined to make a weapon multilateralism obliges it to take the enormously risky and overt steps of forcefully expropriating the property of their partner governments. That might be a causas belli. At a minimum it would declare to the world an intention to make a weapon, a highly dangerous situation in itself. It makes no sense for a country to put itself in this position if it does not have to. So it is interesting that Iran favors multilateralism for itself.

Geoff and I are convinced that Western policy is taking undue risks with the prospect that it will seriously damage Western interests. We have had five years of Western policy, always giving way a little but always too little too late and so we have had five years of failure.

Let's be clear about the real situation not the pie-in-the-sky that some of our leaders yearn for. Here are some facts:

- Iran is securely manufacturing centrifuges; they had help from Pakistan and also from us since we forced them to develop centrifuge expertise and a network of black market suppliers; but now they have learnt and apparently do not need help;

- According to the IAEA, about 3000 centrifuges of the 1R 1 type (which produced the fuel for the first Pakistani weapons) had created by early September approximately 480 Kg of low enriched uranium (LEU);

- By the end of this year, we have to expect that about 6000 centrifuges will be in operation; installation work has begun on a further four units each with 3000 centrifuges; in addition, Iran is currently trying out more efficient types of centrifuge;

- The Iranians have had several years of experience with the 1R1's and for the past 20 months have run them in cascades on an industrial basis; probably they have now learnt all they need to know;

- International pressure has failed to make Iran change course and the latest Security Council resolution, (no 1835 of 27 September) shows that we have reached the limit of what Russia and China will support;

- There is virtually no prospect that Iran will give up what it already has, whatever the inducement; Western pressure has strengthened the hardliners in Iran;

- Policy makers in Washington, London and Paris say their main fear is that Iran will undertake a new secret enrichment program; since the Iranians ceased to operate the Additional Protocol in February 2006 they have had the opportunity to do just that; we have no idea what they have done or not done and yet we continue to give them the time while simultaneously providing the spur for action; this makes no sense;

- The Iranian government has repeatedly said it is interested in a multilateral enrichment center in Iran but we refuse to ask them what they mean; SCR 1835 calls for "an early negotiated solution to the Iranian nuclear issue" but the Western powers cannot bring themselves to follow up on that without unacceptable pre-conditions;

- Western policy is well past the point at which it is damaging the cause of non-proliferation; we need to change and the multilateral idea seems the best bet.

The Forden-Thomson plan which is simply the application of multilateralism to Iran is not without some risk but that risk is small compared to Western policy. Comparison is the name of the game. The general point is this: is a multilateral arrangement likely to be better or worse than a national facility? The answer is a no-brainer but proliferation is not the top priority for our leaders. The recent Indo-US deal proves the point. Whatever their high-flown rhetoric about proliferation, our leaders tend to decide specific cases on quite different political grounds.

I cannot escape the conclusion that the people who did not understand the mortgage bubble and its consequences also do not understand proliferation. They seem never to have looked seriously at what a global policy of multilateralization means and what it could do. So in the Iran crisis they are putting us all at risk. If this workshop helps to educate our leaders, that will be great.

The Nuclear Suppliers Group and Multinational Arrangements for Uranium Enrichment Facilities

Past, Present and Future

By

Fred McGoldrick

Prepared for
MIT Workshop on Internationalizing Uranium Enrichment Facilities

October 20-21, 2008

Introduction

I have been asked to examine how the Nuclear Suppliers Group (NSG) might help promote the idea of placing enrichment facilities under multinational auspices or control, including what rules might need to be changed and how to frame the agreement to get consensus in support of multinational arrangements for sensitive aspects of the fuel cycle. Specifically I have been asked to address the following questions:

- What needs to be changed?
- What are the legal implications?
- How to frame an agreement to get consensus. What is the view from non-supplier countries regarding the nuclear renaissance?
- How can we frame an agreement to get consensus to blocking national enrichment centers?
- Are non-supplier countries willing to forego national enrichment centers?
- How has the US-India deal affected the NSG and its guidelines?

In attempting to answer these questions, I propose to divide my presentation into three parts:

> First, I will describe how the present NSG guidelines deal with transfers of sensitive nuclear technology (SNT), and how and why they took the shape that they have.
>
> Second, I will describe the recent initiative of the U.S. Government to amend the NSG guidelines on transfers of SNT and will attempt to assess its current status and prospects as well as its implications for promoting multinationalizing enrichment plants. The political dynamics that occurred in the NSG as a result of the U.S. proposal to restrict SNT transfers has important implications for any effort to promote multinational enrichment arrangements.
>
> Third, I will take a stab at suggesting steps the NSG might take to help promote the idea of placing enrichment facilities under some form of multinational auspices or control.

Current NSG guidelines on the transfer of sensitive nuclear technology

The NSG was formed for a number of reasons. Most observers cite the fact that the Indian nuclear test of May 1974 prompted some states to conclude that the rules of international nuclear trade needed to be tightened. However, a more urgent issue at the time was the effort of some suppliers to transfer sensitive nuclear technologies to unstable areas of the world where the recipients had not made comprehensive nonproliferation commitments, and where some states were seeking these technologies to enhance their ability to build nuclear weapons. In the mid-1970s France entered into contracts to provide reprocessing plants to South Korea, Taiwan and Pakistan. The

Federal Republic of Germany concluded a contract to provide enrichment and reprocessing technology to Brazil.

After a number of meetings, in September 1977, fifteen supplier states finally agreed upon a common set of guidelines to govern peaceful nuclear exports. These were then published in January 1978 as the IAEA document INFCIRC/254. These guidelines included a number of conditions for the export of nuclear materials and equipment that were identified on a "trigger list," so-called because the export of these items "triggered" a requirement that the recipient state provide certain nonproliferation assurances as a condition of supply. These included the acceptance of IAEA safeguards in perpetuity and a pledge that the transferred items would be used only for peaceful, non-explosive purposes as well as agreement to apply physical protection measures and to accept controls on retransfers of such items.

The members of the NSG also adopted guidelines for the transfer of sensitive nuclear technology (SNT), which included enrichment, reprocessing and heavy water production technology. The guidelines are as follows:

> Nonproliferation conditions. Safeguards, peaceful use assurances, physical protection and controls over retransfer should apply to facilities for reprocessing, enrichment, or heavy-water production, utilizing technology directly transferred by the supplier or derived from transferred facilities, or major critical components thereof.
>
> Restraint in the transfer of sensitive nuclear items: The United States wanted the group to agree on a moratorium on the transfer of enrichment and reprocessing facilities.[1] However, there was considerable opposition to this proposal and, in the end, the NSG adopted a guideline that provided,
>
> > "Suppliers should exercise restraint in the transfer of sensitive facilities, technology as well as weapons-usable materials."
>
> The NSG did not attempt to define or give any specificity to what "restraint" meant in this context.
>
> Multinational or supplier involvement. Some states also wanted to oblige recipients of enrichment and reprocessing technology to accept supplier involvement or some form of multinational participation as a condition of supply of enrichment and reprocessing technology. However, agreement among the NSG members on the idea of requiring such a condition proved impossible. Thus the relevant guideline reads,
>
> > "If enrichment or reprocessing facilities, equipment or technology are to be transferred, suppliers should encourage recipients to accept, as an alternative to national plants, supplier involvement and/or other appropriate multinational participation in resulting facilities, Suppliers should also promote international (including IAEA) activities concerned with multinational regional fuel cycle centres."
>
> The NSG guidelines did not define the meaning of the terms "supplier involvement" or "other appropriate multinational participation." Each individual member of the NSG is free to determine what these terms mean for any given transfer. This is a potentially important ambiguity, since some forms of supplier involvement or multinational participation could promote nonproliferation objectives while others could actually damage them.
>
> No Production of HEU. The guidelines required an assurance by the recipient nation that any transferred enrichment or reprocessing technology or a facility based on such technology will be designed or operated for the production of uranium enriched no higher than 20 % without the consent of the supplier.
>
> Replication of SNT. The NSG members agreed that the transfer of sensitive nuclear facilities, or major critical components thereof, or related technology, should require an undertaking (1) that IAEA safeguards apply to any facilities of the same type (i.e. if the design, construction or operating processes are based on the same or similar physical or chemical processes, as defined in the trigger list) constructed during an agreed period in the recipient country and (2) that there should at all times be in effect a safeguards agreement permitting the IAEA to apply Agency safeguards with respect to such facilities identified by the recipient, or by the supplier in consultation with the recipient, as using transferred technology. This provision was designed to prevent a recipient state that did not have full-scope safeguards from importing SNT under safeguards and then replicating another plant free of international safeguards. This requirement was subsequently deleted from the guidelines when the NSG adopted the requirement of full-scope safeguards as a condition of supply in 1992. Now that the NSG has exempted India from it full-scope safeguards requirement, the absence of a replication provision leaves a potential loophole, if members ever supply enrichment or reprocessing technology to India.
>
> Facilitation of the Application of Safeguards. Finally, the guidelines called upon suppliers to encourage the designers and makers of sensitive equipment to construct it in such a way as to facilitate the application of safeguards.

While the NSG has made a number of amendments and additions to its guidelines over the years and has grown in numbers to 45, the provisions for transfer of SNT have not changed except for the deletion of the replication provision.[2] By and large these

[1] President Ford's statement on nuclear policy of October 27, 1976 called on all nations to avoid transfers of sensitive nuclear technology for a period of at least three years.

[2] The NSG subsequently adopted a "non-proliferation principle" whereby a supplier, notwithstanding other provisions of the guidelines, should authorize a transfer only when satisfied that the transfer would not contribute to the proliferation of nuclear weapons. This principle would apply to enrichment and

guidelines were a pretty reasonable set of conditions for the transfer of sensitive nuclear technology.

Even before the NSG guidelines were published, both the French and German Governments adopted new policies to refrain from transferring reprocessing technology. France terminated its reprocessing contracts with Pakistan and cancelled its supply of reprocessing technology to the ROK and Taiwan. Germany backed out of its reprocessing deal with Taiwan. In December 1976, the French Government announced that it had decided no longer to authorize—until further notice—bilateral contracts pertaining to the sale to third countries of industrial facilities for spent fuel reprocessing. In June 1977 the German Government issued a declaration to the effect that it would not grant any license for the export of reprocessing facilities until further notice. Subsequent governments have reaffirmed this commitment. Although there has never been a similar pronouncement regarding enrichment, German government officials have indicated that it was safe to assume that what was said about reprocessing also applies to enrichment. The French subsequently clarified their policy to allow for transfers of sensitive technologies to countries already possessing such capabilities.

The policy and laws of the United States go even further than the European policies in restricting transfers of enrichment and reprocessing technologies and in sanctioning states that make such transfers.[3]

Since the adoption of the NSG guidelines (with the exception of some possible enrichment assistance by Russian entities to Iran,[4]) none of the NSG members has

reprocessing transfers. However, once again there is no standard interpretation of this clause, and each member of the NSG is free to interpret and apply this standard as it sees fit.

[3] The Nuclear Non-Proliferation Act of 1978 provides for draconian conditions for the export of SNT. Amendments to the Foreign Assistance Act sponsored by Senators Symington and Glenn in 1976 and 1977 provided for a cutoff of economic and military assistance to any country that imported or exported reprocessing or enrichment materials *unless* it agreed to place all such items under multilateral auspices and management when available along with acceptance by the recipient of comprehensive IAEA safeguards.

[4] In 1995 the US became aware that, in addition to signing an agreement to complete the Bushehr reactors in Iran, the Russians had agreed in a secret protocol to provide the Iranians with key fuel cycle facilities, including a uranium enrichment centrifuge plant. The US immediately pressed the Russians to terminate all assistance to the Iranian nuclear program. While the Russians did not agree to cancel their lucrative reactor deal with the Iranians, they did commit to limiting their nuclear cooperation with Iran to the Bushehr reactor project. Notwithstanding this commitment, Russian entities have engaged in extensive cooperation with Iranian nuclear research centers, which is outside the bounds of the Bushehr project. Much of this assistance has involved technologies with direct application to the production of fissile materials. See Robert Einhorn, Rose Gottemoeller, Fred McGoldrick, Dan Poneman, Jon Wolfstahl, The U.S.-Russian Nuclear Agreement A Framework for Cooperation, Center For Strategic and International Studies, Washington, D.C. ,May 2008.

transferred sensitive nuclear technology to states that did not already possess such technology.[5] Those transfers that have occurred were overt, legal, and for peaceful purposes. Most of the transfers involving enrichment were made to nuclear weapon states, and most of those involve the planned construction of enrichment facilities in the United States.[6] Even in several of these cases, there was no actual transfer of technology to the recipient. i.e., the technology was "black-boxed."

However, countries seeking materials, equipment and components for enrichment and reprocessing plants such as Iran, Iraq and Pakistan have been able to obtain from companies in NSG member states various items relevant to uranium enrichment by using surreptitious and illegal methods of procurement. The success of these efforts was in many respects the result of lax export controls exercised by various member states of the NSG. In addition, there have alarming revelations of clandestine transfers of enrichment technology from Pakistan to the DRPK, Iran and Libya.[7]

[5] France and the United States have transferred some reprocessing technology to Japan. For example, in the case of the United States, the Department of Energy began cooperation in the 1990s with Japan in liquid metal reactor reprocessing technology. DOE made the determination, however, that this cooperation did not constitute "sensitive nuclear technology" as defined by the Nuclear Non-Proliferation Act of 1978 since Japan already possesses extensive reprocessing technology. The French have also explained that their reprocessing cooperation with Japan is not inconsistent with France's earlier declarations not to export reprocessing technology because it involves transfers to a country that already possess such technology. (France played a major role in transferring technology to Japan for the construction of the Rokkasho plant and provided reprocessing technology to the Japan Nuclear Cycle Institute (JNC).

[6] NSG members have engaged in the following transfers of enrichment technology for civil projects, including the following:

Urenco has provided centrifuge technology to AREVA.

Urenco is constructing a centrifuge enrichment facility in the United States. (Louisiana Enrichment Services).

AREVA is planning to construct an enrichment facility in Idaho.

Australia is cooperating with GLE, the company created by GE Hitachi to build an enrichment facility in the United States, using the SILEX process. The Canadian company, Cameco, has recently purchased a share in the GLE. Russia has transferred centrifuge technology to China.

Argentina and Brazil have announced their intention to establish a binational company for uranium enrichment, but it is not clear whether this will involve the transfer of enrichment technology.

[7] An important effort to respond to the A.Q. Khan network was the adoption in 2004 of Resolution 1540 by the UN Security Council. UNSC Resolution 1540 calls on states to put in place "appropriate effective measures to account for and secure" WMD-related items in production, use, storage, or transport and to "maintain appropriate effective physical protection measures" of said items. The primary purpose was to deny such items to non-state actors, but it does oblige states establish effective export controls.

The U.S. Proposal

It was against the background of the revelations about the operations of the A.Q. Khan network that President Bush proposed two new initiatives designed to prevent the spread of enrichment and reprocessing capabilities. In a speech on February 11, 2004, President Bush proposed that a) the members of the NSG should refuse to sell enrichment and reprocessing equipment and technologies to any state that does not already possess full-scale, functioning enrichment and reprocessing plants and b) the world's leading nuclear exporters should ensure that states have reliable access at reasonable cost to fuel for civilian reactors, so long as those states renounce enrichment and reprocessing.

I believe the Bush initiative suffered from some serious flaws which have hampered the ability of the United States to achieve the objective it intended to advance.

First the U.S. proposal is good demonstration of the crucial importance of framing an issue properly and of using appropriate language in describing an initiative. The President's February 11, 2004, speech proposed to limit improved fuel assurances only to states that renounced enrichment and reprocessing plants and to restrict transfers of these technologies only to states that already possess these capabilities. In addition, the initial terminology used to describe the U.S.-proposed Global Nuclear Energy Partnership (GNEP) proposed dividing the world into so-called "fuel-cycle states" and "reactor states"— the latter category would consist of states that did not possess enrichment or reprocessing capabilities. A major objective of GNEP is to have a limited number of countries –so-called fuel cycle states, provide nuclear fuel to other states for reactors to generate electricity, and then remove the fuel for reprocessing or disposition.

The reaction of many non-nuclear-weapon states party to the NPT to these kinds of formulations was sharply negative. The language used to describe these U.S. proposals produced widespread perceptions that the United States was trying to establish a new global fuel cycle regime that would be highly discriminatory in nature. Perhaps most incendiary were the remarks of John Bolton, then Under Secretary of State for Arms Control and International Security, to the NPT Preparatory Conference in 2004 where he stated rather categorically that, "The Treaty provides no right to such sensitive nuclear technologies." This view was a significant departure from the position that the United States has taken in the past.[8]

[8] The United States has never supported the view that, regardless of the sensitivity of their national situations, parties to the NPT have an inherent right to acquire enrichment and reprocessing plants. Article IV of the Treaty refers to "the inalienable right of all the Parties to develop research, production and use of nuclear energy for peaceful purposes without discrimination and in conformity with articles I and II of this Treaty." The U.S. has always emphasized that the rights in Article IV were conditioned by a state's compliance with its nonproliferation obligations under the Treaty. Bolton's speech may be the first time that the US Government has ever made the assertion so explicitly and starkly that the NPT provides no right to states to possess enrichment and reprocessing technologies. This position would appear at variance from interpretive statements that the United States has made in the past with respect to Article II, Article III and Article IV of the NPT. For example, during the Senate hearings on the ratification of the NPT in 1968, the then of the Director of the Arms Control and Disarmament Agency, William Foster made the following remarks,

> "It may be useful to point out, for illustrative purposes, several activities which the United States would not consider per se to be violations of the prohibitions in Article II. Neither uranium enrichment nor the stockpiling of fissionable material in connection with a peaceful program would violate Article II so long as these activities were safeguarded under Article III. Also clearly permitted would be the development, under safeguards of plutonium fueled power reactors, including research on the properties of metallic plutonium, nor would Article II interfere with the development or use of fast breeder reactors under safeguards." Extension of Remarks by Mr. Foster in Response to Question Regarding Nuclear Explosive Devices", Hearings before the Committee on Foreign Relations, United States Senate on the Treaty on the Nonproliferation of Nuclear Weapons, July 10, 11, 12 and 17, 1968, p.39.

The reaction of key states have been quite forceful in voicing their objections to any fuel supply assurances scheme that they perceive as requiring them to forego or compromise their sovereign rights as independent states as well as their rights under Article IV of the NPT to pursue their own peaceful nuclear program. In reaction to these concerns, the U.S. began to backpedal from its language of renunciation and denial to emphasize that it had no intention of infringing on the sovereign rights of consumer states to make their own decisions with respect to their nuclear energy policies and programs. The U.S. has also made clear that, if consumer states elect to forego sensitive facilities as a price for gaining new fuel guarantees, they are doing so on a purely voluntary basis.

An illustration of this change in language was the signing of a "Statement of Principles" by states participating in GNEP in the fall of 2007. One of the principles employs language that is much softer than earlier used by the Bush Administration. It says, "States participating in this cooperation would not give up any rights, and voluntarily engage to share the effort and gain benefits of economical, peaceful nuclear energy." This was an important departure President Bush's speech of February 2004 and a far cry from the statement that John Bolton made at NPT Preparatory Committee in 2004.

However, the U.S. Congress reintroduced this kind of language again when it enacted the Henry J. Hyde United States-India Peaceful Atomic Energy Cooperation Act of 2006 (Public Law 109-401). This legislation required the President to make a determination as a condition of initiating nuclear cooperation with New Delhi that "India is working with and supporting United States and international efforts to prevent the spread of enrichment and reprocessing technology to any state that does not already possess full-scale, functioning enrichment or reprocessing plants." The Congress used similar terminology again in section 104 (a) of the United States-India Nuclear Cooperation Approval and

Nonproliferation Enhancement Act or 2008, which requires the President to certify that it is "the policy of the United States to work with members of the Nuclear Suppliers Group (NSG), individually and collectively, to agree to further restrict the transfers of equipment and technology related to the enrichment of uranium and reprocessing of spent nuclear fuel."

Thus, this kind of terminology has already caused a certain amount of damage and suspicions remain about U.S. intentions. Developing countries continue to be concerned (1) that the "voluntary" decision to forgo enrichment will cease to be voluntary, (2) that the NSG is a cartel, and (3) there is a lack of clarity as to how states would be determined to be in "good standing," and therefore eligible to access reliable nuclear fuel mechanisms.[9]

I have spent so much time on this issue of language not because I disagree that the U.S. should try to restrict the spread of enrichment and reprocessing. It is entirely appropriate to distinguish among qualitatively different situations in various countries, and there is nothing inappropriate in taking into account a recipient country's nonproliferation commitments, intentions, civil power needs and the near-term status of its energy program in mapping out prudent approaches to civil nuclear cooperation. However, the success of such a policy depends significantly on how the U.S. promotes this objective and on the kind of the language it uses. The framing of the issue has already had an important effect on the discussions that have taken place in the NSG on a new guideline for transfers of SNT. (See below.)

This brings me to the second flaw in the President's 2004 proposal. The initiative was made in reaction to the clandestine supply network of A.Q. Khan who had sold enrichment technology to Iran, Libya and North Korea. However, the proposal was not really designed to deal with such illegal and clandestine supply networks. It was directed at the members of the NSG. And as I have already noted, with the exception of reported transfers of sensitive technologies by Russian entities, none of these states had transferred enrichment or reprocessing technology since the 1970s to states that did not already possess such technology.

[9] For example, South Africa refused to attend the 16-nation signing ceremony for the GNEP principles. South African Minerals and Energy Minister Buyelwa Sonjica said that one of the unacceptable aspects of the GNEP's "Statement of Principles" was that it suggested that enriched uranium producers would supply other nations, whereas South Africa planned to keep refined fuel for domestic use. She said that, "Uranium is a strategic mineral for us." South Africa was also unhappy that, as a state with major uranium reserves and a past enrichment program it intended to revive, it was not consulted in the drafting of GNEP's covenant. Sonjica said, "That created some discomfort for us. And now that countries have already signed this Statement of Principles, I'm not sure if anyone will be keen to move the goalposts." Sonjica said that ultimately, "we need to ensure that no unwarranted restrictions are imposed on the right of states to pursue nuclear energy for peaceful purposes." See Mark Heinrich, "S. Africa refuses to join U.S.-led atom pact", Reuters, September 19, 2007.

So the President's proposal was in reality trying to formalize a practice that NSG members had quietly adhered to for some time. However, by trying to make this practice into a new formal and more specific NSG guideline, the U.S. proposal has exposed differences on what it means to "exercise restraint" in the transfer of such technologies. NSG members such as Canada, Argentina, Brazil and South Africa are interested in keeping their options open for either acquiring enrichment technology for their domestic nuclear power needs or for selling enriched uranium fuel on the international market, and they saw the U.S. proposal as threatening their economic interests. In addition, some NSG members are particularly sensitive about any proposal that appears to widen the divide between the nuclear-weapon states and the non-nuclear-weapon states.

The United States has pursued its proposal to limit transfers of enrichment and reprocessing in both the Group of Eight (G-8) and the Nuclear Supplier Group (NSG)

The United States persuaded the members of G-8 to adopt statements at each of their meetings from 2004 through 2006 indicating that they would not transfer of enrichment and reprocessing for one year. However, at the Heiligendamm G-8 meeting in 2007, the consensus on a moratorium on the transfer of enrichment and reprocessing began to unravel. Some suppliers, including Australia and Canada, supported a lifting of the moratorium. As a result the G-8 statement at the Heiligendamm summit was much more restrained than in previous years. The Heiligendamm statement reaffirmed the right of all parties to the NPT to the use of nuclear energy for peaceful purposes as enshrined in Article IV in conformity with all their Treaty obligations. Then it went on to state that,

> "We urge the NSG to accelerate its work and swiftly reach consensus. We agree to continue to undertake previously agreed actions on the understanding that should the NSG not reach consensus on appropriate criteria by 2008, we will seriously consider alternative strategies to reduce the proliferation risks associated with the transfer of enrichment and reprocessing goods and technologies."

However, the members of NSG have been unable to reach agreement on the issue of enrichment and reprocessing transfers due to a fundamental disagreement between the U.S. and most other members of the NSG. Although the U.S. sought a new guideline that would ban the transfer of SNT except to countries already possessing such capabilities, most NSG members favored an approach suggested by France that would allow NSG members to export sensitive nuclear technology to countries that meet specific criteria. This approach provided, among other things, that suppliers should not authorize the transfer of enrichment or reprocessing facilities and equipment and technology, if the recipient does not meet, at least, all of the following criteria:

> Is a party to the NPT and is in full compliance with its obligations under that Treaty;
>
> Is implementing a comprehensive safeguards agreement and has an Additional Protocol in force or is acting in accordance with the AP while actively working with the IAEA to conclude and implement an Additional Protocol;

Has not been identified by the IAEA as being in serious breach of its safeguards agreement, is not the subject of Board of Governors decisions calling upon it to take additional steps to comply with its safeguards obligations or to build confidence in the peaceful nature of its nuclear program, nor has been reported by the IAEA Secretariat as a state where the IAEA is currently unable to implement its safeguards agreement.

Is adhering to the NSG Guidelines and has reported to the Security Council of the United Nations that it is implementing effective export controls as identified by Security Council Resolution 1540;

Has concluded an intergovernmental agreement with the supplier including assurances regarding non-explosive use, effective safeguards in perpetuity, and retransfer;

Has made a commitment to the supplier to apply mutually agreed standards of physical protection based on current international guidelines;

Has committed to IAEA safety standards and adheres to accepted international safety conventions.

In addition the criteria-based proposal would provide that suppliers should consider

Whether the transfer would have a negative impact on the stability and security of the recipient state;

Whether the recipient has a credible and coherent rationale for pursuing an enrichment or reprocessing capability in support of civil nuclear power generation programs.

If enrichment or reprocessing facilities, equipment or technology are to be transferred, suppliers should encourage recipients to accept, as an alternative to national plants, supplier involvement and/or other appropriate multinational participation in resulting facilities. (This language is already in the present NSG guidelines and would remain unchanged in the new criteria-based approach.)

Most members have supported this approach. However, Argentina and Brazil objected to the requirement of an Additional Protocol. The U.S. opposed the criteria-based approach and insisted on an outright ban on the export of sensitive nuclear technology to states that do not already possess full-scale, functioning plants, since the President himself had used this uncompromising language in his February 2004 speech.

However, in April of this year, in a reversal of policy, the U.S. finally came to accept the criteria-based approach but proposed three additional criteria:

The transfer must take place under conditions that will not permit or enable the replication of the technology (the so-called "black-box" approach).

Suppliers have to take into account whether a transfer would stimulate other countries in a region to seek their own SNT or whether it might lead to instability in the area.

Suppliers will not transfer SNT to countries that have agreed to refrain from acquiring such technology. This is aimed at the South Korea and North Korea and their 1992 agreement under which both states agreed to refrain from possessing enrichment or reprocessing plants.

However, not all states supported the U.S. counter-proposal. Ottawa in opposed the black-box criterion, since Canada may have an interest in buying centrifuge technology from Urenco and wants to be able to upgrade this technology over time in order to compete effectively in the international market.

As a counterproposal, the Canadians suggested at the NSG meeting in May 2008, that, instead of requiring black-boxing as a criterion for transferring SNT, suppliers would only have to consider the option of black-boxing the technology, or operating a turn-key operation when deciding whether to transfer enrichment or reprocessing to states in good nonproliferation standing.[10] Since the U.S. was unable to accept this counter-proposal, this issue remains unresolved.

In addition, even though South Korea had reached an agreement in 1992 with the North Korea not to introduce enrichment and reprocessing technology to their respective territories, South Korea has a strong interest in acquiring nuclear fuel cycle technologies and objected to the U.S.-proposed criterion that suppliers would should not transfer SNT to countries that have already agreed to refrain from acquiring such technology.

Finally and perhaps most surprisingly, other NSG members objected to the U.S.-proposed criterion that suppliers would have to take into account whether a transfer of SNT would stimulate other countries in a region to seek SNT capabilities or whether such a transfer might lead to instability in the region. Two non-nuclear-weapon states took the position that all states in good nonproliferation standing are entitled to the peaceful benefits of

[10] Transferring enrichment technology under a "black-box" approach has, in fact, been the common practice in recent years. The Russian transfer of centrifuge technology to China, the Urenco transfer of technology to the U.S. and the proposed construction of Areva plant in the U.S. have taken place or are to take place under "black-box" conditions. An exception to this general practice may be the General Electric purchase of Silex technology from Australia. I understand that, unlike centrifuge technology, Silex technology apparently cannot be easily black-boxed, since the lasers involved in a Silex plant need a great deal of tending to by the operator.

nuclear energy, including enrichment and reprocessing. One of these states also said it could not go along with any negative criteria that denied states in good nonproliferation standing their rights to nuclear technology. On the other hand, both states indicated that they were prepared to go along with the objective criteria in the French proposal, e.g. whether a recipient state is not in violation of its nonproliferation obligations, adheres to the NPT, has a comprehensive safeguards agreement and the Additional Protocol in effect, etc. Some states opposed the earlier French-proposed criteria that suppliers should take into account "whether the recipient has a credible and coherent rationale for pursuing enrichment or reprocessing capabilities in support of civil nuclear power generation programs." They believe that this is a "negative" criterion and that only states that are engaged in "bad" behavior should be denied the right to sensitive nuclear technology. By contrast, the U.S. has called for this criterion to be made it mandatory.

Following these NSG discussions, the G-8 Tokyo meeting in July 2008 agreed that "….transfers of enrichment equipment, facilities and technology to any additional state in the next year will be subject to conditions that, at a minimum, do not permit or enable replication of the facilities; and where technically feasible reprocessing transfers to any additional state will be subject to those same conditions."

The G-8 statement reflects the fact that the U.S. has finally abandoned it insistence a new NSG Guideline that would ban the export or enrichment and reprocessing except to states that already possess fully functioning enrichment and reprocessing facilities. However, it does not mean that the Canadians have accepted the black-box approach that the U.S. recently proposed in the NSG. Rather Ottawa agreed to adopt the language in the G-8 statement only as an interim approach for one year.

Thus at this time, NSG members have been unable to agree on a new guideline for enrichment and reprocessing transfers.

The NSG and Multinational Enrichment

So now the question is: where does the NSG go from here, and is there some way that the NSG could promote an international norm that all enrichment facilities should be under some form of multinational auspices or control?

In considering this question, it is important to bear in mind certain fundamental characteristics of the NSG.

> First, the NSG is an informal multilateral export control mechanism whose understandings are not legally binding.
>
> Second, the NSG itself neither denies nor approves exports. Nor does it apply nonproliferation conditions to exports. Each member state approves or denies license applications in accordance with its own national export laws, regulations and policies. These are, however, based on common conditions of supply and principles voluntarily agreed to in the NSG.

> Third, the NSG leaves it to each member to implement its guidelines through national legislation, regulations and policies. This means that member states could have differences in interpreting and applying the principles contained in the guidelines, including what constitutes "supplier involvement" and "other appropriate multinational participation."
>
> Fourth, while the guidelines call upon the members to consult on matters connected with their implementation, the NSG has no mechanism to resolve disputes about differing interpretations of the guidelines, and there are no procedures to challenge the export behavior of members who may be straying from the guidelines or who violate NSG norms.
>
> Fourth, changing the NSG guidelines require approval by all member states. This means that a single member can block any alteration of or amendment to the guidelines. Eliminating consensus as the basis for decision-making seems highly unlikely.

It is important to have a realistic appreciation of these limitations of the NSG and to avoid excess expectations of what this multilateral export control mechanism can do to promote the idea of multinationalizing enrichment facilities.

Let's consider several options.

Black-boxing Enrichment Transfers. Up to this point, the NSG's discussion of new criteria for transferring enrichment and reprocessing technology has not included any explicit suggestions on modifying the existing guideline on encouraging supplier involvement or multinational participation as an alternative to national enrichment or reprocessing facilities. However, the NSG discussions on black-boxing transfers of enrichment technology have employed terminology that transfers must take place under conditions that will not permit or enable the replication of the technology. This language would seem to suggest at least some kind of "supplier involvement" or "other appropriate multinational participation" in the operation of the enrichment plant. If the NSG can agree on a new criterion that either encourages or requires such black-boxing, it would strengthen, or at least give some specificity to, the existing guideline by providing that transfers should not involve the revelation of sensitive information to the recipient. The United States is in a good position to promote the idea of black-boxing, since it has agreed to the construction of enrichment facilities in the U.S. under conditions that black-boxed the technology. However, even though black-boxing would remove some ambiguity from the existing NSG guideline, it still would be up to each supplier to determine what is meant by these various terms and how the guideline would be implemented in practice.

Requiring Multinational Plants as a Condition of Export. Another option would be to revive the debate that took place in the initial meetings of the NSG the mid-1970s when some states argued for a guideline that suppliers should "require" rather than encourage

"supplier involvement" or "appropriate multinational participation" as an alternative to national enrichment plants. Mandating multinational participation as a condition of export enrichment technology could be a complement to the idea of black-boxing technology transfers. However, whether the existing technology holders would be prepared to agree to making multinational participation an obligation is problematic. Moreover, given the sensitivity already displayed in NSG discussions of black-boxing, some members of the NSG may not be willing to take this course of action. Some non-NSG members may see this as a form of discrimination and a violation of their rights under Article IV of the NPT. On the other hand, objections to this criterion might be mitigated if NSG members who are also technology holders were to agree to place their own enrichment facilities under some form of multinational auspices or control. Whether present technology holders would be willing to make such an undertaking is an open question, but it may be worth testing the waters.

Supply Assurances and Offers of Multinational Participation. Some non-nuclear-weapon states, particularly developing countries, have viewed the NSG as a cartel that is aimed at keeping them from acquiring nuclear technology and at relegating them to a position of technical and commercial inferiority. The NSG has made efforts to combat this image by making its guidelines transparent and by launching various outreach activities. However, suspicions remain. While individual states and multilateral institutions such as the G-8 have made commitments to be reliable nuclear suppliers to states that abide the nonproliferation commitments, the NSG has remained exclusively an export control arrangement. The U.S. might consider whether NSG could assume a more positive and cooperative role in international nuclear commerce rather than one that is devoted exclusively to imposing nonproliferation conditions on nuclear exports. One way to do this would be for the NSG to adopt a common statement of principles that NSG members will strengthen the security of supply to importing countries and will not interfere with their supply arrangements as long as such states are in full compliance with their nonproliferation obligations. A suggested set of some principles of nuclear supply is attached. One of these principles could contain an offer to countries that do not possess such plants and that are in good nonproliferation standing the opportunity to participate in the enrichment plants of NSG member states. Such participation would include guaranteed supplies of nuclear fuel but would not include access to enrichment technology. This principle would involve the adoption by NSG enrichment technology holders of the approach that the Russian Federation has established for Angarsk. Whether NSG technology holders would be prepared to make such an offer is open to question, but this may also be worth testing the waters.

Conclusions

Some key states have been quite forceful in voicing their objections to any fuel supply assurance or fuel cycle schemes that would require them to forego or compromise their sovereign rights as independent states or their right under Article IV of the NPT to pursue their own peaceful nuclear program, including enrichment technology. Some NSG members are acutely sensitive to this question.

In the case of most developing countries, charges of discrimination against the NSG may be more political and symbolic than practical, since only a small number of countries have the resources or infrastructure that would justify the establishment of an enrichment capability. Moreover, while several states have expressed an interest in acquiring a commercial enrichment capability at some time in the future, they do not appear to have developed specific plans to do so at this time. Further, the members of the NSG have by and large been exercising restraint in transferring enrichment and reprocessing technology to other countries, and none seem eager to part from this practice.

For these reasons, there is no urgency for the NSG to rush to issue a set of new criteria governing the export of enrichment technology. The U.S. and NSG must proceed carefully and in a manner that recognizes the sensitivities and concerns of consumer states and non-nuclear weapon states in particular.

It is not clear at the present time if or when the NSG members will agree on a new guideline for enrichment and reprocessing transfers or what that guideline will provide. The next U.S. Administration could consider taking a new approach to amending the NSG guidelines on the transfer of enrichment technology. While this approach needs to include effective controls on the transfer of sensitive information, it could go beyond the language of restrictions and denials and propose a more positive approach of offering opportunities for multinational participation in NSG member state enrichment plants.

Whatever the NSG does in this regard, we must bear in mind that the NSG is an informal multilateral regime whose primary purpose is to control nuclear exports. The NSG can play a role in promoting the idea of multinationalizing enrichment plants but that role is limited. If the objective is to make multinational rather than national enrichment facilities an international norm, then it will be necessary to obtain a wider consensus in support of this idea especially and needs to include consumers and non-nuclear-weapon states. One possible way to accomplish this is by persuading the NPT Review Conference to endorse this norm. However, this will be no small task, given the sensitivity of many states with respect to the rights under Article IV of the Treaty.[11] The nuclear weapon states and technology holders would have to embrace this norm for their own facilities and promote this objective internationally with a much greater degree of diplomatic deftness and sophistication that the U.S. has shown thus far.

[11]At the meeting of the 2008 NPT Prepcom, the nuclear weapon states issued the following statement: " We welcome the work of the International Atomic Energy Agency on multilateral approaches to the nuclear fuel cycle and encourage efforts towards a multilateral mechanism to assure access for all countries to nuclear fuel services as a viable alternative to the indigenous development of enrichment and reprocessing." It would be useful if all parties to the Treaty were to join in issuing a similar statement at the 2010 NPT Review Conference.

Attachment:

Suggested NSG Nuclear Supply Principles

The members of the NSG:

Reaffirm the inalienable right of all parties to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) to the use of nuclear energy for peaceful purposes in conformity with their obligations under the NPT.

Agree to promote international cooperation in the peaceful uses of nuclear energy.

In this spirit, NSG members agree to:

Implement all nuclear supply agreements and contracts in good faith and with due regard to the legitimate commercial interests of importing states.

Avoid hampering or delaying the peaceful nuclear activities in the territories of importing states.

Avoid hindering, or interfering in, the peaceful nuclear activities in the territories of importing states.

Take full account of the long-term requirements of the nuclear energy programs in the territories of importing states.

Will not use their supply agreements or contracts to secure unfair commercial or industrial advantage to the disadvantage of the importing state, or to restrict trade or to hamper the international or domestic commercial or industrial interests of the importing states.

Will not use authorizations, including export licenses and authorizations or consents to third parties relating to trade or industrial operations, in order to restrict peaceful nuclear trade.

Will cease cooperation or suspend nuclear supplies only if an importing state materially violates its nonproliferation obligations.

Will urge other nuclear suppliers to cease cooperation or suspend nuclear supplies to a state only if that state materially violates its nonproliferation obligations.

In addition, members of the NSG who operate uranium enrichment plants are prepared to provide states that do not have such facilities and are in full compliance with their

nonproliferation obligations the opportunity to participate in their enrichment plants. Such participation would include guaranteed access to nuclear fuel supplies.

ACA | Arms Control Association

The NSG and Sensitive Nuclear Fuel Cycle Technologies in the Aftermath of the U.S.-Indian Nuclear Cooperation Deal

Oct. 21, 2008
Daryl G. Kimball, Executive Director

A key part of any international strategy to prevent the spread of sensitive fuel cycle technologies and the risk of additional "virtual" nuclear weapon states is an effective nuclear export control regime involving all major supplier states. While denial strategies have their limitations and can produce pushback, they will continue to be an essential element in the years ahead.

For nearly three decades, the Nuclear Suppliers Group has effectively helped to reinforce the nuclear Nonproliferation Treaty (NPT) by helping to restrict nuclear trade to states in good standing with the NPT. The NSG has encouraged a policy of general restraint with respect to the most sensitive fuel cycle technologies. In recent years as the number of participating governments has grown, and until this year's decision to exempt India from its guidelines the NSG had become an increasingly important nonproliferation instrument.

New enthusiasm for nuclear energy, increasing interest in enrichment and fuel disposition services, the risks posed by the black market in nuclear technology and equipment, and the recent exemption of India from NSG guidelines warrant new efforts to update and strengthen NSG guidelines, particularly as they relate to enrichment and reprocessing transfers.

If multinational and/or international fuel cycle centers are developed as an alternative to indigenous enrichment and reprocessing programs and plants, NSG guidelines should be calibrated in such a way as to promote multilateral or international options.

The following is a summary of the current discussion within the NSG regarding tougher guidelines on enrichment and reprocessing transfers and some preliminary recommendations for the near term.

The NSG Waiver for India and Its Aftermath

In an unprecedented move that will undermine the value of the Nuclear Suppliers Group (NSG) and the already beleaguered nuclear Nonproliferation Treaty (NPT), the NSG reluctantly agreed Sept. 6 to exempt NPT holdout India from its guidelines that require comprehensive international safeguards as a condition of nuclear trade.

The decision is a nonproliferation disaster of historic proportions that will produce harm for decades to come. It severely erodes the credibility of global efforts to ensure that access to nuclear trade and technology is available only to those states that meet global nuclear nonproliferation and disarmament standards. India, does not.

The decision by the 45 members of the NSG to exempt India from the comprehensive safeguards condition of supply contradicts one of the key decisions made by the 180-plus NPT states parties at their 1995 Review and Extension Conference. The NSG waiver for India almost certainly will provoke some non-nuclear weapon NPT states parties to resist taking on any additional nonproliferation obligations, including measures that might seek to limit their perceived Article IV rights.

Furthermore, foreign supplies of nuclear fuel to India's civil nuclear sector will clearly reduce or eliminate India's need to sacrifice electricity production to produce weapons-grade plutonium. This will enable India to increase the rate of fissile material production for bombs and worsen nuclear arms competition in Asia. This also constitutes a violation of the spirit, if not the letter, of Article I of the NPT, which commits the five original nuclear weapon states not to assist "in any way" the nuclear weapon program of another state.

Most importantly for the purpose of this discussion, the Bush administration—along with allies such as France, the United Kingdom, Brazil, and South Africa—compounded the damage to the nonproliferation regime by rebuffing efforts by a group of responsible NSG states to incorporate into the NSG statement on India provisions in U.S. law that severely restrict transfers of sensitive nuclear fuel-cycle technologies to India and mandate a cutoff of nuclear trade if India resumes nuclear testing.

Restrictions on enrichment and reprocessing-related trade with India is only common sense given that IAEA safeguards cannot prevent replication for use in India's nuclear weapons program.

Despite U.S. government statements and authoritative written responses to Congress that the fuel supply assurances referenced in the U.S.-Indian agreement for nuclear cooperation are not intended to insulate India against the effects of nuclear testing, the Indian government insists that the United States is politically obligated to maintain such trade even if India tests. How the United States and other nuclear fuel suppliers would respond if India resumes nuclear testing is not clear.

There are other problems with the proposal, but essentially, the NSG decision on India will have several adverse impacts including:

1. Supplier states will be more likely to ignore NSG guidelines: The NSG waiver for India has already prompted China to commit to help NPT-hold out Pakistan build two new reactors at Chasma, which would be a violation by Beijing of current NSG guidelines.
2. Potential enrichment and reprocessing states will be less willing to forego their options. The response of several states to the initiative for nuclear cooperation for India has been, essentially, we have better nonproliferation credentials than India and therefore they should not be subject to more restrictive terms of trade regarding the transfer of enrichment or reprocessing than India. Canada, Brazil, South Africa, Iran, and even Israel have complained in various ways about the double-standard.
3. The purpose of fuel supply assurances has been muddied and the response to Indian nuclear testing is not certain. U.S. 123 agreement, as interpreted by United States is not intended to provide assurances against anything but market disruptions, yet India insists otherwise. Whether Russia would join the United States, France, and others in terminating nuclear cooperation if India resumes testing is not clear. The ambiguous relationship between India's nonproliferation commitments and the continuation of nuclear trade could also make

it far more difficult to create an objective set of nonproliferation criteria for nuclear supply, including access to sensitive fuel cycle technologies.

Plugging the Holes in NSG Policy

The NSG decision on India puts us on a slippery slope, but we have not yet begun to slide down the slope. It is important to consider and pursue some basic improvements in NSG policy regarding enrichment and reprocessing transfers in order to reduce future proliferation risks and plug the enrichment and reprocessing hole in the NSG policy on India.

In practice, it is unlikely that suppliers will transfer enrichment or reprocessing technology to India anytime soon. The NSG waiver for India maintains that NSG states must continue to "exercise restraint" with respect to transfers of sensitive dual-use technologies and enrichment and reprocessing technologies to India or any other state. And, according to the Bush administration, no NSG participating government—including France and Russia—intends to transfer enrichment or reprocessing technology to India. Yet, India continues to demand "full" access to the nuclear fuel and technology market, and supplier states intentions could change, especially if they smell a profit.

Before agreeing to consider the U.S.-Indian nuclear cooperation agreement last month, the House and Senate should have demanded that the United States win support for tougher NSG guidelines on enrichment and reprocessing transfers. Under heavy political pressure to rush the flawed deal through, they failed to do so.

In exchange for quick House approval of the India agreement, however, Secretary of State Condoleezza Rice acknowledged the NSG loophole in a personal commitment to Howard Berman (D-Calif.), chair of the House Committee on Foreign Affairs. Rice promised that the United States will make its "highest priority" to achieve a decision at the next NSG meeting to prohibit the export of enrichment and reprocessing equipment and technology to states that are not party to the NPT.

Tougher NSG standards on sensitive fuel cycle technologies are long overdue. NSG discussions on the matter predate the proposal for opening nuclear trade with India and are ripe for a decision.

The 2004 Bush administration proposal for a complete ban on sensitive fuel-cycle technology transfers to states without such capabilities was a crude if well-intentioned response to the A.Q. Khan and Iran secret enrichment program revelations.

The approach, coming on the heels of the Bush administration's rejection of key commitments related to nuclear disarmament made in the context of the NPT reinforced many NSG states objections. Some states, including France, suggested a criteria-based approach, but the United States said "no" and blocked agreement.

Just ahead of the May 2008 NSG meeting, the United States adjusted its position and threw its support behind a modified version of the French-inspired criteria-based proposal. The May 2008 NSG meeting discussed a proposal that would have led to amendments to NSG guidelines restricting enrichment and reprocessing technologies to states that:

- have not signed the NPT or do not have comprehensive IAEA safeguards;

- have not negotiated and implemented an additional protocol to their International Atomic Energy Agency safeguards agreement;
- are not in compliance with their NPT or safeguards obligations; or
- are located in regions in which such transfers might promote proliferation or undermine security.

Washington also sought that if enrichment or reprocessing transfers do occur, they should be executed only via "black box" technologies, wherein only the supplier can access and own the technology. Canada has opposed this provision, thereby blocking consensus on the package.

On the matter of the so-called "black box" criteria, there is some risk that such a policy could in the long-run be used to justify transfers of enrichment equipment and facilities to states not possessing such technology or that meet some but not all of the objective and subjective criteria of the May 2008 NSG proposal. Furthermore, given that there is currently no standard or common set of definitions regarding what technical and regulatory barriers are necessary in order to achieve "black box," the adoption of this criteria could create a false sense of security.

Nevertheless, the United States and other key supplier states should now follow through and rally NSG support for tougher NSG guidelines along the lines of the May 2008 criteria-based proposa in order to help mitigate some of the damage caused by the waiver for India and to reduce the risks posed by possible enrichment and reprocessing exports in the future.

The NSG will convene for its next Consultative Group meeting in November. By NSG standards, consensus is within reach. Since May 2008, U.S. and Canadian officials has been trying to work out a resolution to their differences and a new draft proposal is apparently in the works.

However, other substantial hurdles must be overcome. Brazil, Argentina, and possibly others must be prevailed upon to drop their opposition to the additional protocol criterion or else a work-around must be pursued to address their concerns. It is likely that the NSG discussion on new guidelines on enrichment and reprocessing guidelines will continue into 2009.

Additional Options

Another key goal of NSG policy could be to further promote multinational or international enrichment options as an alternative to transfers to national facilities in states that do not already possess capabilities. The existing NSG guidelines (para 6) call on "suppliers to encourage recipients to accept, as an alternative to national plants, supplier involvement and/or appropriate multinational participation and also promote international activities concerned with multinational regional fuel cycle centers."

Taking into account the many technical, political, economic, and safeguards hurdles in the way of a new multinational or international approach to the front-end or the back-end of the fuel cycle, how else might the NSG do to improve upon its vague and voluntary policy?

Borrowing from the law governing U.S. nuclear trade with India, a new criteria/limitation that could be incorporated in an amended set of paragraph 6 and 7 NSG guidelines could be to call upon supplier states:

- to ***refrain*** from new enrichment facility startups except in cases where the recipient facility is safeguarded by the IAEA and is part of a multinational or international fuel cycle center.

The shift here is to move away from encouraging multilateral involvement in enrichment projects as an alternative to national ownership, to refraining from involvement in anything but a multilateral or international project.

Depending on perceptions of how the international fuel supply and fuel services industry is organized at the time of the decision, this NSG policy could be perceived as discriminatory, just as the 2004 Bush proposal to bar further NSG enrichment and reprocessing transfers. If so, such a policy might have a limited impact on dissuading states from pursuing indigenous fuel cycle projects.

Nuclear Suppliers Group on "Special Controls on Sensitive Exports" and "on Export of Enrichment Facilities, Equipment, and Technology"

Current NSG Policy (Paras 6 & 7 of INFCIRC/254/Rev.8)	**Criteria-Based Approach** (Proposed May 2008)	**Alternative Approach** Sub-Head (if needed)
• "suppliers should exercise restraint in the transfer of sensitive facilities, technology, and material usable for nuclear weapons …" • "suppliers should encourage recipients to accept, as an alt. to national plants, supplier involvement and/or appropriate multinational participation…" • "Suppliers should also promote intl. activities concerned w/multinational regional fuel cycle centers." • "For a transfer of an enrichment facility, the recipient nation should agree" that it will not be "designed or operated for the production of greater than 20% enriched uranium…."	Suppliers should exercise a policy of restraint …. In the context of this policy, suppliers should not authorize" transfers if the recipient does not meet, at least, all of the following criteria: " • Is party to the NPT and has CSA; • **Signed & is implementing AP;** • Not in breach of safeguards; • Is adhering to the NSG guidelines and is implementing effective export controls as per UNSC 1540; • Has concluded agreement on assurances regarding non-explosive use, effective safeguards in perpetuity, and retransfer; and is meeting phys. protection & safety standards; "Suppliers should [also] consider other factors …." • General conditions of stability and security; • Whether transfer would have a negative impact on stability and security of the recipient; • Whether there is a coherent rationale for E&R tech.; • **Whether the transfer might provoke other countries in the region to do seek sensitive technologies.** Suppliers should design/construct enrichment facility in a way as to preclude enrichment > 20% … and; Suppliers should provide … only complete turnkey systems & facilities; **Suppliers should seek agrmt. that recipient accepts transfer under conditions that don't permit/ enable replication (i.e. black box).**	Existing policy of "restraint," plus: • Key elements of May 2008 criteria, including; NPT signatory, CSA, AP, not in breach of safeguards, adhering to NSG guidelines and export controls; • Supplier states shall not transfer sensitive facilities or technology, particularly those relating to uranium enrichment, spent fuel reprocessing, or heavy water production unless the transfer directly involves an IAEA-safeguarded multilateral or international fuel cycle center; • Recipient state has signed and ratified the CTBT; • Has declared a halt to fissile material production for weapons puposes.

Summary of NSG Participating Government Views on E & R Guidelines

	Broad NSG Support	**Limited NSG Opposition**	**Limited NSG Support**
Current Policy of Restraint	X		
NPT Membership/CSA	X		
Additional Protocol		…from Argentina, Brazil, and possibly others	
Not in Sensitive Region	X		
Black Box		…from Canada, others	… from the United States, others
Mult. Fuel Cycle Ctr. Only	?	?	?

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Assurances of Supply and Non-proliferation – The Legal Aspects

Yury Yudin

20 October 2008

The Need for A New Framework

The increase in global energy demand is driving an expected expansion in the use of nuclear energy. This means an increase in the demand for fuel cycle services. It also means an increase in the potential proliferation risks created by the spread of sensitive nuclear technology… The convergence of these trends points clearly to the need for the development of a new, multilateral framework for the nuclear fuel cycle. In my view, such a framework could best be achieved through establishing mechanisms that would assure the supply of fuel for nuclear power plants – and over time, by converting enrichment and reprocessing facilities from national to multilateral operations…

Introductory Statement to the Board of Governors by
IAEA Director General Dr. Mohamed ElBaradei, 11 June 2007

The View of A New Framework

- A multilateral framework that would facilitate the future use of nuclear energy should be equitable and accessible to all users of nuclear energy, acting with accordance of agreed non-proliferation norms
- No new dividing lines among NPT parties should be created and thus a multilateral framework should not be imposed but be a matter of voluntary agreement (imposed denial fosters resentment and is not effective in the long term)
- The establishment of a new framework would be a complex endeavor that would likely require a phased approach

The View of A New Framework

The IAEA believes that such a multilateral framework could best be achieved through establishing mechanisms that would:

- assure the supply of fuel for nuclear power plants;
- over time, convert enrichment and reprocessing facilities from national to multilateral operations; and
- limit future enrichment and reprocessing to multilateral operations.

A Framework for Assurances of Supply

- Such a framework is voluntary and States are free to choose their fuel options – no rights of States would be compromised
- It is important to retain flexibility. Diversity of proposals enables consumer States to choose options according to their needs
- A possible framework would not be a substitute for the existing international uranium enrichment market, but a backup mechanism

A Framework for Assurances of Supply

According to the IAEA, for LEU supply a possible new framework can be established on three levels:

- Level 1: existing global market arrangements;
- Level 2: backup commitments provided by suppliers of enrichment services and their respective governments to assure supply in cases of political disruptions when predetermined criteria are met;
- Level 3: a physical LEU reserve under IAEA control, or a virtual LEU reserve based on commitments by governments to make LEU available to the IAEA.

A Dozen Proposals

- At present there are 12 proposals for a multilateral approach to the nuclear fuel cycle
- All of these proposals, in one way or another, deal with assurance of supply of LEU
- The solutions so far contemplated can be categorized into three groups:
  - providing backup assurances of supply;
  - establishing an IAEA-controlled LEU reserve;
  - establishing/placing uranium enrichment facilities under some form of international control, including an IAEA-controlled uranium enrichment facility.

The IAEA's Role and Legal Aspects

All of these proposals call for an active participation of the IAEA, envisaging that the status of the Agency would give potential consumer States greater confidence in a multilateral approach.

This raise the question of whether the IAEA's role in them would have a sufficient basis in the IAEA's Stature.

The IAEA's Role and Legal Aspects (2)

The provisions of the IAEA's Stature are sufficiently broad to allow the Agency:

- to establish its own stock of nuclear material purchased from, or donated by, Member States for supply to another Member State;
- to facilitate the supply of nuclear material from one Member State to another;
- to facilitate enrichment and fuel fabrication services by one Member State to another or to the Agency.

The IAEA's Stature

Article III of the Stature sets the general stage. Under this Article the Agency is authorized "to act as an intermediary for the purposes of securing the performance of services or the supplying of materials, equipment, or facilities by one Member of the Agency for another; and to perform any operation or service useful in research on, or development or practical application of, atomic energy for peaceful purposes".

Article III.C determines that "the Agency shall not make assistance to Members subject to any political, economic, military, or other conditions incompatible with the provisions of this Statute".

The IAEA's Stature (2)

Article IX.A and **B** of the Stature provide that nuclear materials made available to the Agency may, at the discretion of the Member making it available, be stored either by the Member concerned or, with the agreement of the Agency in Agency storage facilities.

If the Agency undertakes that storage, **Article IX.H** requires "that the Agency shall ensure the geographical distribution of these materials in such a way as not to allow concentration of large amounts of such materials in any one country or region of the world".

The IAEA's Stature (3)

Article IX.D provides that "a Member shall, from the materials which it has made available [to the Agency], without delay deliver to another Member or group of Members such quantities of such materials as the Agency may specify".

Article IX.E provides that the quantities, form and composition of materials made available by any Member can only be changed with approval of the Board.

Article IX.J determines that no Member has the right to require that the materials it makes available are kept separately or used only for a project designated by it.

The IAEA's Stature (4)

The Stature sets a number of requirements that have to be met in order to make the supplied material available to a Consumer State.

Article XI.A and **C** require specific "Agency projects" as a precondition to assist Member States in securing nuclear materials, services, equipment and facilities.

The term "Agency projects" should be understood as covering all types of assistance granted by the Agency including assistance in the context of assurances of supply.

The IAEA's Stature (5)

With regard to the release of nuclear materials, **Article XI.E** lays down a number of specific criteria, including:

- the usefulness of the project, including its scientific and technical feasibility;
- the adequacy of plans, funds, and technical personnel to assure the effective execution of the project;
- the adequacy of proposed health and safety standards for handling and storing materials and for operating facilities;
- such other matters as may be relevant.

The IAEA's Stature (6)

The last bullet precisely allows for the establishment of additional release criteria regarding compliance with non-proliferation obligations and lack of access to normal commercial supply due for political reasons.

In order to ensure equal access by all Member States to any proposed mechanism for assurances of supply, these release criteria will have to be pre-established and be the same for all States wanting to avail themselves in this mechanism.

As IAEA Director General has stated, such criteria would have to be "non-political" and "applied in a consistent and objective manner".

The IAEA's Stature (7)

Article XI.F sets out certain project criteria. Some of them are:

- ensuring that the material is used for peaceful purposes and that safeguards are applied to the material;
- making the necessary security arrangements for the material;
- meeting of the applicable health and safety standards;
- covering patents and copyrights that may arise out of the supply of the material;
- provision for the settlement of disputes.

Needed Legal Arrangements

A number of legal arrangements would be needed to make any assurance of supply mechanism in the context of Level 3 work in practice. These arrangements would vary depending on whether title to the material passes through the Agency or whether it passes directly from the Supplier State to the Consumer State.

The most obvious arrangements are listed below:

Needed Legal Arrangements (2)

- an arrangement between the Supplier State and the Agency (Supply Agreement). In this context, elements of national law, such as consent rights, licensing, transport and immunities have to be considered;
- an arrangement between the Consumer State and the Agency (Project Agreement) to include inter alia the issues listed in **Article XI.F** of the Stature;
- underlying commercial contracts between the actual supplier company (whether state or industry), the Agency and the customer company (again whether state or industry);

Needed Legal Arrangements (3)

- in case the Agency establishes an actual bank of nuclear fuel, agreements covering safeguards, security and possibly liability for nuclear damage with the host State as well as transit agreements with neighboring States need to be concluded. The host country agreement should also cover corresponding privileges and immunities;
- in case a commercially run enrichment plant is established in a territory administered by the IAEA, agreement on protection of technology between the Agency and the host country of supplier of technology and the supplier of technology need to be concluded.

IUEC in Angarsk

According to Rosatom, the basic principles of IUEC are:

- equal and non-discriminatory membership;
- guaranteed access to uranium enrichment services for IUEC members;
- the IUEC is a commercial open joint stock company;
- transparency of IUEC activities through placement of its nuclear materials under IAEA safeguards;
- the IUEC is a “black box”, as participant states would not have access to Russian enrichment technologies;
- political and economic advantages from membership in the IUEC would discourage its participant-states from development of indigenous technologies.

IUEC in Angarsk (2)

In addition to uranium enrichment services, Russia will help create an IAEA-controlled LEU fuel bank at the Angarsk site, which would provide the Agency with means to assure supply to customer states in case of a politically motivated disruption of supply. The bank would hold about 120 tones of LEU.

IUEC in Angarsk (3)

- Russia hopes that the IUEC in Angarsk would serve as a model for similar international enrichment centers in other parts of the world
- The IUEC is a first step to make the IAEA's Multilateral Nuclear Approaches concept a reality
- No matter the outcome, the lessons of the IUEC will be shared by all

IUEC in Angarsk – Legal Aspects

- Russia implemented numerous necessary changes in domestic legislation
- Russia has paved the way for IAEA inspections at the Angarsk facility by ratifying and signing into law the IAEA Additional Protocol;
- An agreement between Russia and IAEA, outlining the Agency's role in the project, is expected to be signed soon

IUEC and a New Supply Framework

- Level 1: provides guaranteed access to enrichment capabilities to IUEC members; diversities the list of suppliers; is "market neutral"
- Level 2: IUEC can fill the gap if another supplier defaults on supply for political reasons
- Level 3: an independent IAEA-controlled fuel bank can help build a significant layer of confidence in "assured supply"

NTI LEU Stockpile

- The Nuclear Threat Initiative offered a conditional grant of $50 million to the IAEA to help create a LEU stockpile owned and managed by the IAEA
- Level 3: an independent IAEA-controlled fuel bank can help build a significant layer of confidence in “assured supply”
- Key issues still to be determined include the stockpile's content, location, access criteria, safety and export control issues, the fuel’s pricing, etc.

MESP

- The German proposal – Multilateral Enrichment Sanctuary Project (MESP) – favors the creation of a multilateral enrichment center under IAEA control and supervision and on a site that had been granted extraterritorial status
- An independent management board or consortium would finance and run the plant on a commercial basis
- The IAEA would have responsibility for oversight of such a center and would decide whether to supply LEU according to pre-determined criteria

MESP (2)

- The IAEA would not have any access to sensitive technology and know-how; the plant would be constructed as a “black box”
- A MESP host country should not already have enrichment capabilities but needs to have a suitable infrastructure and political stability, adhere to safeguards agreement, and to be in good standing with the NPT
- Members of MESP “remain free to develop their own enrichment technology, if they choose to do so and circumstances require”

MESP and a New Supply Framework

- Level 1: diversities the list of suppliers; it is not a completely “market neutral” but “politically neutral” option
- Level 2: MESP can fill the gap if another supplier defaults on supply for political reasons
- Level 3: MESP might be a part of this mechanism but details are yet to be determined. It was preliminary discussed to include a small revolving buffer stock under the direct control of the IAEA

MESP – Legal Aspects

- The MESP concept is still require further refining
- Currently two model agreements are being drafted, which could serve as legal basis for MESP: a Host State Agreement between the IAEA and a host state and a Multilateral Framework Agreement between the IAEA and a Group of States interested in participating in MESP

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Some Conclusions – Legal Aspects

- A greater progress toward a multilateral approach has already been made than was possible during 1970s and 1980s
- The IAEA's Stature provides a sufficient legal basis for the IAEA's role in a multilateral approach
- To actually make any assurance of supply mechanism work in practice, many more legal arrangements are needed
- Valuable lessons will be learned from the IUEC, MESP and other proposals

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Enrichment Needs and Nonproliferation Assurances in India and Pakistan

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Presentation at the MIT Workshop on

Internationalizing Uranium Enrichment

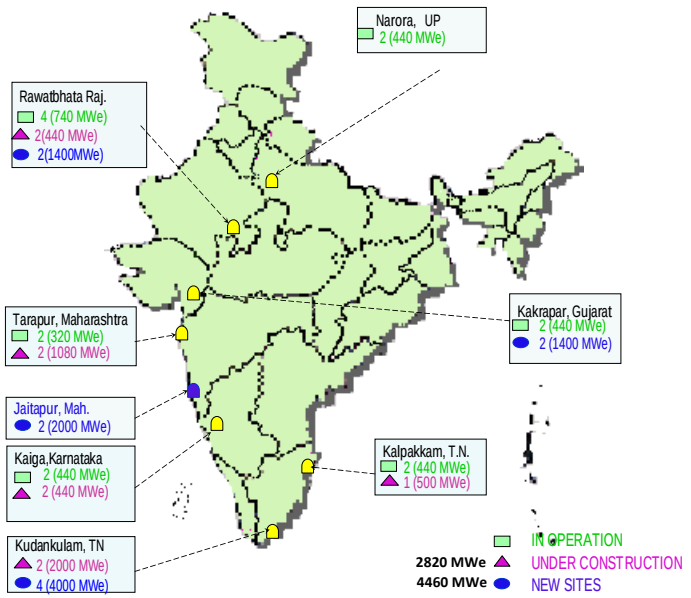
Cambridge, MA
October 20-21, 2008

India's Nuclear Program

India Nuclear Capacity Projections to 2020

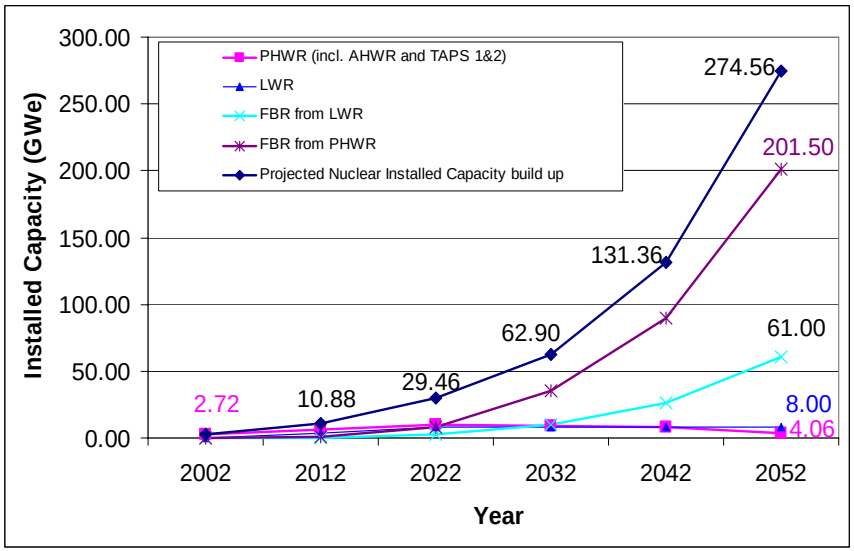
Reactor Types and Capacities	Capacity (MWe)	Cumulative Capacity (MWe)
17 Reactors at Six Sites in Operation; Tarapur, Rawatbhata, Kalpakkam, Narora, Kakrapar, Kaiga	4,120	4,120
3 PHWRs under Constructon at: Kaiga 4 (220 MWe), RAPP 5 & 6 (2 x 220 MWe)	660	4,780
2 LWRs under Construction at Kudankulam (2 x 1,000 MWe)	2,000	6,780
PFBR under Construction at Kalpakkam (500 MWe)	500	7,280
Total Installed Capacity by ~ 2012		**7,280**
Future PHWRs by 2010 - 2020 (8 x 7oo MWe)	5,600	12, 880
Future FBRs 2012 – 2020 (4 x 500 MWe)	2,000	14, 880
Future AHWR (1 x 300 MWe)	300	15,180
Total Year 2012 Capacity Plus India Technology Nuclear Plants by 2020		**15, 180**
Future Imported LWRs 2012 - 2020 (6 x 1,000 MWe)	6,000	21,180
Total Installed Capacity by 2020		**21,180**

Nuclear Power Plants in India - Sites



- 3360 MW in operation
- 3920 MW under construction
- 8800 MW new sites identified

Projected Installed Nuclear Power Capacity build-up – Reactor Type Breakdown



New ALWR Construction Plans – October 2008 - NPCIL

- **Following passage of U.S. India Deal, plans for new ALWRs construction are being developed:**
- **New ALWRs will be constructed by Nuclear Power Corporation of India Limited (NPCIL), possibly by National Thermal Power Corporation (NTPC), both India Government monopoly corporations**
- **Other large industrial corporations will provide components before allowed in as nuclear power plant (NPP) owners**
- **NPCIL, NTPC will contract with Areva, General Electric, Westinghouse, Rosatom for ultimate supply of 6-8 ALWRs each**
- **Total ALWRs capacity expected as 20 – 30 GWe by 2020, at total investment of ~ 80 Billion Dollars**
- **Planned Capacity could reach 40 Gwe of ALWRs by 2020 (A case of 'Irrational Exuberance'?)**

New ALWR Construction Plans – October 2008 (Cont.)

- **New ALWRs will allow additional time for DAE/Bhavini to accelerate FBRs construction, close FBR fuel cycle**
- **Closing FBR fuel cycle (rep-fabrication step) much more important near-term technology import for India, rather than importing enrichment plant technology**
- **Each foreign vendor will receive dedicated site for its NPPs;**
  - **Rosatom will construct at least 4 additional VVER-1000 (4,000 MWe) at Kudankulam site of current 2 VVER-1000 construction**
  - **Areva will receive Jaitapur site for 2 EPRs (2 x 1,500 Mwe PWRs). Further 4 EPRs planned for that site later**

New ALWR Construction Plans – October 2008 (Cont.II)

- **Westinghouse, GE, will each construct two ALWRs on a new site. (AP-1000 – 1,140 MWe, ESBWR – 1,700 MWe). Four new sites are now short-listed by India Government**
- **Kaiga site (4 x 220 MWe PHWRs) could incorporate future ALWRs (2 x 1,000 MWe ALWRs)**
- **NPCIL can now finance 10 ALWRs. Not all announced NPPs can be constructed concurrently due to supply limitations**

Power Reactors Planned or Firmly Proposed – 10/2008

Reactor	Type	MWe net, Each	Project Control	Start Operation
Kakrapar 3 & 4	PHWR	640	NPCIL	2012
Rawatbhata 7 & 8	PHWR	640	NPCIL	2012
Kudankulam 3 & 4	PWR - VVER	1000/1200	NPCIL	
Jaitapur 1 & 2	PWR - EPR	1600	NPCIL	
Kaiga 5 & 6	PWR	1000/1500	NPCIL	
?	PWR x 2	1000	NTPC	2014
Jaitapur 3 - 6	PWR - EPR	1600	NPCIL	
?	PHWR x 4	640	NPCIL	
?	FBR x 4	470	Bhavini	2020
?	AHWR	300	?	2020

Uranium Enrichment in India

- **Currently there is very limited enrichment capacity in India; Operating centrifuge enrichment plant in Rattehalli near Mysore of ~ 15,000 SWU/Year capacity**
- **Plant consists of about 6,000 centrifuges of 2-3 SWU/machine/year. Few generations of centrifuges installed. Later generation based on maraging steel rotors with one bellow, supercritical speed**
- **Plant dedicated to Prototype naval reactor, research reactors**
- **Indian PHWRs, FBRs do not require Uranium enrichment:**
  - **PHWRs fueled with natural Uranium. Using slightly enriched Uranium (SEU) to improve fuel utilization optional**
  - **FBRs planned to operate on closed U-Pu fuel cycle, later on Pu-Th cycle. Both cycles do not require enriched Uranium**
- **Current enrichment services supply, demand in balance**
- **Current plant too small for enrichment needs of large ALWRs**

Estimated Annual Indian Enriched Uranium Requirements 2006

Currently known reactor requirements

Naval Reactors:		
Prototype Reactor	**15-30 kg U-235 in HEU**	**5,600-11,000 SWU**
1st Sub Reactor	**20 kg U-235 in HEU**	**3,700 SWU**
Apsara Research Reactor	**<0.6 kg U-235 in HEU**	**<100 SWU**
Subtotal SWU Requirements :		**9,400-14,800 SWU**
Future reactor requirements		
Multipurpose Research Reactor (MPRR)	**11 kg U-235 in LEU**	**2,000 SWU**
Total SWU Requirements		**11,400-16,800 SWU**

Pakistan's Nuclear Program

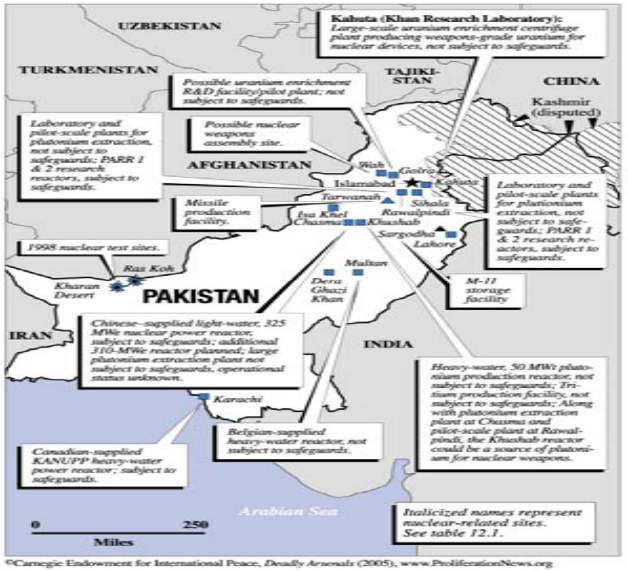
Pakistani Current Nuclear Power Program

- **Two Operating Nuclear Power Plants, One under Construction**
- **KANUPP**

  125 MWe (Net) CANDU Type reactor, Near Karachi, commercial operation 12/1972
- **CHASNUPP-1**

  300 MWe (Net) PWR, Near Chasma in the Punjab, commercial operation 9/2000
- **CHASNUPP -2**

  300 MWe (Net) PWR, Near Chasma, Under construction, commercial operation expected ~2012



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Pakistan Nuclear Power Expansion Plans

- **Pakistan's 2005 Mid-Term Development Framework (MTDF) calls for total installed Capacity of 8,800 MWe by 2030. Discussions with China re exporting eight 600 MWe units – 4,800 MWe total**
- **Possible imports of 2 x 300 MWe Qinshan phase I PWRs considered in context of President Zardari visit to Beijing on October 15 - 18, 2008**
- **Qinshan Phase I PWR is only reactor manufactured entirely of Chinese components, thus can be exported without foreign components or approvals by other NSG members. Represents smallest capital outlay for cash-strapped Pakistan**
- **Should only one or two 300 MWe unit be imported they might be constructed at Chasma Site as CHASNUPP-3, 4**
- **First two 600 MWe units to be imported planned for KANUPP site**
- **Assume all new units of 600 MWe capacity. Need to import 14 units to meet capacity expansion target, probably located in multiple-unit sites of 4 x 600 MWe capacity per site**

Nuclear Plant Import Options for Pakistan

- **Proposed U.S. India Nuclear Deal, NSG exemption, may be used by China as precedent**
- **China might offer mirror-image deal to Pakistan, submit it to NSG approval. NSG support more uncertain given Pakistan's proliferation record**
- **Under such prospective Agreement:**

  -Pakistan submit all nuclear power plants to IAEA Safeguards (Already done)

  - Pakistan military program outside scope of Agreement

  - Pakistan will align export policies with NSG Guidelines & UNSC Resolution 1540 requirements

  - A. Q. Khan's investigation might be declared completed?

  - Pakistan negotiate participation in FMCT regime

  - Pakistan promise to refrain from nuclear weapons testing?

Recent Trends in Pakistan's Nuclear Program

- **One (Possibly two) new large Plutonium production reactors under construction in Khushab site. Sizes could be up to 1,000 MWth based on dimensional analysis of air photographs**
- **Reprocessing plant in Chasma site, based on French design, left unfinished since 1975, appears to be completed**
- **Nuclear program seems driven more by perceptions of competition with India than by nuclear energy considerations**
- **Pakistan interested in developing new, safeguarded, enrichment plant. Part of effort to separate civilian, military, programs to prepare ground for similar deal to U.S. –India deal**
- **All Pakistani power reactors under IAEA safeguards. Pakistan participates in WANO, CANDU Owners GROUP (COG)**
- **Pakistan internal efforts to manage operations of power reactors impressive. Might not be sufficient for modern ALWRS**

Pakistan's Nuclear Fuel Supply Issues

- **Pakistan's nuclear capacity too small to justify commercial size (1.0 Million SWU/Year) enrichment plant, until entire program of 8,800 MWe NPP capacity is realized by 2030 – 2040 time frame?**
- **Pakistan manufactures its own CANDU type fuel assemblies for KANUPP-1**
- **Pakistan likely imports PWR type fuel for the 300 MWe CHASNUPP-1, the follow on CHASNUPP-2, and future Chinese origin PWRs from China**
- **In future Pakistan might produce own PWRs fuel given extensions of own enrichment, fabrication facilities**
- **Pakistan might not need large imported enrichment plant for several decades. Might not be able to join other regional enrichment center until its nonproliferation status is resolved**

Uranium Enrichment in India

Future Enrichment Needs in India

- **Need for low enriched Uranium (LEU) supply only in context of providing fuel requirements of future operating ALWRs in India as supply assurance measure**
- **Assuming 10 + GWe of ALWRS operational by 2020, India might require ~ 1.0 Million SWU/Year enrichment plant, justified on economic grounds**
- **All future imported ALWRS will be safeguarded. LEU Fuel supply will be provided under IAEA safeguards**
- **It does not make sense to expand domestic Indian un-safeguarded enrichment plant in Rattehalli to meet ALWRs enrichment requirements since:**
  - **LEU fuel would come under safeguards once brought to ALWR plants**
  - **Indian centrifuges of lower efficiency, higher cost, than internationally provided large enrichment plant**
- **Only new rationale for expanding un-safeguarded enrichment plant – provision of SEU for un-safeguarded Indian PHWRs**

Institutional Arrangements for Future Indian Uranium Enrichment Plant

- Assuming India maintains good nonproliferation credentials per U.S. India deal by 2020 & assuming ALWRS capacity growth as projected, India might then justifiably seek to import foreign enrichment plant(s)
- Issue of ban on exporting enrichment, reprocessing, plants to India was hotly debated during NSG exemption to India discussions. India provided private assurances. No action was taken, India received 'clean exemption'
- Nevertheless, any prospective export of sensitive fuel cycle technology to India will be extensively scrutinized given that debate, & considering India's unique nonproliferation status
- U.S. USEC American Centrifuges technology, even if commercially successful (yet unclear) might not be suitable for exports due to high machine performance

Institutional Arrangements for Future Indian Uranium Enrichment Plant (Cont.)

- Large-scale enrichment plants could be imported from Urenco, Areva, or Rosatom
- Centrifuge plants imports from either Urenco or Areva will require centrifuges supply from Enrichment Technology Corporation (ETC). ETC holds monopoly rights on centrifuges technology, sells centrifuges on black-box basis only
- Rosatom sold centrifuge plant to China, on black-box basis in past. New agreement with China for Tianwan 3 + 4 envision construction of new enrichment plant based on centrifuges technology transfer to China
- China represents special case as declared nuclear weapons state
- Difficult to predict Russian willingness to transfer centrifuges technology, particularly if tied to large future NPPs order

Institutional Arrangements for Future Indian Uranium Enrichment Plant (Cont. II)

- Smaller-scale plants might be imported from Brazil (Domestic centrifuges), South Africa (Helicon nozzle process), with possible technology transfer, under safeguards
- Japan possesses centrifuges technology, however might not wish to export domestic centrifuges technology, might feel constrained by India's special nonproliferation status
- Assuming Russia refrains from centrifuges technology transfer to India, then all large-scale enrichment plant sales to India will likely be conducted under safeguards on black box basis
- All Indian reactors likely to be served by Indian enrichment plant will be safeguarded. So would enrichment plant, per NSG guidelines, & Letter of Understanding with U.S. Government related to U.S. India deal

Regional Enrichment Plant in India

- India might be interested in hosting regional enrichment plant, supplying needs of neighboring countries
- Limited demand for Indian plant in immediate neighborhood:
  - Pakistan will ultimately (2030?) have up to 8,800 MWe of NPPs, however might not wish to rely on Indian supplies
  - Bangladesh, Myanmar, Afghanistan, Sri Lanka too isolated, under-funded, to afford nuclear power plants. One-off NPP might not justify Indian regional enrichment plant
- Need to consider further away new nuclear countries as bases for India regional enrichment plant status. Three possible groupings, or combinations of above, might emerge as prospective enrichment customers:
  - Southeast Asia countries – Indonesia, Thailand Philippines
  - Middle East countries – UAE, Saudi Arabia, Jordan
  - Partner industrializing countries – Brazil, Argentina, South Africa

Regional Enrichment Plant in India (Cont.)

- **Some of above countries might combine with India in 10 – 20 years, to support large enrichment plant in India providing parts of India & their own enrichment requirements**
- **India as lead country would contract with Urenco, Areva, or Rosatom (Techsnabexport) to construct, operate, enrichment plant in India to supply all partners' enrichment needs**
- **Enrichment plant will likely be installed, beyond 2020, as two-tier black-box plant**
- **On technology level:**
  - **Urenco, Areva will contract with ETC to provide centrifuges on black-box basis**
  - **Rosatom will provide its own centrifuges, likely on black-box basis. (Six Kudankulam VVER-1000 reactors may not be adequate inducement for technology transfer)**
  - **Each operator will keep plant design features confidential for commercial reasons**

Conclusions

Conclusions Regarding Regional Future Enrichment Plants in India

- **Proposal for evolution of regional enrichment plants based on two-tier 'black-box' arrangement applicable to Northeast Asia, India, Middle East, South America, others**
- **In South Asia only India could eventually justify large-sized commercial enrichment plant provided under safeguards by international enrichment Corporation**
- **Small, un-safeguarded, Indian enrichment plant not suitable to provide fuel requirements of future ALWRs. Incremental benefits of its expansion do not justify incremental costs in comparison with importing large safeguarded plant**
- **India enrichment plant likely post 2020 with increased ALWRs capacity installed (More than 10 GWe)**
- **India could act as hub for extended-region enrichment plant supplying requirements of like-minded consumer countries**

Backup Slides

Fueling India's Nuclear Capacity Expansion Plan

- India's Uranium Resources will Suffice Only for Lifetime Requirements of ~ 12 GWe of PHWRs listed Above
- All LWRs expected to be fueled by Imported Uranium, based on:
  - Early LWRs 'Grandfathered' from NSG Supply Constraints
  - India's Uranium Supply Deals with Non-NSG Suppliers
  - Version of U.S.-India Deal is Ultimately passed. Uranium Supply Restrictions from NSG Countries lifted
- India's Future Nuclear Capacity Growth based on FBRs (Ultimately Also AHWRS)
- All expected FBRs Capacity fueled with Indian Plutonium provided from:
  - Conversion from Uranium U-238 in existing PHWRs
  - Conversion in Future Imported LWRs
  - High Breeding Gain in Future Metallic Plutonium fueled FBRS
- Entire Large FBRs Capacity ~ 250 GWe would be fuelled ,over Its Lifetime, by Plutonium produced from Above-listed Sources
- Even if FBR Capacity Expansion Plans are delayed – Any FBRs Capacity Growth will contribute to India's Large Demand for Electricity Generation
- Ultimate Transition to Thorium-U233 based fuels, relying on India Domestic Thorium Resources, frees Future Nuclear Capacity Expansion from Uranium Supply Constraints

Role of LWRs in India's Nuclear Program – DAE's Perspective

- Limited Role due to lack of Indigenous Uranium Resources
- Imported LWRs will have to import Their Uranium Fuel Requirements
- LWRs viewed by DAE as Near-Term Capacity-Fillers Until Domestic FBRs Program matures:
  - Total Projected LWRs Capacity by 2030 ~ 30 GWe
- DAE concerned that Imported LWRs will:
  - Siphon-off Engineering Talents from DAE Reactors, R&D Programs
  - Create Competition by Foreign Vendors, Construction Companies
  - Create Regional Nuclear Generating Corporations
  - BREAK DAE's NUCLEAR MONOPOLY
- Ambivalent Attitude to Nuclear Technology Imports constraining Domestic Nuclear Development Program

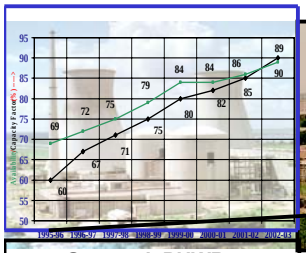
India's Operating Nuclear Power Reactors October 2008

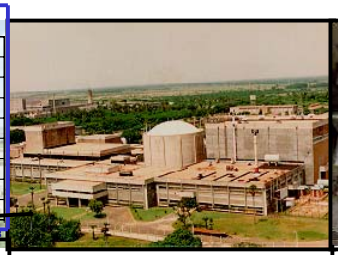
Reactor	Type	MWe net, each	Commercial operation	Safeguards status
Tarapur 1 & 2	BWR	150	1969	item-specific
Kaiga 1 & 2	PHWR	202	1999-2000	
Kaiga 3	PHWR	202	2007	
Kakrapar 1 & 2	PHWR	202	1993-95	by 2012 under new agreement
Kalpakkam 1 & 2 (MAPS)	PHWR	202	1984-86	
Narora 1 & 2	PHWR	202	1991-92	by 2014 under new agreement
Rawatbhata 1	PHWR	90	1973	item-specific
Rawatbhata 2	PHWR	187	1981	item-specific
Rawatbhata 3 & 4	PHWR	202	1999-2000	by 2010 under new agreement
Tarapur 3 & 4	PHWR	490	2006, 05	
Total (17)		3779 MWe		

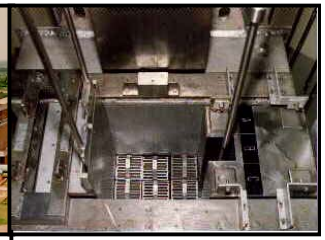
India's Nuclear Power Reactors under Construction – October 2008

Reactor	Type	MWe net, each	Project control	Commercial operation	Safeguards status
Kaiga 4	PHWR	202 MWe	NPCIL	end of 2008	
Rawatbhata 5 & 6	PHWR	202 MWe	NPCIL	end of 2008, 3/09	by 2008 under new agreement
Kudankulam 1 & 2	PWR (VVER)	950 MWe	NPCIL	9/2009, 12/09	item-specific
Kalpakkam PFBR	FBR	470 MWe	Bhavini	2010	unlikely
Total (6)		2976 MWe			

THREE STAGE NUCLEAR POWER PROGRAM







Stage – I PHWRs

- 16- Operating
- 4- Under construction
- Several others planned
- Scaling to 700 MWe
- Gestation period being reduced
- POWER POTENTIAL ≅ 10,000 MWe

LWRs

- 2 BWRs Operating
- 2 VVERs under construction

Stage - II
Fast Breeder Reactors

- 40 MWth FBTR - Operating
  Technology Objectives realized
- 500 MWe PFBR- construction commenced
- POWER POTENTIAL ≅ 540,000 MWe

Stage - III
Thorium Based Reactors

- 30 kWth KAMINI- Operating
- 300 MWe AHWR- Under Regulatory Examination
- POWER POTENTIAL ≅ Very Large. Availability of ADS can enable early introduction of Thorium on a large scale

FBR Program in India

- India started FBR program with construction of FBTR
- FBTR is a 40 MWt (13.5 MWe) loop type reactor. Design is similar to Rapsodie-Fortissimo except for incorporation of SG & TG (Agreement signed with CEA, France in 1969)
- FBTR is in operation since 1985
- 500 MWe Fast Breeder Reactor Project (PFBR) through Indigenous design and construction
- Govt. granted financial sanction for construction in September 2003
- Construction of PFBR has been undertaken by BHAVINI
- PFBR will be commissioned by 2011
- Beyond PFBR: 4 units of 500 MWe FBR (twin unit concept) similar to PFBR with improved economy and enhanced safety by 2020
- Subsequent reactors would be 1000 MWe units with metallic fuel

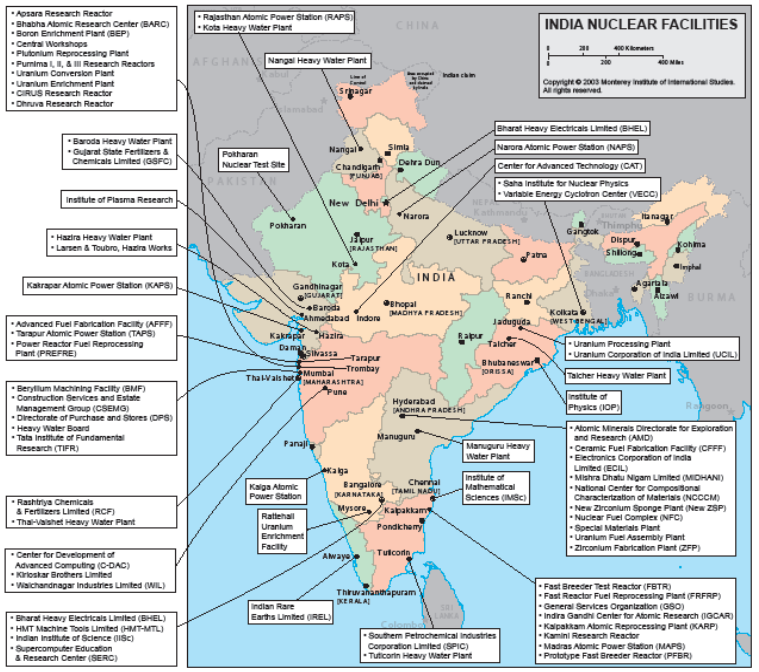
Implementation Constraints on India's Fast Breeder Reactors

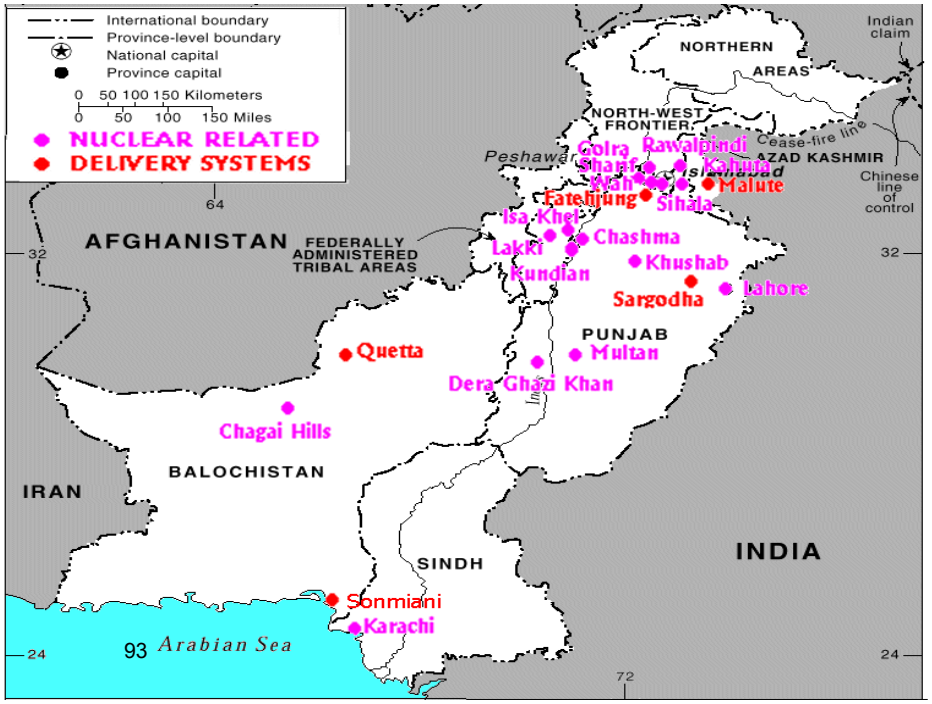
- Successful Completion & Startup of PFBR
- Closing Nuclear Fuel Cycle in PFBR & Follow-up FBRs
  - On-site Reprocessing & Re-Fabrication
- Fuel Cycle Transition from Oxide to Metal Plutonium Fuels, Thorium-U-233 Fuels
- Funding Future FBRs, Fuel Cycle Facilities Construction
- Constructing ~250 GWe in Forty Five Years
  - Past Record ~ 7 GWe in Forty Years
- Managing Interfaces between FBRs constructors, Operators, Fuel Cycle Providers & Regulators at each site
- Opening up New FBR Sites –One Site/Year for Forty Years
- Training Manpower for all FBRs, Fuel Cycle Facilities, Construction corporations
- Industrial Fabrication Capacity dedicated to DAE Missions

Reprocessing in India

- First plant to reprocess metallic fuel was set up in 1965 at Trombay
- A plant was set up at Tarapur to reprocess BWR fuel. However, it was not used for BWR fuel. It was modified and used for PHWR fuel. Another plant has been set up at Kalpakkam
- Pilot scale plant has been set up at Trombay to reprocess thorium oxide fuel
- India has been successful in reprocessing high burn-up carbide fuel from FBTR
- Military Pu reprocessed at Trombay. Plant capacity of 50 MTU/Year suffices for spent fuel output of CIRUS and DHRUVA
- Two additional PHWR fuel reprocessing plants are planned for Kalpakkam (100 MTHM/Year) , & Tarapur

Name	Location	Type	MTHM/Yr	Start Date	
Power Reactor Fuel Reprocessing Plant (PREFRE)	Tarapur	Industrial scale	100	1977	
Kalpakkam Reprocessing Plant (KARP)	Kalpakkam	Industrial scale	100	1997	
Fast Reactor Fuel Reprocessing Plant (FRFRP)	Kalpakkam	Full scale	Unknown	Future	
Lead Minicell Facility	Kalpakkam	Demonstration	Unknown	2003	





CHASNUPP-1 Chasma Nuclear Power Plant – Unit 1

- Based on China Qinshan Phase I plant. Exported by China National Nuclear Corporation (CNNC)
- First example of South-South export of commercial nuclear power plant
- Performance record much better than KANUP, still lower than Qinshan Phase I
- Chasma site also houses Pakistani nuclear fuel reprocessing plant based on French design, built, operated by PAEC
- Khushab Plutonium Production Reactor (40 MWth) located nearby

CHASNUPP-2 Chasma Nuclear Power Plant – Unit 2

- Copy of Unit 1. also based on Qinshan Phase I with modifications
- Expected total unit cost ~ 860 Million Dollars
- Chinese loans & export credits of 350 Million Dollars
- Nuclear Island (NI) equipment not yet manufactured in China. Pressure vessel in Japan, Primary pumps in Germany
- Supply contract signed 2004 with CNNC, construction start 2005, Commercial operation expected 2011
- China supplied reactor despite becoming NSG member claiming contract discussions predate NSG membership, contract 'Grandfathered'

Security Problems Associated with Pakistan Nuclear Plants Expansion Plans - Summary

- Fissile Material Diversion from Nuclear Power Stations
- Terrorist Attack, Seizure, or Take-Over of Nuclear Power Stations
- Possible Airplane Attack on Nuclear Power Stations
- Military Take-Over of Nuclear Station Sites
- Foreign Military Attacks on Nuclear Station Sites

Nuclear Plant Import Options for Pakistan (Cont.)

- Pakistan interested in importing 600 MWe nuclear plants from China, based on Qinshan Phase II station now in commercial operation in Zhejiang Province
- Qinshan Phase II station:
  - Domestic Chinese design with French support
  - 55-60 percents domestic content. NI equipment manufactured in Japan
  - Now replicated in China as Qinshan Phase IV station, located near Qinshan Phase II station in Zhejiang Province site
  - Technology not yet exported. Limited operational experience
- Export of Qinshan Phase II plant from China may require Japanese consent if prior approval required by Japan as condition of supply
- China agreement with Pakistan, if approved by NSG may open doors for other nuclear exporters to Pakistan: Canada, France, Russia, eventually U.S.

Pakistan Nuclear Power Program - Security and Safety Issues – Conclusions

- Nuclear capacity expansion plans depend on resolving Nonproliferation status through Agreement similar to U.S./ India deal, & obtaining NSG approval to such Agreement
- China most likely country to offer such Agreement – mirror image of U.S./India deal
- Other vendor countries will likely follow – Canada, France, Russia, eventually U.S.
- Pakistan nuclear expansion plan requires opening at least three additional multi-unit nuclear power station sites within less than twenty years. This in addition to two existing sites

Regional Two-Tier 'Black Box' Enrichment Plant Concept

- **Regional enrichment plant to be operated within a region could be built under two-tier commercial, technical, structure:**
  - **- Commercial First Tier: Commercial decision-making vested in Board of Directors whose membership chosen by participating states within region, & by international technology provider, in relation to their relative investments in plant**
  - **- Technology Second Tier: Enrichment technology to be provided by international enrichment corporation under 'black box' arrangement**
- **Flexible application of 'Black box' arrangements, depending on nonproliferation credentials of participating countries**
- **Participation in regional enrichment plant to be conditioned on signing, ratification of IAEA Additional Protocol**

Possible Evolution of Regional Enrichment Centers

- **Evolution of regional enrichment centers might include:**
- **Establishing regional nuclear fuel purchasing agency for participating member states including all their operating nuclear power plants (NPPs). Agency patterned after European Supply Agency (ESA)**
  - **- Seek volume discounts for larger consolidated orders**
  - **- Brazil/Argentina announcements of August 2008 point in similar direction. Might combine with India now**
- **Member states within region agree not to build new small enrichment plants, or expand existing facilities serving domestic markets only. Any new enrichment plant constructed – only in context of serving regional needs under international agreement**
- **Any existing small enrichment plants operating in regional countries brought under organization of regional supply agency**

Possible Evolution of Regional Enrichment Centers (Cont.)

- **Regional enrichment plant to operate under regional mutual safeguards regime similar to ABACC in South America, with additional IAEA top-layer inspections**
- **Prospective regional customers might invite international enrichment corporations to build regional enrichment plant(s) providing enrichment requirements of NPPs in participating member states**
  - **-Plant to be located within region (Urenco plant in U.S.)**
  - **- Plant to be located outside region (GCC proposal)**
  - **- International plant, or international stockpile, supplying regional needs (MESP, IUEC, NTI proposals)**
- **Minimum size for regional enrichment plant – 1.0 Million SWU/Year, supplying requirements of about seven 1,000 MWe NPPs (~ 4.0 % enrichment, 0.25 % tails)**

Possible Evolution of Regional Enrichment Centers (Cont. II)

- **Joint ownership of regional plant by regional consumer states, international supplier**
- **Two-tier black box model. Consumer countries participate in commercial decision-making. Enrichment operations under control of technology provider**
- **Will require agreements between Governments of enrichment technology Corporation and regional consumer countries, to prevent political interference in operation of regional enrichment plant**
  - **- This represents extension of Enrichment Bonds concept**
- **Regional enrichment plant – nucleus of regional fuel cycle center – as proposed by IAEA in 'Multilateral Approaches to the Nuclear Fuel Cycle', Report INCIRC/640, February 2005**

Regional Two-Tier 'Black Box' Enrichment Center Concept

- **Member states fund & fully participate in commercial operation of enrichment plant. Entitled to withdraw enriched Uranium product to meet their NPPs requirements**
- **Regional enrichment plant operate under contract by international enrichment corporation with limited technical access & participation by member countries, or host country**
- **Enrichment plant safeguards arrangement would be based on ABACC model, including:**
  - **Cross-national safeguarding of plant by member countries**
  - **Top tier of IAEA safeguards**
  - **Member countries sign, ratify Additional Protocol**
- **Proposed arrangement conceptually similar, updated version of, EURODIFF, SOFIDIFF, IUEC, LES corporate structures**

Conclusions Regarding Regional Enrichment Plants

- **Future enrichment plants based on:**
  - **International or regional ownership involving (extended) regional countries & international enrichment Corporation**
  - **Two-Tier 'Black Box' arrangement (flexibly interpreted)**
  - **ABACC-type mutual safeguards with IAEA top-tier inspections**
  - **All user countries ratify CSA + AP Agreements with IAEA**
  - **Host Governments of enrichment plant provider should sign 'Enrichment Bonds' type guarantees not to interfere in commercial enrichment operations for political purposes**
- **Concept offers best possibility for safeguarding enrichment plants while assuring fuel supplies**
  - **Ultimately depends on good will of supplier, user Governments**

Responding to needs in South America and the regional approach to Non-Proliferation

Carlos Feu Alvim and Olga Mafra
Economy and Energy - e&e
MIT Workshop on Internationalizing Uranium Enrichment Facilities
Cambridge USA - October 20-21, 2008

Content

- Preliminary Issues
- Meeting Organization questions
- Additional questions

1- Preliminary issues

- Effect of regional enrichment facilities on barriers and motivation related to proliferation issue
- The creation of ABACC (Brazilian Argentine Agency of Accounting and Control of Nuclear Materials) and Bilateral Agreement
- The Quadripartite Agreement
- International Agreements or Tlatelolco and NPT

Barriers and Motivation for Proliferation

- Non-proliferation can only be achieved with a correct balance between barriers and motivation. Often barriers against proliferation result in motivation for developing potential proliferating technologies
- The present motivation for Nuclear Proliferation is regional and it is natural that it can be easily solved in a regional approach.
- The lack of confidence among neighbors has been the major reason for tentative (and successful) proliferation in the last times as can be demonstrated by very well known examples.
- Mutual concessions are politically more acceptable.
- Regional arrangements can be a connection to international commitments. In the case of Brazil and Argentina the Bilateral Agreement was the way to a later acceptance of the international controls.

Barriers and Motivation (suite)

- A clear example of the failure of barriers policy was the embargo on nuclear fuel supply to the Angra I Nuclear Power Plant (breaking previous agreements) by the Carter Administration.
- With the Carter Administration restrictions it was definitively buried the idea that Brazil could depend on external supply of nuclear fuel. At the present stage, due to economic reasons, Brazil has accepted buying external enriched uranium, but it can now rely on the possibility of independent internal supply of enriched uranium.

Brazil and Argentina General Figures and Facts

Argentina and Brazil are, respectively, the 8th and 5th largest countries by landmass in the world. Together, 11,300 million square kilometers.

Brazil and Argentina General Figures and Facts (suite)

- Population of more than 200 million inhabitants.
- Two thirds of South America's surface, population and Gross National Product (GNP).
- Industrializing countries with a medium size industrial capacity.
- Together Uruguay, Paraguay, Brazil and Argentina have set up a commercially integrated area, the Mercosul, which has increased trade in the region by 300% in five years.
- More than a century without war.

Brazil and Argentina General Figures and Facts (suite)

- Prior to 1991, neither Brazil nor Argentina had adhered to an internationally recognized instrument for the verification of nuclear energy uses.
- Concerns of the international community about the possibility of these two countries becoming engaged in the development of a nuclear device.
- With regard to neighbor relationship, the uncertainty generated by the fact that Brazil and Argentina could domestically nourish the desire to assemble a nuclear device represented a hazard to their peaceful relationship.

International concern about the two countries before the Quadripartite Agreement

- No full scope safeguard agreement in force in the two countries unless related to international cooperation.
- Tlatelolco Treaty (nuclear weapon free zone in Latin America and the Caribbean) was not in force.
- No commitment about "peaceful explosions".

The creation of ABACC

- The creation of the ABACC (Brazilian Argentine Agency of Accounting and Control of Nuclear Materials) demanded a long historical process.
- The path leading to the generation of trust was a long one and required many years of negotiations performed in stages marked by joint declarations that, little by little, promoted opening and mutual knowledge about the nuclear activities in Argentina and Brazil.

The creation of ABACC (suite)

- After many steps, in June 1991, Brazil and Argentina signed the Guadalajara Agreement for the Exclusively Peaceful Use of Nuclear Energy (Bilateral Agreement) in which, among other actions, the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC) was created, aiming at performing mutual inspections in the nuclear materials from Brazil and Argentina.
- Once the Agency was created, in December 1991, an Agreement was signed by Brazil, Argentina, the IAEA and ABACC that would consolidate the system for application of safeguards that is currently in force in both countries – The Quadripartite Agreement that entered into force in March 1994

International Initiatives

- The Quadripartite Agreement, entered into force in March 1994, after long discussions, mainly on its approval by the Brazilian Congress and side letters were signed preserving enrichment plants.
- After the acceptance by the OPANAL* Council of the amendments to the Tlatelolco Treaty (weapons free zone area) the Treaty came into force for Argentina and Brazil in January and May 1994, respectively.
- In February 1995 Argentine authorities presented the legal instruments for the country adherence to the Treaty on the Non-proliferation of Nuclear Weapons (NPT) . In September 1998 Brazil did the same

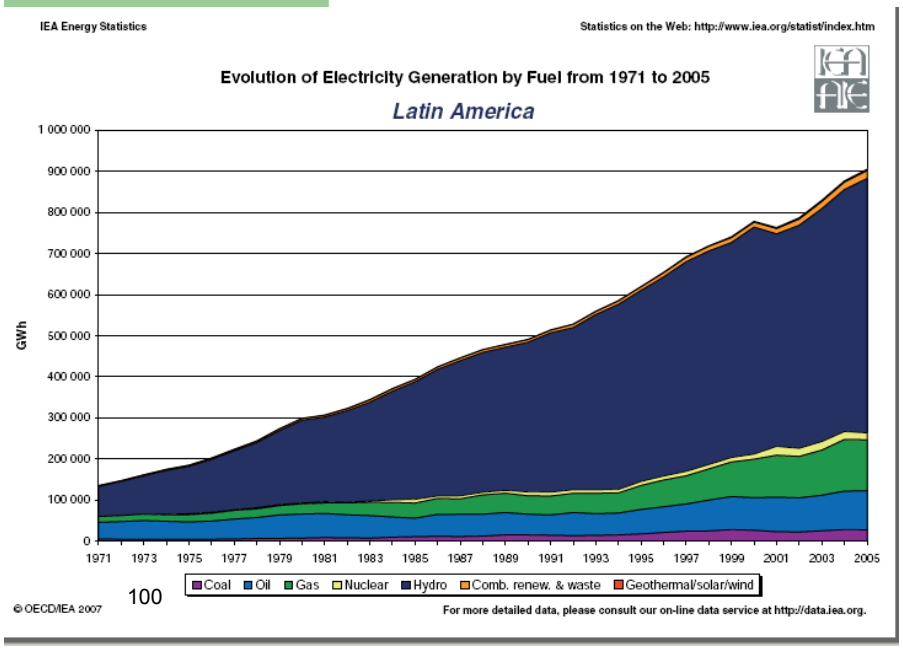
*Organismo para la Proscriptión de las Armas Nucleares en la America Latina y el Caribe

2- Meeting Organization questions

- Are there regional issues/problems that are either especially suited for international enrichment centers or that would make such centers especially difficult to implement?
- What are the regional energy requirements and the future prospects for nuclear energy in the region?
- On what time frame multinational enrichment facilities should or must be brought into operation? How does this timeframe affect the prospects for multinational enrichment centers?
- How would a regional multinational enrichment facility affect the regional security issues?
- Which candidates would be likely to join/host such multinational centers?

Regional energy requirements and prospect for nuclear energy – the Brazilian case

- Nuclear Energy is only 3% of electric generation in Latin America and 0,9% of primary energy use
- In South America only Brazil and Argentina have nuclear power stations
  - On operation (3 in Brazil, 2 in Argentina)
  - Under construction (one in each country)
- The Brazilian energy plan considers 4 to 7 new nuclear plants (1000 MW each) until 2030
- The present share (3%) on electricity production will be almost the same.



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Regional issues/problems related with international enrichment centers

- The question will be centered in the next years on Brazil and Argentina
- Venezuela and Chile must be considered for the future
- Integrated electric system can centralize electric production in a few countries
- It will be very difficult to share enrichment technology
- Different development levels regarding gas diffusion in Argentina and ultracentrifuge in Brazil

Time frame for multinational enrichment facilities

- The time frame is not a critical issue for South America unless there are new restrictions for using international enrichment capacity,
- Argentina is testing low enriched fuel in heavy water reactors but it is not a critical issue,
- The planned capacity for the Brazilian enrichment facility is to achieve 60% of internal demand in 2010 (Angra 1 and 2). (240 t/ 3% enriched uranium). Only in 2014 the capacity will be enough for Angra 1, 2 and 3)
- Some delay is expected in this chronogram

Security issues related to regional enrichment

- Brazil and Argentina are negotiating a joint facility to enrich uranium
- That will not be an easy discussion although there is considerable support from the high government authorities
- The Navy doesn't want to share centrifuge technology even with the civilian Brazilian Nuclear Industry (INB)
- It will be even more difficult to share it with neighboring countries

Security issues related to regional enrichment (suite)

- In large or medium size countries the philosophy of not developing nuclear technology does not prosper since they aim at having an important role in their regions and in a lower grade at a global level.
- A very restrictive action in relation to preventing these countries to access the nuclear technology provokes a more active position in demonstrating capability in the area.
- The existence of a local facility can assure regional countries about nuclear fuel supply

Candidates for joining/hosting such multinational centers

- If it is an external technology facility it will be easy to accept a smaller country as a neutral choice (as happens in Europe) but this solution seams not feasible,
- For local technology, the country that owns the technology will probably host the installation (Brazil for ultracentrifuges and Argentina for gas diffusion)
- It could be acceptable the participation of nuclear states in this initiative

3-Additional questions

- Is Additional Protocol good for non-proliferation in the South America?
- There will be a role of regional safeguards in non-proliferation?
- Can enrichment facilities in the region contribute to proliferation?

The role of regional safeguards organizations

- The Brazilian – Argentinean Bilateral Agreement was very effective to solve the proliferation tensions on the region
- The regional or bilateral agreements look for less intrusive mechanisms since the potential opponent is involved in the measurements of verification. They can, for this reason, be less proliferating (leakage of information) than the international agreements, since more care is taken in dealing with sensitive information.

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Additional Protocol and regional safeguards organizations

- In the Additional Protocol, the role of regional organizations is reduced, since the power of the national and international authorities has been reinforced.
- It is important to analyse the AP in relation to this aspect because it can be harmful to the regional safeguards organizations.

Multinational enrichment facilities and proliferation

- The regional multinational enrichment facility avoids its use for proliferation (There was never doubts about the only peaceful use of the material produced in this type of organization)
- However, multinational organizations (safeguards agencies included) have less control on their personal. It is also more difficult to control information about suppliers and about technical important issues
- Special measures must be taken to have sufficient control of information and of personnel involved

Some Ideas to Avoid Proliferation

- Countries that have developed the enrichment technology should increase their control over it;
- It is necessary to reinforce the effective control with regional inspections;
- It is necessary to assure that international and regional inspections are not a source of proliferation;
- It is one more reason to reinforce the democratic regimes.

Thank you

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Avoiding Carbon Emissions

- Without renewable and nuclear energy carbon emissions in Brazil would be 110% higher.
- In Brazil emissions are around 1.57 tons of CO_2 per toe, while in the OCDE countries emissions are 2.37 tons of CO_2 per toe, that is, 51% greater.
- Between 1994 and 2005 the share of the energy sector in emissions increased from 12% to 17%.

Alternative to the Additional Protocol of the Nuclear Safeguards Agreement with the IAEA*

- The global warming problems associated with the greenhouse gases effect have led many countries to consider increasing the share of nuclear energy in their energy matrix in the next decades. Countries where the nuclear option has been kept open, like China and Japan, have announced the intention of intensifying their programs. In Brazil, the Angra 3 construction was re-started and there are plans for building four more nuclear power plants.

*Article published by Mr. Carlos Feu at e&e № 52.

Main technological achievements in each country Argentina (Natural Uranium Fuel Cycle Option)

- Mining and Yellow Cake production;
- Purification (UO2 nuclear grade);
- Conversion (UF6);
- Gaseous diffusion enrichment in laboratory scale;
- Heavy Water production in laboratory scale (indigenous technology) and industrial scale (with international cooperation and under INFCIRC/66 type safeguards agreements);
- Research Reactors building including fuel elements (with external enrichment);
- Power Reactors Natural Uranium Fuel Elements Production ;
- Active Participation in Power Reactor Building and Conception (Atucha I under German Agreement);
- Development of some special material for reactors;
- Metallic Uranium Production at laboratory level;
- Medium Size Industrial and Technological Capacity.

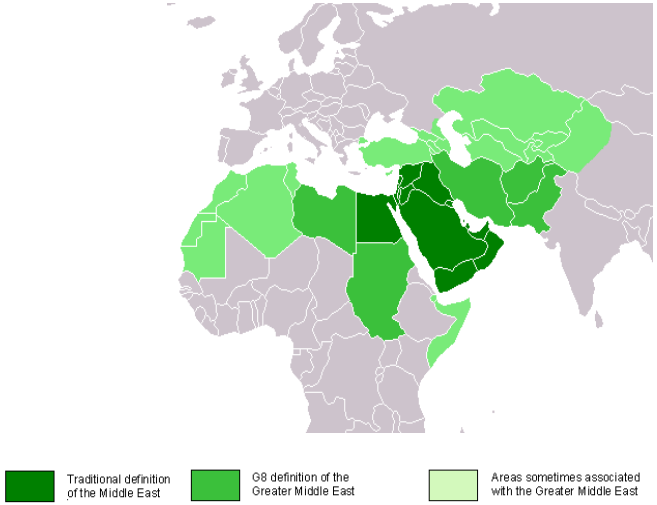
Brazil (Enriched Uranium Fuel Cycle Option)

- Mining and Yellow Cake production;
- Purification (UO2 nuclear grade);
- Conversion (UF6);
- Ultra centrifuge plant in demonstration scale;
- Commercial ultra centrifuge plant under construction;
- Research Reactors (zero power) building including fuel elements (with external enrichment);
- Development of some special material and equipment for reactors;
- Power Reactors Enriched Uranium Fuel Elements Assembling;
- Participation in Power Reactor Building (Angra II under German Agreement);
- Metallic Uranium production at demonstration scale;
- Medium Size Industrial and Technological Capacity.

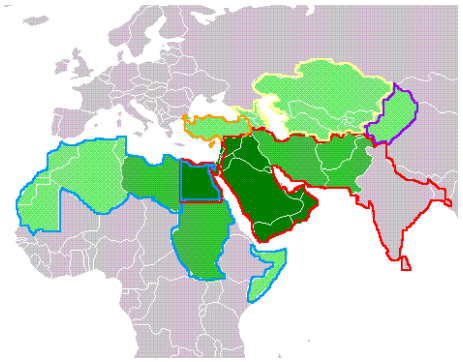
Internationalizing Uranium Enrichment: Responding to Regional Needs

CENTER ON INTERNATIONAL COOPERATION

The Middle East (Traditional and "New")



The Greater Middle East and IAEA Areas



RED = Middle East & South Asia; BLUE = Africa; ORANGE = Western Europe; YELLOW = Eastern Europe; PURPLE = Far East

Source: Wikipedia

Important Recent Milestones

Dec. 2006 Gulf Cooperation Council meeting: plans announced for a study to explore "a common program in the area of nuclear energy for peaceful purposes"

February 2007 GCC States agree with IAEA to cooperate on feasibility study for regional nuclear power and desalination program

March 2007 League of Arab States Summit (Riyadh):
Resolutions:
(a) in favor of expanding peaceful uses of nuclear technology;
(b) exploration of joint ventures for development of nuclear technology applications

Current Nuclear Status*

Gulf States (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, UAE):

Bahrain: no significant nuclear infrastructure/training/research
Oman: some nuclear desalination research undertaken (Middle East Desalination Research Center)
Kuwait: some nuclear research undertaken (university-level)
Qatar: some nuclear research undertaken (university-level); National Centre for Nuclear Information established, 2007.
Saudi Arabia: some nuclear research undertaken; Atomic Energy Research Institute established 1988.
UAE: some nuclear research undertaken (university-level)

No existing research or power reactors
(Source: IAEA Nuclear Energy Handbook)

Desalination demonstration site. Credit: Lothar Wedekind, IAEA.

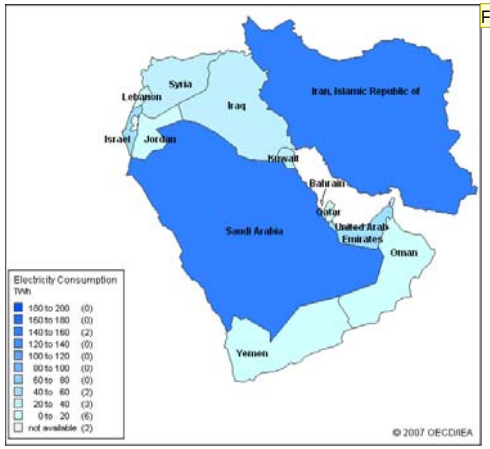
*States selected from those recently indicating interest in developing nuclear energy for peaceful purposes

Current Nuclear Status

Egypt: Two research reactors (22MW & 2MW); fuel manufacturing pilot plant; research and development nuclear fuel laboratory (IAEA safeguards applied)
Jordan: No known nuclear facilities or significant quantities of safeguarded material; significant (i.e. in top 20 countries) uranium deposits (est. 79,000 tons)
Syria: One research reactor (30KW; IAEA safeguards applied)
Algeria Two research reactors (15MW & 1MW); one pilot uranium concentration purification unit; one fuel fabrication plant (IAEA safeguards applied)
Libya: One research reactor (10MW); one uranium R&D facility (IAEA safeguards applied)
Iraq: One storage facility (IAEA safeguards applied)
Yemen: Some nuclear research undertaken (university-level)

Source: IAEA (GC(52)/9) and IAEA Nuc. Energy Handbook

Current Energy Requirements



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Slide 7

FS1 Fiona, 10/18/2008

Projected Energy Requirements

Increasing Domestic Energy Demand in Region – IEA Factors*

- Growing population (OAPEC estimate: 460 M in 2020, or 2-4.4%/annum)
- Economic growth (OAPEC estimate: GDP growth of 2-5.6%/annum)
- Energy Subsidies

Primary Energy demand expect to double by 2030

Example: UAE reference scenario envisions national annual peak demand for electricity to rise more than 40,000MW by 2020 (i.e. growth of 7% from 2007 onwards)

As identified by the International Energy Agency's *World Energy Outlook 2005*, which focused on the Middle East/North Africa

Planned Nuclear Development

UAE: Nuclear Energy Program Implementation Organization established; Emirates Nuclear Energy Corporation, created under its auspices as a public entity, to evaluated and implement nuclear power plans;

Memorandum of Understanding signed with US; UAE undertakes to forgo domestic enrichment/reprocessing

By 2020, anticipates two NPP running and producing electricity

Bahrain: Memorandum of Understanding signed with US (Mar 2008); Bahrain undertakes to forgo domestic enrichment/reprocessing in exchange for cooperation on civil nuclear power

Saudi Arabia: Memorandum of Understanding signed with US (May 2008); Saudi Arabia; same terms as MOU with Bahrain

Source: World Nuclear Association

Planned Nuclear Development

Egypt: Nuclear cooperation agreements signed with Russian Federation (2004 and 2008) and China (2006);
By 2015, anticipates 1000MWe reactor to be constructed at El-Dabaa; project open to foreign participation

Syria: Nuclear power under consideration again; alleged reactor similar to that at Yongbyon destroyed by Israeli airstrike in September 2007; participated in IAEA study on desalination

Jordan By 2015, anticipates a NPP operating for electricity and desalination purposes; program for nuclear power to provide 30% of domestic electricity demand by 2030, as well as exports

Libya: Cooperation agreement signed with France, including MOU related to construction of plant for desalination (supplied by Areva); no NPP envisioned for next 10-15 years (according to statement at Nov 2007 IAEA Board meeting).

Source: World Nuclear Association

Regional Safeguards Status

Comprehensive Safeguards Agreements

Signed but not yet in force: Bahrain; Saudi Arabia

Approved by the IAEA's Board of Governors, but not yet signed: Qatar

Additional Protocol

Signed and entered into force: Jordan, Kuwait, Libya

Signed, but not yet in force: Iran, Iraq, Morocco, Tunisia

Approved by the Board, but not yet signed: Algeria

No Additional Protocol being pursued: All others

Source: IAEA

Internationalizing Uranium Enrichment in the Middle East (external appeal)

General Concerns: Regional Expansion Nuclear Power

- **Proliferation:** Fears that interest in nuclear power has been triggered by Iran (thus stands as a potential proliferation scenario); limitations of safeguards, esp. when signature of Additional Protocol is often tied to movement on Middle East Nuclear-Weapons-Free Zone
- **Nuclear Security:** Lack of regulatory capacity (PNNL Study 2007): concerns regarding potential for increase in nuclear trafficking

Multilateral Approaches to the Nuclear Fuel Cycle – Assumptions

- The spread of sensitive fuel cycle technology will increase the likelihood of weapons proliferation
- Therefore: (a) the spread of enrichment (and reprocessing) facilities may be mitigated by assuring fuel supplies and/or establishing international nuclear fuel cycle centers
  (b) such approaches ***may*** also enhance nuclear security as a consequence of joint oversight/peer group review of security approaches (less certain, esp. if common lack of regulatory capacity exists, i.e. in some suggested multilateral approaches, such as a regional fuel cycle center)

Internationalizing Uranium Enrichment in the Middle East (Prospects and Hurdles)

Enrichment/assurance of supply services provided from outside the region

Regional Incentives:
- Lower costs: enrichment facility extremely capital intensive (esp. if not servicing large reactor fleet or commercial market)
- Reduces impact of domestic personnel shortages (i.e. global as well as regional shortages in nuclear engineers, etc.)
- Avoids debate over where, in region, to site an international facility or fuel bank
- [If fuel leasing/take-back provided, would avoid need to deal with spent fuel]

Regional Disincentives:
- Fear of disruption for political reasons/sensitive political climate (esp. true in Middle East)
- Violation of political principles inalienable rights under NPT Article IV to develop nuclear energy for peaceful purposes; perceived double standard vis-à-vis Israeli nuclear program
- Distaste for dependence on foreign sources of supply; desire for national/regional energy security

Internationalizing Uranium Enrichment in the Middle East (Prospects and Hurdles)

Enrichment services provided by the region (i.e. regional nuclear fuel cycle center)

Regional Incentives:
- No dependence on foreign suppliers
- Pride/prestige of indigenous/regional development
- Potential spin-offs for industrial/technological/economic development
- Potential for eventually entering the commercial market

Regional Disincentives:
- More expensive; varying degrees of lack of personnel/infrastructure
- Subject to external concerns regarding regional instability
- Potential concerns for cut-off from within (in the case of a facility sited regionally)

Relationship of Existing Proposals (Extra-Regional Assurances of Supply) to Possible Regional Incentives/Disincentives

	Lower costs	Reduced impact on personnel shortages	Take-back option provided for	Siting debate avoided	Addresses disruption fears	Entails sacrifice of political principles
US 17t reserve	YES	YES	NO	YES	MAYBE	MAYBE
Angarsk	YES	YES	NO	YES	MAYBE	YES
GNEP	YES	YES	POSSIBLY	YES	MAYBE	MAYBE
WNA proposal	YES	YES	NO	YES	MAYBE	YES
Six-Country (RANF) proposal	YES	YES	NO	YES	NO/MAYBE	YES
Enrichment bonds	N/A	N/A	NO	N/A	YES	YES
MESP proposal	YES	SOME	NO	YES (for participants)	REDUCED	REDUCED
Standby arrangements	N/A	N/A	N/A	N/A	MAYBE	NO
NTI fuel bank	YES	YES	NO	YES	MAYBE	MAYBE

Internationalizing Uranium Enrichment in the Middle East (most useful MNA proposals)

All proposals address the concerns of extra-regional supply to greater or lesser degrees. Notably:

- German MESP approach allows for greater day-to-day involvement of states without needing to site a fuel cycle center in the region (thus mitigating concerns of international community regarding enrichment center siting in "unstable" region)
- Enrichment bond; NTI fuel bank; WNA proposals are well-placed to redress concerns of disruption for political reasons, which are likely to be particularly worrisome for states within the region
- GNEP approach has contemplated providing for fuel take-back, reducing proliferation risk and need for investment in spent fuel storage

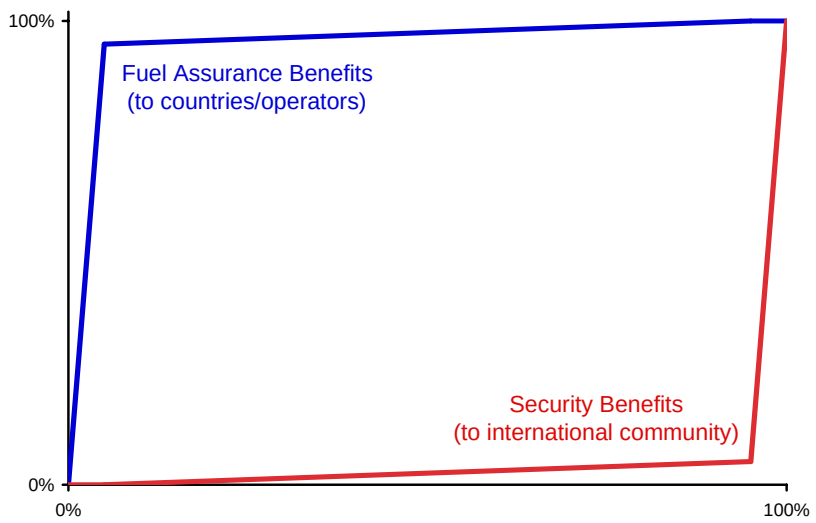
However:

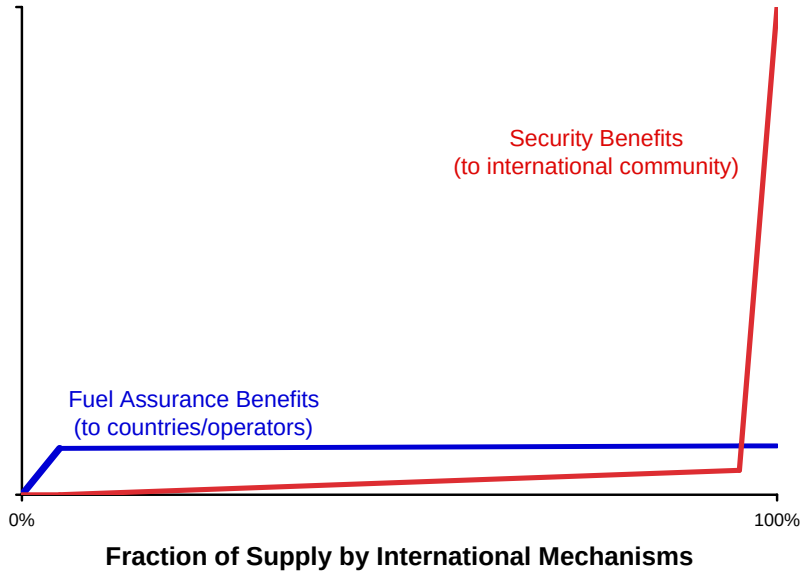
- No proposals, based on the premise of extra-regional assurances of supply, can address suspicions/concerns regarding potential for infringement of NPT Article IV rights
- No states in the region (save Iran) have thus far expressed interest in developing indigenous enrichment/reprocessing capacity (hence willingness of some states to sign Memoranda of Understanding to the effect).
- Recent suggestions have been to regionalize less sensitive aspects of the fuel cycle, i.e. uranium ore supply, fuel fabrication, supply of spare parts to NPP (see: M.Shaker, Disarmament Forum 2008, no.2).

Relationship between Multinationalization of the Fuel Cycle and Nuclear Disarmament

Two Objectives

- Assurance of fuel supply
- Limiting the spread of sensitive technology





Comments on the Broader Security Context

MIT Workshop on Internationalizing Uranium Enrichment Facilities

October 20-2, 2008

John Steinbruner

University of Maryland

Background Situation

- For the United States especially and most other countries as well the threat of imperial aggression is no longer the dominant security concern.
- For those countries for whom it remains a dominant concern the unique military capabilities of the United States makes us
  - the principle source of threat
  - and the only source of reliable protection.

2

- Effective response to this situation will require radical revision of prevailing United States security policy.
  - Primarily to subject our inherent capacity for preemption to formal legal restraint.
- Fundamental US requirement is to convey global reassurance in order to legitimize substantial military advantage.

3

- For the world as a whole including the United States the principal immediate threat is that posed to local and global economic performance by endemic civil violence and associated terrorism.
  - Defense of legal order is superseding defense of national territory as the central objective of security policy.
- Over the longer term the threat of global catastrophe is likely to override all intentionally organized threats as the dominant, organizing security concern.

4

Implications

- For those countries that consider themselves threatened by the United States, acquisition of nuclear weapons is more likely to provoke attack than to deter it.
  - Difficult to legitimize
  - If not legitimized, then subject to preemptive attack.
- Extraction of security assurances is a far better option, arguably the only viable one.

5

- Basic formula outlined in the six party agreement with North Korea:
  - Release of explosive material to international control
  - And dismantlement of production capability
  - In exchange for
    - General security assurances
    - Guaranteed access to energy sources and fuel cycle services
    - Political and economic normalization.

6

- Resolution of the Iran case likely to require application of the same formula with an additional provisions
  - Allowing Iran to operate their current centrifuge plant under advanced monitoring measures.
  - With international control of the product .

7

- Could offer participation in an internationally managed, state-of-the-art plant as an alternative incentive.
  - Current Iranian centrifuges far below the international standard.

8

- Generalizing the rule of international fuel control for all future cases would close the NPT loophole and strengthen the regime.

- Would presumably require:
  - Robust rules for equitable access
  - And a credible schedule for eventually internationalizing all fuel cycle facilities.

9

Broader Context

- Currently proclaimed US security policy is too exclusively based on the use of force for national advantage to be sustainable.
  - Technical and economic requirements of decisive superiority cannot be met.
  - Denigration of legal restraint undermines the foundations of security policy necessary for most other countries.
  - Primary threats cannot be addressed with decisive force.
  - Predominant emerging interest in defending the global rule of law requires equitable collaboration.

10

- Pressure of circumstance dictates
  - constraint on military operations of traditional scale
  - in order to enable mutually protective measures for controlling civil conflict and terrorist violence
  - and to allow ultimate control of global warming.

11

- Development of responsive measures can be expected to involve:
  - Transformation of deterrent force operations ,
  - Global accounting and enhanced physical security of nuclear weapons and explosive isotopes,
  - International control of nuclear programs in North Korea and Iran under an upgraded NPT standard,
  - Development of reactor designs, fuel cycle management practices and security relationships to allow expansion of nuclear power generation,
  - Oversight of advanced biotechnology,
  - Regulation of long range precision strike capability.
  - Protocols for response to civil conflict.

12

- Measures for internationalizing fuel cycle control have a better chance of succeeding in the context of a broad program for security accommodation that they do as separate initiatives.
- Need for more accurate accounting of the global inventory of nuclear weapons and explosive isotopes likely to drive the development of comprehensive material accounting measures.

13

- Incentives to develop a broad program of security accommodation are substantial
  - Inherent danger of deterrent force operations
  - Predictable requirements of stabilizing Iraq and Afghanistan
  - Ultimate response to global warming.

14

Questions

- Is profit sharing necessary?
  - Yes, presumably through open market investment.
- 2010 review conference
  - Advance the idea of a comprehensive global accounting system.
- NWS facilities
  - All NWS states would have to be included in a comprehensive accounting system.
  - FMCT an important supplement.

15

- Internationalization of USEC?
  - If not necessary to save it, then necessary to develop a comprehensive global accounting system.

16

"Equity is more than a share": A Presentation by Paul Meyer to Session VII MIT Workshop on Internationalizing Uranium Enrichment Facilities, Oct. 20-21, 2008.

As is probably evident by this point in the workshop, it is not possible to consider options for the internationalization of Uranium Enrichment facilities in isolation from the broader non-proliferation and disarmament context. In the nuclear realm, this context is deeply rooted in the Nuclear Non-proliferation Treaty (NPT) and the regime built around it. You will all recall the so-called 'grand bargain' this treaty has enshrined: the foreswearing of nuclear arms by the non-nuclear weapon states in return for the commitment to nuclear disarmament by the nuclear weapon states and the possibility for all NPT states parties to exploit the peaceful uses of nuclear energy. This tripartite deal of non-proliferation, disarmament and peaceful use has provided the diplomatic-legal foundation for the international security order we have prospered under for 40 years.

The NPT-based security order is currently under great stress and violations of its norms and commitments have become more prominent. The first withdrawal from the NPT in its history occurred with North Korea's defection from the treaty in 2003. This step was taken against a background where North Korea, Iraq and Libya had violated their obligations as states parties and continued suspicions relating to Iran's nuclear program remain unresolved. Treaty compliance, or more precisely non-compliance, has become the focus of much NPT-related discussion, but this theme has often been applied in a subjective and self-serving fashion. The non-proliferation dimension of the treaty has been emphasized over its concomitant disarmament and peaceful uses aspects. This has tended to deepen the pre-existing fault line of the NPT, its discrimination between the nuclear weapon possessing states and those states which have pledged not to acquire nuclear weapons. Initiatives that have the effect of exacerbating rather than mitigating the discriminatory features of the Treaty will weaken it over time. Unfortunately, the renewed interest in multinational approaches to the nuclear fuel cycle is being raised in this unpropitious context.

The perception of many non-nuclear weapon states (NNWS) in recent years has been that they are being subjected to ever more stringent and demanding forms of non-proliferation controls while simultaneously their Art IV rights are being constrained and infringed upon. At the same time, the nuclear weapon states (NWS) are not only exempt from many of the non-proliferation controls but also demonstrate scant regard for their Art VI disarmament obligations. A series of contentious meetings of the NPT membership including the failed 2005 Review Conference have only contributed to a sense of grievance over the perceived inequities of the treaty and the failure of leading states parties to address them. Unless the upcoming NPT Review Conference in 2010 helps correct some of the key imbalances in the treaty's functioning, there is a likelihood that the NPT's authority will be further eroded.

The chief non-proliferation rationale for devising multinational enrichment options is to provide an alternative to the indigenous development of sensitive nuclear technology. If

properly carried forward such an approach may well be attractive for those NNWS wishing to avail themselves of it. Among the tools for strengthening the international safeguards system, however, the establishment of multinational enrichment facilities is not central or a priority. Many states would emphasize the importance of ensuring adherence to the existing IAEA approved safeguards. There are still 30 states parties who have not concluded a comprehensive safeguards agreement with the Agency, a basic obligation for all NPT members. These states are the equivalent of "black holes" for the IAEA's monitoring effort as the Agency has no authority to examine them. Similarly the Additional Protocol (adopted by the Agency's Board of Governors over a decade ago in the wake of the Iraqi clandestine nuclear weapons program) is still only in force in a minority of NPT states parties. In the view of some states, the diplomatic energy and financial resources being devoted to international enrichment options might be better directed to universalising these fundamental instruments of the global safeguards system, not to mention helping to cover the IAEA's growing budgetary needs in this regard.

An official expression of this point of view was put forward in a working paper submitted to the April 2008 NPT Preparatory Committee meeting in Geneva by ten leading NNWS known as the Vienna Group of Ten. While the working paper takes note of the renewed interest in multilateral approaches to the nuclear fuel cycle and the provision of assurances of nuclear fuel supply as an alternative to acquisition of sensitive technologies, it continues by stating: "At the same time, the Vienna Group recognises that multilateral approaches to the nuclear fuel cycle should be complementary to the primary non-proliferation instruments of effective and universal implementation of IAEA safeguards, including the Additional Protocol, and effective export controls. Strengthening and implementing these primary instruments, including the adoption of criteria for the transfer of proliferation-sensitive nuclear technology, remains of paramount importance. In addition, multilateral approaches to the nuclear fuel cycle should be considered as complementary to other measures to reinforce the non-proliferation regime, such as the CTBT and an FMCT." In other words, while multilateral nuclear supply arrangements merit further consideration, there are more pressing steps to be taken to strengthen the non-proliferation regime, including delivering on outstanding non-proliferation and disarmament commitments.

As the benefits of multinational enrichment approaches relate to one part of the NPT-centric non-proliferation regime, it will be necessary in packaging any initiative of this nature, to bear in mind how it would be played at the 2010 NPT Review Conference. In my opinion, the prospects for any such initiative would be improved if it could be situated as part of a comprehensive package of measures representing concrete progress across all three "pillars" of the NPT. In the absence of major revitalization of the disarmament track, there may be little willingness among NNWS states to accept new burdens or limitations on their civilian nuclear programs for supposed non-proliferation gains.

Why, for example, should a country like Canada, with a strong non-proliferation record and a major uranium industry that leads the world in exports, deny that industry from pursuing lucrative enrichment possibilities including accessing relevant technologies?

Enhancing the value –added portion of processing a raw resource is a well established model in commodity economics and it is not evident that other current producers are ready to apply such self-denying ordinances to themselves. Given that NWS figure prominently among the current possessors of enrichment technology, it doesn't take a cynic to wonder if the sudden interest in restrictions on sensitive technology transfers has more to do with protecting existing privileges and market share than with strengthening the non-proliferation regime. In short, if industry is to be brought on board in eventual multinational enrichment arrangements, these arrangements will have to be commercially interesting in and of themselves.

One possible route to gaining wider acceptance of proposals for internationalizing enrichment facilities, would be to subsume these as part of a comprehensive accord to control fissile material. This umbrella accord could comprise a Fissile Material Cut-off Treaty providing for the cessation of production of fissile material for nuclear weapon purposes as well as additional agreements covering all stocks of fissile material of both a civilian and military nature. A key driver would be the need to achieve transparency and maximum international control over the essential ingredient for nuclear weapons. By extending transparency to NWS holdings it would also serve to reduce the discriminatory nature of the current nuclear material control system and thereby also help shore up the foundations of the NPT. The initiation of negotiations on an FMCT is one of the top priorities (alongside entry into force of the CTBT) on the NPT's disarmament agenda (both were promised as part of the 1995 package of decisions that resulted in the indefinite extension of the NPT) and its realisation would be seen as an indication that forward progress on the disarmament front had been restored.

The obligation for NWS to submit to IAEA scrutiny, including in what previously were considered highly sensitive enrichment and reprocessing facilities, may not be readily embraced. At the same time, insisting on a system whereby NWS are exempted from meaningful monitoring while NNWS are subjected to intrusive and detailed surveillance, is not going to be viable over the longer term and threatens continued adherence to the NPT. If the world is ever to get a solid grasp on how much fissile material is out there, a precondition of effective control, a much more comprehensive reporting system needs to be established.

In a working paper submitted to the Conference on Disarmament in May 2006 (CD/1770), Canada outlined several measures addressing transparency of fissile material holdings, declarations of excess fissile material and arrangement for such material to be placed under international verification pending its disposition. These steps were viewed as complementary to efforts to conclude an FMCT which might have to be limited to a ban on future production. Underlying these ideas was the recognition that stocks of fissile material needed to be addressed in some manner for both diplomatic and substantive reasons and that greater transparency and accountability concerning fissile material would be desirable features regardless of the progress made towards negotiation of an FMCT.

In a more recent working paper submitted to the NPT PrepCom this April (WP.21 30 April 2008), Germany made the case again for why an FMCT is "the next logical step" for nuclear disarmament and non-proliferation, but also laid out several incremental steps that could create positive momentum towards this goal. These included a political declaration containing a cut-off commitment and an engagement to initiate negotiations without preconditions; conceiving of an FMCT as a "framework" treaty with separate implementation protocols and support for a "Fissile Material Control Initiative" that would encourage multilateral voluntary measures regarding global fissile material holdings.

Implementation of existing obligations relating to fissile material control would also be useful complements to future action on an FMCT and significant confidence building measures. The implementation of the Trilateral Initiative whereby surplus fissile material would be deposited by Russia and the United States with the IAEA and subjected to its control was Step #8 of the so-called "13 Steps" for practical disarmament agreed to as part of the 2000 NPT Review Conference, but which was not carried out by the two states concerned. Similarly, Step #10 called on all NWS to place fissile material designated as surplus to military programs under IAEA control and has not been realised by these states. It is understandable, that many states are sceptical about new proposals for controlling enrichment or reprocessing capacities being sponsored by NWS when these states have largely failed to honour their existing commitments made within the NPT context. Merely providing for some share in the profits to participating industrial concerns is unlikely to gain the necessary governmental backing in the absence of corrective action to restore more equitable progress on all three facets of the NPT. Equity in the enrichment facility is no substitute for equity in the non-proliferation and disarmament regime.

In conclusion, if proposals for internationalizing uranium enrichment are to be made palatable in the present non-proliferation and disarmament context and garner the general support required to be endorsed at the 2010 NPT Review Conference, they will need to be part of a broader package of measures devoted to fissile material control and will need to have a distinct disarmament dimension.

Background Papers

Internationalizing the Nuclear Fuel Cycle

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Summary

Where we are right now. The Bush administration has tried to persuade the Nuclear Suppliers Group (NSG) not to sell technology and equipment for enrichment and reprocessing to any state that does not already possess full-scale, functioning plants of this type. The proposal was rejected, even by close friends of the United States. The United States is now trying to accommodate its policy to a "criteria-based" approach proposed by France and other NSG members. Efforts to block the spread of enrichment and reprocessing capabilities have fallen short for four main reasons: (1) access to the base technologies required for entry into the field is relatively easy; (2) several states were determined to acquire their own enrichment and/or reprocessing capabilities for various reasons, e.g., to reduce energy dependence, conserve energy resources or to manage nuclear wastes; (3) no combination of incentives and threats short of military action have sufficed to dissuade nations intent on acquiring a nuclear weapons capability from exploiting these technologies; and (4) many nations that have no current intention of building nuclear weapons and no special animosity towards the United States reject the idea of a two-tier system as regards possession of enrichment and reprocessing facilities, believing they have every right to develop all aspects of a civil nuclear power program. Stopping the further proliferation of nuclear weapons will depend on developing policies that deal effectively with these four factors.

Key Issues.

1. Would it be useful to take credible steps to eliminate the "two-tier" system, both in civil nuclear power and in nuclear weapons?
2. Can equal rights to fuel cycle services be satisfied through assurances of reliable access at reasonable cost to fuel for civilian reactors?
3. Could a stronger effort to internationalize the fuel cycle help to limit the spread of technology and facilities?
4. Would it be feasible to create an international norm requiring that sensitive nuclear fuel cycle facilities be placed under some form of multinational control?
5. Are there criteria beyond (1) multinational ownership and management and (2) IAEA safeguards, which could gain international acceptance as a means to limit the number of uranium enrichment facilities in the world and prevent the spread of enrichment technologies?
6. How could agreements to internationalize nuclear fuel cycle services be enforced?

Conclusions and Recommendations.

1. It should be U.S. policy to work, step-by-step, toward the goal of a world free of nuclear weapons. In this framework, the credibility of actions to remove the "two-tier" stigma from the arena of fuel cycle service would be enhanced and efforts to block the spread of technology and equipment that can be used to build atomic bombs are likely to be more successful.
2. Current programs and proposals advanced by several nations to assure reliable supplies of nuclear fuel at reasonable costs to states with responsible nonproliferation records should be supported, while recognizing that these programs are not a complete answer to demands for an end to the "two-tier" system. One of these programs, the Bush administration's Global Nuclear Energy Partnership (GNEP) should include a wider array of technical options than it currently does, especially ones that do not require more emphasis on reprocessing with existing technology to produce mixed oxide (MOX) fuel. The Partnership also should make infrastructure development, including internationalization of the nuclear fuel cycle, one of its priority goals.
3. Priority attention should be given to establishing uranium enrichment facilities under multinational control. The United States should take the lead in proposing that: (1) as of a given date all plans for new commercial uranium enrichment facilities should be based on the presumption that the facilities will be multinationally owned and their operations safeguarded under conditions approved by the Nuclear Suppliers Group (NSG). After that date, the NSG should give preference to such facilities when considering selling enrichment equipment and technology; (2) existing commercial facilities or those under construction that are not already multinationally owned should be encouraged to convert to multinational ownership, with their operations similarly safeguarded.
4. Models of multinational enrichment facilities include:
    - Urenco, a multinational board of directors with plants in Germany, The Netherlands, and the United Kingdom. Major policy committees, plant management, and operating staff includes nationals of the three founding countries. Technology is shared among these countries but not with others. Urenco shares are not for sale.
    - Eurodif, owned by Areva, has a plant located in France, managed and run by French personnel. Areva is a multinational corporation dominated by French interests. Technology is not shared. Angarsk, a Russian enrichment facility partly owned by Kazakhstan, apparently will follow the Eurodif model. GE Hitachi may adopt this pattern as well.
    - A generic model in which the board, senior management and operating staff is multinational, and includes consumer states. Access to sensitive technology would be limited to participants who already possess such technology.
5. U.S. policy should continue to seek to limit the number of uranium enrichment facilities in the world and to limit the spread of sensitive enrichment technology.

In addition to conditions imposed by U.S. laws and policies, NSG conditions for transfers of enrichment technology and equipment should include the following:

- A recipient of enrichment equipment or technology must be a member in good standing of the NPT and have an IAEA "Additional Protocol", in effect or in the process of being put into effect;
- Proposals for new enrichment facilities should be based on sufficient domestic demand or in cases where the export market is a consideration exports of enriched uranium must be in compliance with NSG Guidelines;
- Protecting sensitive technology must be a priority objective, including "black box" arrangements for uranium facilities;
- All exporters of enriched uranium fuel assemblies, including the nuclear weapon states, must support an increase in the IAEA safeguards budget sufficient to provide for the actual application of IAEA safeguards using Limited Frequency Unannounced Access (LFUA) at their uranium enrichment facilities;

6. The most difficult question is whether multinational enrichment facilities should be encouraged in potentially unstable areas in return for rolling back incipient nuclear weapons programs. The test case is Iran. The Iranian government stated on May 8, 2008 that it is ready to consider "establishing enrichment and nuclear fuel production consortiums in different parts of the world – including in Iran." This should be explored in appropriate channels. A requirement for international staffing should be a part of the agreement in cases like Iran where regional security considerations are a factor.
7. Enforcement mechanisms should be devised in case of violations of NPT/IAEA agreements, enabling the UN Security Council to establish a "response mechanism," including a series of pre-agreed incremental sanctions.
8. Ideally, the presidents of the United States and Russia should launch a nonproliferation initiative by declaring, early in 2009, that their mutual intention is to work toward a world without nuclear weapons. Tangible evidence of this would be their agreement to reduce the numbers of warheads in the 2002 Strategic Offensive Reductions Treaty from 1700-2200 to 1000 and to add to that treaty verification provisions drawn from START.
9. In any case, the United States should begin consultations with other countries at an early date (1) to make the elimination of nuclear weapons a truly global enterprise and (2) to ensure that all states in compliance with their nonproliferation obligations have access to the benefits of peaceful nuclear energy, including reliable fuel supplies and, if desired, the possibility of ownership of multinational uranium enrichment facilities.
10. The United States should consider opening domestic uranium enrichment facilities to joint ownership and co-management with entities of other nations, under conditions approved by the NSG. The goal would be to make safeguarded multinational uranium enrichment the normal way of doing business and to make substantial progress toward that goal not later than the 2010 Review Meeting of the Nonproliferation Treaty.

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Internationalizing the Nuclear Fuel Cycle

Nuclear Dilemmas

The fact that nuclear energy can be exploited both for weapons and for civil purposes has presented a dilemma which has been managed but never resolved in over six decades. Uranium and plutonium can provide abundant, carbon-free energy but also the means for producing the most destructive weapons ever invented. Enriching natural uranium is useful for producing nuclear fuel for reactors, and for bomb-making. Removing pure plutonium from spent fuel produces material from which a bomb can be made. In his "Atoms for Peace" speech of December 8, 1953, Dwight Eisenhower put it this way: "…if the fearful trend of atomic military build up can be reversed, this greatest of destructive forces can be developed into a great boon, for the benefit of all mankind." This dilemma has never been satisfactorily resolved. In the context of a serious international commitment to work for the goal of a world without nuclear weapons, perhaps it can be.

Two interconnected concepts that might resolve the dilemma were advanced in the Acheson-Lilienthal Report not long after Hiroshima and Nagasaki. The ideas were to eliminate nuclear weapons and to create an international authority to manage the peaceful uses of nuclear energy. Eliminating the very few nuclear weapons that existed in the late 1940s would have been relatively easy to do as a technical matter. Conflicting national objectives at the time made the task impossible. Today, in contrast, eliminating nuclear weapons is a more complex task, as a technical matter. But the national objectives of the major nations may be more in alignment, as they consider the threat posed by nuclear weapons.

As in 1946, establishing some form of international authority over the most dangerous aspects of the nuclear fuel cycle is likely to be the most effective long-term remedy for the proliferation problem. And, as in 1946, the key to success is to carry out the process of internationalizing the nuclear fuel cycle in parallel with the process of eliminating nuclear weapons. Decisions to act cooperatively in this sensitive area were impossible for the major governments in the 1940s and 1950s. Cooperation on nuclear energy will be politically difficult, but perhaps not impossible, in the 2010s. In contrast to 1946, an incentive-driven, "bottom up" approach may augment public policies and this combination could lead, over time, to an international authority of limited scope.

The goal of a world without nuclear weapons should serve as a compass to guide public policy in the here and now, not in some distant future. Nowhere is such a policy framework more necessary than in decisions concerning the nuclear fuel cycle. The end of the Cold War, the globalization of the economy, and deadly challenges posed to all states by non-state organizations, have created an environment that should make the need for international cooperation more apparent. The level of cooperation that would insulate the nuclear fuel cycle from potential misuse is on a lesser scale than the authority

envisaged in the Acheson-Lilienthal Report. The technical/material obstacles confronting the task of eliminating nuclear weapons are formidable, but probably can be overcome if the task is addressed carefully and incrementally. Progress in escaping from the nuclear deterrence trap altogether is dependent on significant improvements in the relations among the major nations but progress in one should breed progress in the other.

The Nuclear Renaissance

One solution to the nuclear dilemma would be to phase out nuclear reactors, which is precisely what some people advocate, but even a world without nuclear weapons is not likely to be a world without civil nuclear power plants.[1] The rising demand for energy, especially in Asia, has made it all but inevitable that a surge in the construction of new reactors will occur over the next two decades. That will pose issues regarding the building of new uranium enrichment facilities and of reprocessing facilities, or the expansion of existing facilities. The question of assured nuclear fuel supply already is on the table, as are the perennial questions of what to do with spent fuel and whether to exploit for power generation purposes the plutonium that is contained in the spent fuel. Getting the answers right will be a crucial test for public policies, in the United States, and elsewhere.

Growing energy demands and the need to curb greenhouse gases have created the much publicized "renaissance" in proposals for new nuclear reactors. Many projects have reached the advanced planning stage or are already being constructed. Centrifuge technology for enriching uranium also has made significant advances and the cost of separative work has been reduced. The cost will drop further as the transition to centrifuge technology from gaseous diffusion technology continues. The base technology is spreading. There may be exaggerated expectations associated with the renaissance and the time frame for its full flowering is likely to be very long, but new reactors are being planned on a scale unseen in recent years. All that remains uncertain is the *rate* of nuclear power growth.

Assumptions suggesting that nuclear power growth will be slow depend primarily upon some level of stability in the Middle East so that oil supplies from there are not interrupted, and on there being no rapid and major change in the earth's climate. If these conditions changed, or if dependence on oil from unstable regions simply becomes too risky for major oil exporters to tolerate, the world could decide to make a transition to a heavy dependence on nuclear power. If the example of France is a guide, it could do so on a global scale in 25 years.[2] On the other hand, if there were another Chernobyl-like accident or some dramatic diversion of nuclear materials from civil power programs to a nuclear bomb, the predicted expansion of dependence on nuclear power might be slowed down or even stopped.[3] On balance, the best bet is that nuclear power plants will become a larger part of the energy mix, which means that managing the nuclear fuel cycle will present "front burner" issues for governments. In the United States, these issues come in the form of a transition to centrifuge-based enrichment technology and possibly to laser-based enrichment, persisting problems regarding storage of nuclear waste material, and whether to begin encouraging the use of plutonium as a reactor fuel.

Rejection of a Two-tier World

In addition to uncertainties about the rate of growth of nuclear power generation, there are very strong political currents in the world that distort the picture provided by objective economic analyses. One of these is the view held by many nations that a "two-tier" world is unacceptable, that it is not right that some nations are allowed to have enrichment and reprocessing facilities for peaceful nuclear energy programs, while others are forbidden to have that infrastructure. Very few nations would willingly be caught on the inferior side in a permanent "two-tier" system where some nations are entitled to the infrastructure for a civil nuclear power industry, and others are not. Assurances of reliable, uninterrupted supply of nuclear fuel, while removing some incentives, do not respond to the "entitlement" motivation. To address that, a mechanism that gives any nation that wants it at least some form of vested interest in one or more major elements of fuel cycle services is required.

Another powerful determinant of national policies is the desire to have an option to acquire nuclear weapons. This consideration has played a major role in several national decisions to build uranium enrichment facilities. To address this motivation, expectations about the future have to be changed. Nations have to become convinced that global trends are in the direction of less dependence on nuclear weapons for security, and that there are better alternatives. Otherwise, they will try to keep the nuclear weapons option and will build the infrastructure needed to do so.

The Bush administration has tried valiantly to make a two-tier system work, offering assurances of reliable supplies of nuclear fuel as an incentive. A notable example of this was the president's speech at the National Defense University, in Washington D.C., on February 11, 2004, perhaps his most comprehensive policy statement on nuclear proliferation. He proposed seven steps to block nuclear proliferation. One of them was:

> The world's leading nuclear exporters should ensure that states have reliable access at reasonable cost to fuel for civilian reactors, so long as those states renounce enrichment and reprocessing…the 40 [*now 45*] nations of the Nuclear Suppliers Group should refuse to sell enrichment and reprocessing equipment and technologies to any state that does not already possess full-scale, functioning enrichment and reprocessing plants.

The administration tried to obtain the agreement of the members of the Nuclear Suppliers Group to this new rule but ran into strong opposition from states, including Canada, that insist on maintaining the option to develop their own fuel cycle capabilities. Non-nuclear weapons states parties to the Nonproliferation Treaty (NPT) believe that Article IV of the treaty gives them the right to participate fully in the peaceful uses of nuclear energy.[4] Currently, the administration has modified its policies to fit with a "criteria-based" approach proposed in the Nuclear Suppliers Group by France and accepted by all others. This would permit transfers of enrichment technology and equipment under certain specified conditions.

On a case-by-case basis, the administration also has sought to reinforce a "two-tier" rule with sanctions, but these have been aimed only at countries deemed to be unfriendly, like Saddam Hussein's Iraq, Iran and North Korea, not friendly nations like Brazil, India, or Pakistan.

Most of the nations that are interested in acquiring energy from nuclear sources are not presently contemplating the building of a nuclear arsenal. Presently, the demand for small, nationally-controlled enrichment facilities is fairly limited but high prices for uranium, as well as uncertainties about supply may be enough to encourage some countries to build enrichment facilities just on economic grounds. Thus, the current economic situation may not act as a sufficient economic disincentive to the building of small-scale enrichment facilities.[5]

Most nations in this category are opposed to the acquisition of nuclear weapons by Iran and North Korea. But still they are not comfortable with a two-tier system. This attitude was captured in a statement made by the IAEA director-general, Mohamed ElBaradei, at the Oslo Conference on "Achieving the Vision of a World Free of Nuclear Weapons", on February 26, 2008:

> …we *must develop a new framework for the utilization of nuclear energy*. As I continue to advocate, a multilateral approach would ensure security of supply of nuclear fuel, while reducing the risk of proliferation. A number of proposals have been made, including a fuel bank under IAEA auspices and multinational enrichment facilities. The ultimate goal in my view should be to bring the entire fuel cycle, including waste disposal, under multinational control, so that no one country has the exclusive capability to produce the material for nuclear weapons. I do not believe that any country will give up its right to engage in fuel cycle activities unless the multinational framework is based on equal rights and obligations for *all* participants.

Thus, added to the economic and technical dimensions of nuclear energy is the imperative identified by Dr. ElBaradei: the need to create a level playing field through a new framework that is based on equal rights and obligations.

Back to the Future?

A new framework for the peaceful uses of nuclear energy must also prevent the proliferation of facilities useful for manufacturing nuclear weapons. A tall order? Yes, and the magnitude of the challenge can be appreciated by recalling the solution to the same problem offered by the authors of the Acheson-Lilienthal Report, in 1946.[6] The Acheson-Lilienthal Report was written in a world free of nuclear weapons, or very close to it, and its authors tried to imagine how to keep it that way. Faced with this challenge, the authors proposed the creation of an Atomic Development Authority, which would own and operate the basic means of producing materials that could either fuel power plants or be used to build an atom bomb. Access to uranium and plutonium was regarded

as a key choke-point in preventing nuclear weapons development. The Acheson-Lilienthal Report specifically left in national hands the construction and operation of energy-producing nuclear reactors, provided there was some oversight of reactor design, construction, and operation.

That report was amended by the Truman administration in ways that made it less acceptable to other nations, and specifically to the Soviet Union. It was then presented to the United Nations by Bernard Baruch on behalf of the United States government, and became known as the Baruch Plan. After years of futile debate in the depths of the Cold War, the proposal was withdrawn, long after it had ceased being a topic of international negotiation. The vision of a world free of nuclear weapons was not discussed seriously again by American leaders until 1986, when President Ronald Reagan and Soviet General Secretary Mikhail Gorbachev met at Reykjavik. They failed there to reach an accord on total elimination of nuclear weapons, but they did succeed in launching a trend toward many fewer warheads in the U.S. and Soviet/Russian stockpiles.

In 2006, on the 20th anniversary of the Reykjavik meeting, Reagan's Secretary of State, George P. Shultz, and Dr. Sidney Drell convened a meeting at Stanford University's Hoover Institution for the purpose of discussing whether Reagan's hopes could be rekindled. That meeting of knowledgeable people from around the country led to an extremely influential article published in *The Wall Street* Journal on January 4, 2007, signed by Shultz, former Secretary of State Henry A. Kissinger, former Secretary of Defense William Perry, and former Chair of the Senate Armed Services Committee, Sam Nunn. It endorsed "setting the goal of a world free of nuclear weapons and working energetically on the actions required to achieve that goal."

Another conference held a year later, sponsored by the Hoover Institution and the Nuclear Threat Initiative, resulted in a second article by the same four authors. It reaffirmed the vision of moving toward zero nuclear weapons and called for "developing an international system to manage the risks of the nuclear fuel cycle." And so today, in 2008, the dilemma faced by the authors of the Acheson-Lilienthal Report in 1946 has re-surfaced, again in the context of a world free of nuclear weapons. The Acheson-Lilienthal recommendations would have required sweeping political changes that were not possible in the 1940s. Even in 1986 the world was not ready for such a dramatic shift in policies and public attitudes. Today, the attitude is more like: "Why has it taken so long?" And nearly everyone who has thought about the dilemma now believes that if a world free of nuclear weapons is to be achieved, international authorities of *limited* scope, on a more modest scale than the one proposed in the Acheson-Lilienthal Report, will become necessary at some point in the process.

A Goal and a Compass

If that is the case, then policies in the United States and elsewhere should begin laying the foundation for an international authority, recognizing that steps in that direction will have to be incremental, building on what exists today. Examples of international authorities of limited scope exist today in the nuclear field, and while they

are much less ambitious in their reach than the authority envisaged in the Acheson-Lilienthal Report, they are multinational. Some provide for joint ownership and operations of key functions of the power industry, specifically uranium enrichment.

The process of institution-building in the nuclear field may come to resemble the function-oriented process advocated by Jean Monnet as he imagined how a united Europe could be created. Monnet's scheme started with a Coal and Steel Community, although his longer-term vision was to re-create the political structure of Europe. Similarly, the creation of an international authority to manage civilian nuclear power could begin with multinational organizations of fairly limited scope which later might coalesce. [7] Economic incentives, not top-down directives, can provide much of the motivation for progress in this direction. But a clear and convincing U.S. policy framework is needed to chart the course.

The past history of efforts to internationalize the nuclear fuel cycle does not give grounds for optimism about current efforts – but times have changed. The anticipated surge in construction of nuclear power reactors may create a steeply rising demand for nuclear fuel services, including enrichment of uranium. Four new enrichment facilities now are being planned or actually being built in the United States alone.

A second factor is the growing realization among nations that present trends in the nuclear arena court disaster. The two *Wall Street Journal* articles by Shultz, Kissinger, Perry, and Nunn received enormous public attention around the world. Their warning that the world is at a tipping point in terms of nuclear proliferation resonated strongly. As states such as Iran and North Korea have acquired the means of enriching uranium and to separate plutonium and as the clandestine network operated by A.Q. Khan has shown the ease with which technology can be transferred to such states as Iran, Libya, and North Korea the proliferation of the infrastructure for bomb-making has become a pressing concern. Instability and terrorist activities in Pakistan suggest that nuclear programs there also must be considered a potential crisis.

On the positive side, the rise of the global economy has created economic and political conditions that are more receptive to multinational cooperation, including the nuclear fuel cycle.

First Priority to the Front End of the Fuel Cycle

Construction of new nuclear reactors is a slow process and this affords time for deliberation and for building a consensus regarding appropriate multilateral responses to the anticipated demand for enriched uranium. A successful effort to internationalize the nuclear fuel cycle is likely to be an incremental process and so a basic policy question arises: should the process take place across the spectrum of fuel cycle operations or on a sector-by-sector basis?

The main sectors are 1) uranium mining, 2) uranium enrichment, 3) fuel fabrication and supply to recipient countries, and 4) reprocessing or storing spent fuel and

storing waste material. Three types of fuel cycle facilities entail high capital costs and large economies of scale: uranium enrichment, reprocessing, and storage of waste and spent fuel. These economies of scale can be used to support nonproliferation policies. [8] It appears that uranium enrichment could be the spearhead in the process of internationalizing the fuel cycle. The lower costs of nuclear fuel provided by large, modern centrifuge facilities should help to discourage, on economic grounds, the building of small, high-cost enrichment facilities. It would be far less expensive for nations and companies to take part ownership in a multinationally-owned facility, perhaps using leased centrifuge machines under "black box" conditions, than to build their own. But the case for this choice of priority is based not only on economics but also on the fact that centrifuge technology is becoming more efficient, less expensive to operate, and more widely available. The transition from gaseous diffusion to centrifuge and laser technology means that plans have been developed to build new enrichment facilities in the United States, which makes the political and economic dynamics more favorable for multinational ownership than in the past. Furthermore, there is considerable experience in managing multinationally owned enrichment facilities. And interest has been expressed by the Permanent Members of the U.N. Security Council, among others, in a multinational mechanism as a viable alternative to indigenous development of nuclear fuel services.

A few large enrichment facilities, as opposed to many smaller facilities around the world, should help to contain the spread of national capabilities for constructing nuclear weapons. [9] The participation of several nations in ownership management, and, in some cases, in plant operations should help to deter cheating. ***It must be recognized that for this plan to work, some jointly owned and managed enrichment facilities must be open to participation by those nations that are the consumers of enriched uranium supplied by multinational facilities. One of the principal purposes of encouraging multinational enrichment facilities is to give consumers a stake and a say in the running of such facilities so that they have fewer legitimate incentives to build their own facilities.***

Multinationally owned and managed uranium enrichment facilities situated in various regions of the world should develop common ground rules for supplying nuclear fuel. They should agree on effective approaches for safeguarding the plants to prevent diversion of enriched uranium to non-civil purposes and to ensure that enrichment does not proceed beyond a certain level. They should work closely with the IAEA to develop effective safeguards to detect and deter the construction of separate clandestine enrichment facilities. Such multinational facilities, some of which would be quite small to begin with, would have the potential to evolve into the sole lawful suppliers of enriched uranium, fulfilling one element of ElBaradei's vision.

If the United States takes the lead in encouraging for multinational facilities, fuel centers might be developed in the following locations:

a. Brazil, based on the Resende uranium enrichment facility. Argentina already is associated with Brazilian nuclear activities.[10]
b. Russia, based on the Angarsk facility.

c. Iran, if that proves to be feasible or, if not, another Middle East-dedicated facility outside the region as proposed by the Saudis.
d. The United States/Canada.
e. China and/or Japan.

A Different Solution for the Back End of the Fuel Cycle

The proposition that reprocessing facilities should be established on a multinational basis has been the subject of discussion for many years. The proliferation potential of nationally-owned facilities, which produce plutonium useable for nuclear weapons, is the basis for this interest. A thorough analysis of this idea was conducted as early as 1976 by private-sector experts, most of whom considered that it was feasible and had nonproliferation advantages. [11] This was at a time when it was also thought that reprocessing spent fuel and burning MOX was going to be economically beneficial. This has not been the experience with existing technology.

The very few commercial reprocessing facilities that exist today perform all the services required by nations that want pure plutonium for manufacturing fuel for civil nuclear reactors, either as mixed uranium and plutonium oxides (MOX).

The basic issue is whether to encourage the nuclear power industry to move on a large scale into building reactors that burn plutonium as fuel. The proliferation potential of such a move has made the United States and some other governments hesitant, until recently. Currently proposed technical solutions have not answered the concerns that many still have. It still makes sense, at this time, for the United States to be skeptical about the widespread use of plutonium as a fuel and to discourage the building of reprocessing facilities. Burning already separated plutonium as a means of disposing of it, however, is another matter.

There are three uses for plutonium separation facilities: for weapons, for waste management, and for producing plutonium for use as fuel in reactors, now or in the future. Plutonium is being used as a fuel today, as MOX. In a pure form it can be "burned" in fast neutron reactors, as a form of waste management and power generation. Exploiting plutonium as a reactor fuel may, with improving technology, grow to the point where a multinational approach to reprocessing would be justified, because of economies of scale. France and Japan already are exploiting MOX fuel as a very high-cost energy source as are some other nations. Japan and France already have MOX fuel fabrication facilities and related reprocessing plants. India has plans to follow suit on a large scale.

The rate of growth of energy production from plutonium-based fuel (primarily MOX) over the next two decades is not likely to be on a scale that would justify large multinational facilities. The costs are very high and current reserves of uranium are adequate to provide fuel for reactors for a long time to come. If that picture changes, perhaps due to rising costs of uranium, then expansion of the plutonium-based reactor economy could proceed more rapidly than now anticipated.[12] But for now, it appears that there is no need to move to MOX-based reactor fuel except to perhaps eliminate existing

stocks of separated plutonium (in particular in the UK).[13]. In the future, nationally-controlled MOX fuel centers in Europe or Asia might be considered as candidates for multilateralization, perhaps as "energy parks"[14].

Spent Fuel Storage

A more urgent near-term need is an international used nuclear fuel storage center. Storage of spent fuel is a valid interim or even long-term procedure. The technology exists, the costs are low, it could be done quickly, and the benefits are large. An international used nuclear fuel storage center would encourage supply policies that provide for spent fuel to be returned to the supplier, since the question of where to put waste material would be easier to answer. This option deserves serious attention as a prime candidate for multinational cooperation.

Implications for U.S. Policy

One of the first concerns of U.S. policy should be to deal equitably with those states that believe they have the right, as a matter of principle, endorsed by the Nonproliferation Treaty (NPT) itself, to own facilities essential to a nuclear power program, including uranium enrichment facilities. Such states may find multinationally owned enrichment facilities attractive, because of (1) the economic advantages over creating and operating their own infrastructure and (2) a strong commitment by the United States and other nuclear-armed states to work seriously for a world without nuclear weapons. In that case, the very small number of states that insist on having their own facilities, for military purposes, can be more easily isolated. Their decisions can possibly be reversed. Iran and North Korea already have been influenced by international pressure, and this should have even more effect in the framework of ending the "two-tier" system.

How to proceed? The United States should propose that: (1) as of a given date all plans for new commercial uranium enrichment facilities should be based on the presumption that the facilities will be multinationally owned wirh their operations subject to effective safeguards. After that date, the Nuclear Suppliers Group should give preference to such facilities when considering selling enrichment equipment and technology; (2) existing commercial facilities or those under construction that are not already multinationally owned should be encouraged to convert to multinational ownership, with their operations similarly safeguarded.

The former proposal is a variation on one already advanced by the Bush administration. The second would require a new decision, taken jointly by government and private industry. It would mean that the U.S. Enrichment Corporation would create a joint venture out of its planned new enrichment facility near Portsmouth, Ohio.

Another U.S.-based enrichment facility under construction in New Mexico already is owned by a multinational entity, Urenco. Such a decision might also mean that the French-based multinational corporation, Areva, should be encouraged to enlarge its

plans for an enrichment facility in Idaho to include part ownership by American and Canadian entities, and others. GE Hitachi, another multinational corporation, is planning another enrichment facility in North Carolina. The Canadian firm Cameco has taken a 24% stake in GLE, the company created by GE Hitachi.

The possibility of participating in some way in a multinational facility is the key to discouraging totally national enrichment facilities for nations that are consumers of enriched uranium. Many of these nations may be satisfied with assurances of reliable fuel supplies at reasonable costs. For those that are not, the multinational option should be available. The case for relying for enrichment services on a few large enrichment facilities (roughly, one for each continent), is persuasive economically if properly designed, and can provide major nonproliferation benefits. That case may not be accepted, however, unless it is seen in the context of a new deal between the current possessors of advanced nuclear technologies, including weapons capabilities, and those nations that are still considering their nuclear options. USEC's new facility is the only one in the United States that does not have international partners. A move to internationalize USEC's new Portsmouth facility would help to convince other nations that a new deal is in the making. Furthermore, opening the facility to participation by consumer-states may be a more practical proposition than in the other three enrichment facilities. USEC's Congressional mandate (Privatization Legislation) stipulates that there is a public interest in domestic enrichment facilities but there is nothing in the mandate that suggests that the public interest would not be met by a multinational facility on U.S. soil.[15]

An equally important component of this course of action would be a U.S.-led effort to encourage China, Japan, and Brazil to open their enrichment facilities to multinational ownership and management, not an easy task. But Russia has already embarked on this course in its Angarsk facility and has advocated a network of multinational enrichment facilities. China has worked closely with Russia on enrichment services. During President Medvedev's May 2008 visit to China, Russia signed a new agreement with China whereby Russia will help to build a fourth stage of a Chinese enrichment facility. China might see commercial advantages in replicating Russia's Angarsk initiative, also as part of a network of multinational enrichment facilities. Japanese firms have many joint ventures with U.S. and European companies in the nuclear field, including the GE Hitachi enrichment project. Brazil and Argentina already are engaged in a modest degree of nuclear cooperation; the question is whether to deepen it and open it to other nations, especially in Latin America. It should be noted that the Japanese and Brazilian facilities are quite small, not oriented presently toward export.

A political impulse will have to be provided by high-level governmental leaders if a program of internationalizing the nuclear fuel cycle is to gain any traction. Nations that have nuclear weapons and those that do not should join in making this program a truly joint enterprise.

Complementary Polices

Commercial markets have generally worked satisfactorily in terms of assurance of nuclear fuel supply. But energy security, naturally, is a matter of prime concern for any nation and the high costs of building a nuclear power industry cause governments to be extra wary about the reliabilities of fuel supplies. Several plans already have been advanced by the United States, Britain, Japan and other nations to provide assurances of reliable fuel supply. These should be encouraged and should be developed further.[16] These may not meet perceived requirements for a level playing field, but they weaken one argument for developing indigenous fuel cycle services. They may well satisfy the economic and political interests of most consumer-nations. Each of the proposals has the advantage that it adds to the diversity of suppliers, which is one of the most effective guarantees of uninterrupted supply of nuclear fuel. This also is true, of course, of multinational enrichment facilities, provided that the geographic distribution and the political complexion of the owners/managers are diversified.[17]

The nuclear fuel bank option, advanced by the Nuclear Threat Initiative (NTI) and endorsed by many others, should be an excellent form of assurance, depending on conditions of supply set by the IAEA, and the nation supplying the fuel. The fuel bank is both multilateral, in the sense that the IAEA supervises it, and responsive to demands for equality. Dr. Pierre Goldschmidt, former deputy director general of the IAEA, has suggested that

> an IAEA low enriched fuel reserve should, for practical reasons, be physically located (in the form of UF6) at the sites of all commercial enrichment plants. In addition, the Agency should conclude contracts with all manufacturers of fuel assemblies, whereby it would have the assurance to have access, in case of necessity, to some fabrication capacity.[18]

The Global Nuclear Energy Partnership

The Global Nuclear Energy Partnership (GNEP) is one of the Bush administration's efforts to answer concerns about reliability of fuel supply. The Department of Energy's research and development under GNEP currently is predicated on the concept of a U.S.-developed reactor (most likely a sodium-cooled fast reactor) that will use "recycled" fuel, but this is still in the early stages of development. The Department of Energy also is investigating a more proliferation-resistant separation process (UREX+1 and UREX+1a). GNEP's current focus appears to be too narrow at this point in time. A broader array of technology options could be added to its programs.

Precedents and Possibilities for Multinational Enrichment Facilities

Gaining control of the nuclear fuel cycle through internationalizing it could help to turn governments away from acquiring the complete nuclear fuel cycle. Private-sector initiatives within a policy framework established by governments and backed by

government support could play a major role. In contrast to the "top down" approach of the Acheson-Lilienthal Report, a mixed approach, relying in part on private-sector initiatives could become a major motivator.

But the utility of economic incentives in this field has to be understood in the context of the three multinational uranium enrichment facilities being planned for construction in the United States. They are multibillion dollar enterprises with multibillion dollar investments in proprietary technology developed over decades. They operate in a business that has very high barriers to entry and complex risk/reward calculations. One, located in Lea County, New Mexico, is being built by LES, which is owned by Urenco. It will be on-line in 2009 as the first centrifuge plant in the United States. A second, to be built 18 miles west of Idaho Falls, Idaho, will be owned by the multinational French-based firm, Areva. It also will use centrifuge technology. Technology will be protected in these two cases by "black boxes." The third, using laser technology, is planned by the U.S.-Japan joint venture GE Hitachi Nuclear Energy and its subsidiary, Global Laser Enrichment (GLE). The technology was developed by Silex Systems Limited of Australia. The plant will be built at Wilmington, North Carolina and is expected to be in operation on a commercial scale in 2012. Cameco, a Canada-based uranium producing company, recently has brought a 24% stake in GLE.

A fourth new plant will be built by the U.S. Enrichment Corporation. USEC is planning to operate its centrifuge plant at Piketon, Ohio on a commercial scale in late 2009 and will have 11,500 machines deployed in 2012. It will use American technology, the only plant in the United States to do so.

Urenco is a particularly interesting model of a multinational facility but it may also be unique because of its membership. It is a multinationally owned and operated facility in which technology is shared among the founding participants. The United States will have access to the technology only to the extent necessary to grant licenses. Urenco was established by the Treaty of Almelo, signed March 4, 1970, by Great Britain, Germany, and The Netherlands. The treaty entered into force in 1971. Urenco, as of 2007, had 23% of the world's market share for enriched uranium.[19] All three founding countries are close allies and share basic values so decision-making, which is based on unanimity, has not been a problem. Urenco was the source of A.Q. Khan's blueprints for an advanced centrifuge which later became the basis for Pakistan's uranium-based nuclear weapons program, which is an obvious blight on its record. The overall experience shows that, among like-minded states, with resources available for large-scale investments, multinational facilities are practical and commercially viable

Areva and GE Hitachi are more in the mold of classic multinational corporations, which means that many nations potentially could become shareholders, if not real managers of operations. Management and staff operations have been limited to nationals of the nations whose companies dominate these multinationals.

Iran

The most difficult question about multinational enrichment facilities is whether they should be encouraged in unstable areas in return for rolling back incipient nuclear weapons programs. The test case is Iran, where a study by John Thomson and Geoffrey Forden, of MIT, suggests that measures can be taken to prevent the expropriation of a multinational facility by the Iranian government and that the likelihood of discovery of any concealed enrichment facility in Iran would be enhanced by establishing such a facility.[20]

They have postulated a multinationally owned and operated enrichment facility located in Iran, using Urenco or Russian centrifuges, which would supplant Iran's nationally operated enrichment facility. In their analysis they describe legal, organizational, and technological barriers to nuclear proliferation, as well as barriers to nationalization. They point out that increased potential for detection of overt enrichment facilities could result from this arrangement, based on UNMOVIC and UNSCOM experience in Iraq. This is an example of the model where consumer countries would be heavily involved in ownership and management, although the technology would be "black-boxed". It is a model that may answer the level playing field arguments but, as should be expected in violence-prone regions, has proliferation risks of its own. An alternative that should be explored is a Saudi proposal for a multinational enrichment facility to supply reactors located in the Middle East, including Iran. The facility would be located outside the region, possibly in Switzerland.

Forden and Thomson report that Iranians with whom they have talked have expressed an interest in involving India and South Africa in such a facility. In a letter dated May 8, 2008 to the UN Secretary General from the Foreign Minister of Iran, it was stated that the government of Iran is ready to consider "establishing enrichment and nuclear fuel production consortiums in different parts of the world – including in Iran." The letter also spoke of "nuclear disarmament."[21]

Preventing the spread of advanced centrifuge or laser uranium enrichment technology would be a matter of concern in any multinational enterprise, even if the partners were on good terms. The technology is sensitive, and in cases of multinationally owned and managed facilities where the partners may not be equally advanced in enrichment technology, or even on very good terms with each other, that technology will not be shared among all the owners and managers, or with IAEA inspectors. This problem has been resolved in the past by the "black-box" approach to protecting technology and an on-site inspection system developed for the Urenco situation known as "Limited Frequency Unannounced Access." This gives inspectors unannounced access to the cascade hall under specified conditions. This system should be adopted by all states involved in a multinational enrichment enterprise. The question of conditions is common to all fuel supply options but applies with special force in unstable regions. Treaties or contracts should include provisions for: (1) enforcing Nuclear Supplier Group conditions for supply of fresh fuel; (2) safeguards against the host nation's seizing unilateral control of the enrichment facility; (3) a method of preventing the transfer of sensitive nuclear

technology to participants in a plant who did not previously have access to that technology, in accordance with NPT and Nuclear Suppliers Group rules.

Asia

Asia presents special complications. India, Pakistan, China, and Japan each have enrichment facilities ranging from pilot plants in the case of India to full-scale production facilities in the other countries. Japan has a commercial uranium enrichment facility (Rokkasho) and China has two, Lanzhou 2 and Shaanxi. China also has a gaseous diffusion plant for production of highly-enriched uranium. Pakistan has a centrifuge facility at Kahuta and probably one at Golra Sharif, as well. India has two pilot-scale uranium enrichment facilities.

China's commercial enrichment facilities use Russian technology, apparently under "black box" conditions and are under IAEA safeguards. Russia and China are cooperating actively in uranium enrichment services and nuclear fuel transfers. **With Russia now strongly promoting a network of international uranium centers, it is conceivable that China might agree, if only for its own commercial interests, also to open one or more of its enrichment facilities to international ownership and joint management**. It certainly should be asked, perhaps by Russia.

Japan and the United States signed a Joint Nuclear Energy Action Plan on April 18, 2007. One of its four main areas of cooperation is "establishment of a nuclear fuel supply assurance mechanism." [22] In the meantime Japan's strategy has been to form joint ventures with companies operating in the nuclear field. This includes GE and Hitachi, Areva and Mitsubishi, and Toshiba's acquisition of Westinghouse. [23] The purpose is to capture part of the market for building new reactors. Japan Nuclear Fuel Limited (JNFL), owned largely by Japanese electric companies, controls the nuclear fuel cycle in Japan, including the Rokkasho uranium enrichment plant and a new mixed oxides (MOX) fabrication plant. A reprocessing plant is now under construction. ***Consultations with Japan should start soon, aimed at investigating the possibilities for transforming the Rokkasho enrichment facility into a multinationally owned joint venture in parallel with a similar development in the United States.***

Pakistan and India require special consideration as non-members of the nonproliferation treaty who have also tested nuclear weapons. There is a great deal of well-documented sensitivity in both countries about rights to fuel cycle technologies. Each nation also has growing needs for energy. Nuclear power plants clearly will figure importantly in the mix of electric power-generating capacity in the subcontinent in the decades ahead.

In the near-term there is little chance either India or Pakistan will give up its enrichment facilities and each will retain an interest in domestic reprocessing facilities, most of which are involved in their weapons programs. But two developments might change this outlook over the mid-term: First, a growing coalition of the nuclear weapons states and others to move towards a world without nuclear weapons, a movement that

would change current expectations about the future salience of nuclear weapons in defense strategies; second, a global movement towards multinationally owned and operated enrichment facilities in which the United States, Canada, Russia, China, Western Europe, Japan and other nations are involved. [24] **A policy of relying on a few multinationally owned and operated enrichment facilities for the supply of fuel for reactors can become a serious possibility even in India and Pakistan if the goal of a world without nuclear weapons is generally adopted and if multinational enrichment facilities become the norm.** In fact, if India succeeds in its current plans to develop and build a large number of breeder reactors, India's requirements for enriched uranium may not grow at the same pace as its nuclear power program. A Fissile Material Cutoff Treaty would also help, as could the Iran international enrichment facility advocated by Forden and Thomson.

The major challenge to nonproliferation policies lies in the arc of uncertainty from South Africa, through the Middle East, to South Asia, and on to Australia. South Africa and Australia both appear to be considering their indigenous enrichment options. There are opportunities for cooperation in this area, since several nations are well disposed to the idea of preventing the proliferation of nuclear weapons. But there are also serious obstacles.

Enforcement

Although this paper focuses as a first priority on internationalizing facilities for enriching uranium, several other actions must be taken to prevent nuclear weapons proliferation. They include:

- Limiting the spread of reprocessing facilities and technology
- Controlling exports of nuclear materials and technology;
- Removing high-enriched uranium from exposed locations to secure storage facilities.

All of these actions, as well as the effort to ensure that uranium enrichment is used only for peaceful purposes, will be successful only if the international community is willing to take enforcement actions in cases of violations of NPT or IAEA obligations. This requires an international consensus, or something close to it, that violations of nuclear-related norms and agreements present a serious challenge to international peace and security. This consensus has been impossible, thus far, to achieve. Unless that problem can be effectively addressed, nuclear proliferation will proceed and the vision of a world without nuclear weapons will not be realized.

An international review, perhaps sponsored by the UN Security Council, should be conducted as to whether enforcement mechanisms could be devised that could be put into practice in case of violations of agreements. The issue of enforcement is fundamental and has never been satisfactorily resolved in nuclear matters. It needs a thorough airing in international arenas, and discussions by the UN Security Council. UNSC Resolution 1540 might be a suitable base for exploring what the Council could agree to, in advance, to deal with non-compliance.

Dr. Mohamed ElBaradei has drawn attention to this problem and to the need for the UN Security Council to have a "response mechanism".[25] Several levels of sanctions agreed in advance should be identified, for example: removal of nuclear-related equipment supplied to a nation that withdraws from the NPT; an embargo on all future nuclear-related transfers; mandatory transparency measures; financial and commercial restrictions; and disabling of key nuclear facilities. If military action is necessary, it should focus on compliance issues, and hold the non-compliant regime to account for correcting any violations.[26]

Military actions obviously would be warranted only by an apparent and imminent threat to international peace and security, but a Statement of the UN Security Council President on January 31, 1992 would seem to support that interpretation in most cases of a nation's withdrawal from the NPT. A scenario involving the use of force might include limited naval or air forces in an intercept mission similar to those for which the Proliferation Security Initiative (PSI) was created. Aerial surveillance, such as was carried out in Iraq during the years prior to the invasion in 2003 is another possible scenario. An idea that might represent a "last resort" in an escalating situation was advanced by Dr. Jessica Mathews, president of the Carnegie Endowment for International Peace in 2002.[27] It was a plan for "coercive inspections". Her proposal dealt with the issue of UN inspections in Iraq, but it is an enforcement mechanism which could have relevance in other dire situations. Dr. Mathews suggested that the UN Security Council might adopt a resolution authorizing multinational enforcement action to enable inspectors to carry out their UNSC mandate. She envisaged that the Security Council would authorize the creation of an "Inspections Implementation Force" to act as an enforcement arm for IAEA. The IAEA inspection team would be "*accompanied by a military arm strong enough to force immediate entry into any site at any time with complete security for the inspections team.*" (italics added) Dr. Mathews made it clear that the "military arm" would be a very powerful force consisting of air and armored cavalry units with substantial air support. "Use of all necessary means" would be the next step beyond the use of an Inspections Implementation Force.

A World Without Nuclear Weapons: Relating the Vision to the Steps

In any estimate of the current nuclear situation, it is impossible to ignore the core problem. This is the general assumption, shared alike by nuclear-armed nations and by those nations that have forgone nuclear weapons that the development and acquisition of nuclear weapons will proceed, that a nuclear-armed world is here to stay. That assumption has to be changed, for assurances of fuel supply by any imaginable means will not be sufficient indefinitely to block the gradual spread of nuclear-armed states. Eliminating the two-tier system of nuclear and non-nuclear armed states must go hand in hand with eliminating the two-tier system in civil nuclear power because otherwise, slowly but surely, more states will become capable of making nuclear weapons and those states will have at least the option of starting a weapons program.

A basic proposition of this paper is that a solution to the fuel cycle problem depends on embedding it in a broad commitment to a world free of nuclear weapons and

vice versa. The way to move forward is, first, to engage the United States and Russia in a commitment, at the highest levels, to work jointly toward a world free of nuclear weapons. The leaders of the two countries should follow this up with specific programs to reduce their strategic nuclear forces below the levels specified in the May 24, 2002 Treaty of Moscow. While implementing this commitment, and others, the presidents of the United States and Russia should invite other nations to join their two countries in working toward a world free of nuclear weapons. Each nation would be asked to commit to achieving a world without nuclear weapons and also to make a contribution to this goal, according to its special circumstances. A commitment to multinationally owned and managed nuclear fuel centers should be a key part of this program.

Unless impending decisions in several countries regarding the fuel cycle are made in a coherent way, with a view to how they contribute to the achievement of a world without nuclear weapons, these decisions will instead contribute to the spread of nuclear weapons capabilities. Conversely, if the goal of a world free of nuclear weapons is accepted by the international community and actions regarding the fuel cycle are consistent with that goal, it should be easier to expand the use of nuclear power without running the risk of nuclear weapons proliferation. The two have to be linked, not in lock-step, but in a way that permits each track to proceed as rapidly as events permit. Progress in one area should encourage progress in the other but, conversely, sensible progress in one area should not be delayed while waiting for progress in the other. The basic condition for success in escaping from the world's nuclear dilemma lies, as it did at the beginning of the nuclear age, in broad acceptance of the goal of a world without nuclear weapons.

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[1] Helen Caldicott, Nuclear Power is Not the Answer (The New Press, 2006)

[2] Dr. Charles W. Forsberg, Executive Director, MIT Nuclear Fuel Cycle Study, private communication. Dr. Forsberg notes that oil hit $133/barrel on May 21, 2008 and "that is over $3.00 per gallon for gasoline in just the oil costs. It implies that about two trillion dollars per year is being transferred primarily to five oil exporters: Saudi Arabia, Iran, Iraq, Kuwait, and Venezuela. It is the largest and fastest transfer of wealth in the history of mankind. If it continues for a decade, much of the U.S. economy will be owned by these countries. That is noteworthy because it's tough to argue with your banker about nonproliferation."

[3] Dr. Henry Rowen, Stanford University, private communication.

[4] Earlier in 2008 Canada told the United States that it would no longer support the G-8 moratorium on not transferring technology to any state that does not already possess enrichment or reprocessing capabilities This led the U.S. to shift its position at the Nuclear Suppliers Group (NSG) away from a moratorium and toward the inclusion of criteria in the NSG Guidelines. For background see http://www.armscontrol.org/act/2008_05/NuclearExport.asp and http://ap.google.com/article/ALeqM5ipQB9GzyPIIY_UCu2oLvVfTgyA4wD90719AO0

[5] This point has been developed by Dr. Geoffrey Rothwell, Department of Economics, Stanford University. See presentation by Dr. Rothwell, "The Economics of International Supplier States and Recipient State Regimes for Worldwide Nuclear Fuel Services", presented at the Howard Baker Jr. Center for Public Policy, October 3, 2007. Rothwell believes that market intervention to stabilize prices near reasonable cost, as mentioned by President Bush on February 11, 2004, may become necessary.

[6] http://www.learnworld.com/ZNW/LWText.Acheson-Lilienthal.html A ground-breaking work in this field was written by Dr. Lawrence Scheinman in 1981. Published originally in International Organization, as "Multilateral Alternatives and Nuclear Nonproliferation", it was republished under the title "The Nuclear

Fuel Cycle: A Challenge for Nonproliferation" in Disarmament Diplomacy, No. 76, March/April 2004, The Acronym Institute.

[7] Many scholars, particularly those adhering to the "constructivist" school of international relations, have written about international institutions as they have developed in the era of globalization. These institutions, such as the World Trade Organization, can have supranational characteristics in the specialized field in which they function. Professor Amitai Etzioni has written cogently about emerging global governance through the new institutions for transnational cooperation that have been created incrementally without benefit of a single overarching organization. As an example, Etzioni points to international cooperation in the field of counterterrorism and counterproliferation. He regards the Bush administration's Proliferation Security Initiative as a nascent enforcement mechanism for such an authority. See "Genocide Prevention in the New Global Architecture." The British Journal of Politics and International Relations, 2005 Vol. 7, 469-484. He also envisages a branch of the "Global Safety Authority" that would deal with what he calls "deproliferation". For a comprehensive analysis, see his From Empire to Community: A New Approach to International Relations (Palgrave Macmillan, 2004). The informal accumulation of responsibilities by an international authority acting on behalf of national governments is a process that could occur in the fuel cycle area.

[8] As is stressed by Charles W. Forsberg in a private communication and elsewhere.

[9] According to the IAEA, uranium enrichment facilities exist in Argentina, Brazil, China, France, Germany, India, Iran, Japan, The Netherlands, Pakistan, Russia, the United Kingdom, and the United States. Some of these are quite small and some already are multinationally owned and operated. It has been estimated that existing uranium enrichment facilities are capable of supplying all the reactors on line or expected to come on line in the next decade or so with the type of enriched uranium useful for reactors. But a transition from high-cost gaseous diffusion technology to less expensive centrifuge technology is underway and the rate of growth of reliance on nuclear power is uncertain. See the IAEA's INFCIRC/640.

[10] Irma Arguello, "Confidence Building in Regional Conflicts Involving Nuclear Dangers", presented at the Oslo Conference, February 26, 2006. A new Brazil-Argentian company that will engage in nuclear enterprises, including enrichment, has been created.

[11] Abram Chayes and W. Bennett Lewis, International Arrangements for Nuclear Fuel Reprocessing (Ballinger Publishing Company, 1977)

[12] According to the World Nuclear Association, more than 30 reactors use MOX fuel in Europe (Switzerland, Germany, and France) while about 40 reactors are licensed to do so. In Belgium all the plutonium recovered from the reprocessing of 670 tonnes of spent fuel has been recycled as MOX fuel in two nuclear power plants. Japan also has a plant to use MOX fuel in about 20 of its reactors. Most reactors today accept 50% MOX assemblies. (www.world-nuclear.org/info/inf29.html). India is planning to embark on a very ambitious breeder reactor program.

[13] Burton Richter states that while "MOX fuel has become a standard product…there is no real necessity for its use now." "Nuclear Power and Proliferation of Nuclear Weapons", Stanford University, February 22, 2008.

[14] See Lawrence Scheinman's, "Safeguarding Reprocessing Facilities: The Impact of Multinationalization", International Arrangements for Nuclear Fuel Reprocessing edited by Abram Chayes and W. Bennett Lewis, (Ballinger Publishing Company, 1977). Also see, pg. 4 "The Future of Nuclear Power", MIT interdisciplinary study, July 2003, http://web.mit.edu/nuclearpower/. "Energy parks" are proposed. Charles Forsberg notes that energy parks present two challenges. If electricity is the product, there are many transmission lines to the customers. The longer the electric transmission lines, the greater are the electrical loses. Second, all power systems require cooling water. That can be a limitation to the power output of the energy park. If the energy park is producing a fuel such as hydrogen, the energy transport problem disappears, because a relatively small pipeline moves far more energy than many power lines. Private communication.

[15] Laura Holgate, NTI, has suggested the possibility of Canadian participation in the new Areva facility. Private communication. Areva is a public multinational conglomerate based in France which was formed by merging two French companies. Siemans is a large shareholder.

[16] See Chaim Braun, "Nuclear Fuel Supply Assurance" (unpublished draft) for a comprehensive review and assessment of these plans. Another excellent review is a Congressional Research Service Report for Congress, "Managing the Nuclear Fuel Cycle: Policy Implications of Expanding Global Access to Nuclear

Power", updated January 30, 2008, by Mary Beth Nikitin, Jill Marie Parillo, Sharon Squassoni, Anthony Andrews, and Mark Holt.

[17] Charles W. Forsberg puts it well: "…there have to be multiple enrichment suppliers that do not have strong political ties to each other, and preferably, dislike each other."

[18] Dr. Pierre Goldschmidt, lecture at the 24th Conference of the Nuclear Societies, Israel, February 19-21, 2008

[19] http://www.urenco.com/

[20] http://mit.edu/stgs/irancrisis.html

[21] The text of the nuclear section of the Iranian proposal is as follows:

" C – The Nuclear Issue:

With regard to the nuclear issue, Iran is ready- in a comprehensive manner, and as an active and influential member of the NPT and the IAEA- to consider the following issues:

1. Obtaining a further assurance about the non-diversion of the nuclear activities of different countries.
2. Establishing enrichment and nuclear fuel production consortiums in different parts of the world- including Iran.
3. Cooperation to access and utilize peaceful nuclear technology and facilitating its usage by all states.
4. Nuclear disarmament and establishment of a follow up committee.
5. Improved supervision by the IAEA over the nuclear activities of different states.
6. Joint collaboration over nuclear safety and physical protection.
7. An effort to encourage other states to control the export of nuclear material and equipment."

[22] U.S. DOE press release, April 25, 2007

[23] "GE, Hitachi to join nuclear-power businesses", Reuters, November 13, 2006.

[24] Judgments regarding India and Pakistan are derived in part from Subrata Ghoshroy, MIT, in a private communication.

[25] In a discussion at the Council on Foreign Relations in New York on May 14, 2004, Dr. Elbaradei remarked that the French foreign minister had told him that "maybe you have to have an agreed system of sanction, agreed in advance in the case of a country's withdrawal, so you would know the cost in advance before you decide to withdraw."

[26] The IAEA's "Report of the Commission of Eminent Persons on the Future of the Agency", released on May 23, 2008 recommends that

> The UN Security Council should go beyond its Resolution 1540 by: passing a new resolution making clear that the proliferation of nuclear weapons is a threat to international peace and security; legally prohibiting any state that withdraws from the Nonproliferation Treaty from using for military purposes any nuclear facility, materials, or technologies that it received for peaceful purposes while a party to the NPT; and legally imposing safeguards obligations, going well beyond the Additional Protocol, on any state that substantially violates its safeguards obligations.

Dr. Goldschmidt has written extensively on this subject. He has recommended that the UN Security Council should adopt a generic and legally binding resolution stating that if a state withdraws from the NPT (an undisputed right under its Article X) after being found by the IAEA to be in non-compliance with its safeguards undertakings, then such withdrawal constitutes a threat to international peace and security as defined under Article 39 of the UN Charter. He suggests that it would be logical and legitimate for the Security Council to pre-agree that, in these circumstances, all military cooperation with the non-compliant state would be suspended. Also, "all materials and equipment made available to such a state or resulting from the assistance provided to it under a Comprehensive Safeguards Agreement would have to be forthwith removed from that state under IAEA supervision and remain under Agency's Safeguards"

Dr. Goldschmidt also proposed several ways in which enforcement could be mandated by the UN Security Council. He has suggested, for example, that in cases of a state's noncompliance with safeguards agreements:

- "the non-compliant state [must] provide the Agency with the necessary additional verification authority…prompt access to persons, broader and prompter access to locations, in site access to

original documents and copies thereof, broader and faster access to information, and the lifting of other types of restrictions which experience has shown can be employed as obstructive tactics."

See his "Mechanisms to Increase Nuclear Fuel Supply Guarantees", Pierre Goldschmidt, Carnegie International Non-Proliferation Conference, Washington DC, November 7-8, 2005 and lecture at the 24th Conference of the Nuclear Societies, Israel, February 19-21, 2008.

[27] "Iraq: A New Approach", August 2002, Carnegie Endowment for International Peace.

The Stanley Foundation

policy analysis brief

Innovative approaches to peace and security from the Stanley Foundation

Multilateralism as a Dual-Use Technique: Encouraging Nuclear Energy and Avoiding Proliferation

March 2008

Recommendations

- Multilateralism should be welcomed in principle both as a means to promote nuclear energy and for its nonproliferation values.
- In practice, it should be pursued ad hoc making use of existing facilities, where they exist, as a nucleus; regional cooperation, where politically feasible, makes particular sense.
- As a contribution to meeting their obligations under the Nuclear Non-Proliferation Treaty (NPT), the nuclear states should make special efforts, including financial ones, to assist in the establishment of the first few multilateral organizations.
- Multilateral facilities should normally be sited in accordance with Article IV of the NPT in "the developing areas of the world."
- Since a multilateral operation is by its nature big, complex, and expensive, it should be undertaken only if sufficient political will has been committed and confirmed by a treaty covering the main points.
- No one participant should be able to override the others.
- All participants should be members of the NPT or should at a minimum have accepted the main NPT obligations.
- The operations should be run on commercial lines.
- The International Atomic Energy Agency (IAEA) should be consulted from the outset.
- Technical measures to prevent expropriation by the host country should be investigated and applied as appropriate.

John Thomson and Geoffrey Forden

Sir John Thomson is a research affiliate at the Massachusetts Institute of Technology (MIT). Among many posts in the British Diplomatic Service, he was Permanent Representative at the UN in New York, High Commissioner in India, Under-Secretary for Defense and Disarmament, and Head of Policy Planning. He was also the founding chairman of what became the Nuclear Suppliers Group (NSG).

Geoffrey Forden, a physicist and researcher at MIT, was Chief of Multidiscipline Analysis at UNMOVIC, the UN weapons inspection agency for Iraq and, before coming to MIT, Principal Analyst for Strategic Weapons and Arms Control at the US Congressional Budget Office.

For governmental decision makers in any country, national problems involving high capital costs are potential candidates for multilateral organization and funding. This is especially true if cost-effectiveness, as for example with electricity, is important to electorates. Spreading the costs, employing top-quality technology, assuring security of supply, and proving their prowess in prestigious projects appeals to all governments. Multilateralism may be the only way to achieve these objectives for countries whose needs or resources are below the level at which a self-sufficient national program is cost-effective or even possible. For all countries, it offers a gateway to security of fuel supply without political strings.

As one example, from the dawn of the nuclear age, nuclear energy has been well-suited for multilateralism, both economically and politically. In the political field, this affinity can be seen in the Baruch Plan, Atoms for Peace, the International Atomic Energy Agency, and the Nuclear Suppliers Group. In the industrial field, it is seen in Urenco (a consortium of the British, German, and Dutch governments) and the French-dominated European Gaseous Diffusion Uranium Enrichment Consortium (Eurodif). Urenco and Eurodif show that multilateralism can be attractive even to advanced wealthy countries. For smaller, less advanced, or

poorer countries the case for multilateralism is still more compelling. In addition, by obviating the need for nationally owned-and-operated facilities, multilateralism makes an important contribution to nonproliferation.

The nub of the case is cost-efficiency, but until the recent surge in expectations of the use of nuclear power, much of the argument has been cast in political and nonproliferation terms. The case for multilateralism rested on twin pillars: assuring security of supply despite hostile political interventions and reducing if not eliminating the need for enrichment and reprocessing plants in countries that do not already possess them.

Recognizing these issues and their tensions, in June 2004 IAEA Director General Mohamed ElBaradei tasked an expert group, chaired by Dr. Bruno Pellaud, to deal with the concern "that wide dissemination of the most proliferation sensitive parts of the nuclear fuel cycle could be the 'Achilles' heel' of the nuclear non-proliferation regime." Subsequently, this "Pellaud group" issued a February 2005 report focused on assurances of supply and services not involving ownership of facilities. (This is presumably why the report refers consistently to *Multilateral* Nuclear Arrangements [MNA] rather than to *International* ones.) It also covers, much less comprehensively, two other types of multinational or multilateral arrangements: the conversion of existing national facilities to multinational control and the construction of new facilities, multinational from the first.

The market mechanisms that the Pellaud report commends and proposes to strengthen have worked well. If everyone is content with this system, there is no reason to change it. However, some countries worry that it is or may become unfair and unreliable. If the manufacturing and sale of nuclear materials and services is profitable, why should the business be reserved to a few countries? If it is not, what explains their keenness to maintain their cartel-like monopoly? Underlying the rationale for these and similar questions is the fact that the five permanent members of the UN Security Council are also the only five countries officially classified as nuclear weapon states (NWSs) and that among them they control the bulk of the legitimate market in nuclear sales. The other countries with significant share—Germany, Canada, and Japan—are closely associated with the three Western permanent members. The "big boys" seem to have the nuclear power market sewn up.

The present level of resentment against the United States is unprecedented. Much of this is due to the adventure in Iraq, and American protection of nuclear-armed Israel does not help. Some of it is closely connected with the issue of security of supply. The United States has shown itself ready—often eager—to impose sanctions on regimes it does not like. However justified these sanctions may be to an objective observer, on nonproliferation grounds they still constitute a threat to security of supply, and all the more so in light of the Bush doctrine of anticipatory preemption. If the United States looks unreliable, Russia seems even more so. It has already cut off oil and gas supplies to some of its neighbors, thereby closing the supply lines to more distant customers in Europe. Russian rhetoric leaves no doubt that the supply of energy will be used as a political weapon to achieve national ends.

Political resentments and uncertainties are largely to blame for what appears to be a growing unwillingness to depend exclusively on the existing market for nuclear supplies and services. If the Great Powers would amend their behavior in ways acceptable to potential customers (an issue to which we return below), dependence on existing market mechanisms would become more viable. But this does not necessarily mean that the old monopolies can be safely maintained. So much damage has already been done that it will be hard to restore confidence. Moreover, if there is a renaissance in nuclear energy, confidence will be required on a larger scale and by more people than ever before. To insist that the present market arrangement is the only answer looks politically unacceptable and economically risky.

We do not know whether the world is on the cusp of a nuclear renaissance or, if so, how far and fast that might proceed. Yet on the basis of current trends, it seems reasonable to suppose that several countries will want to include some "exposure" (as the stock brokering fraternity says) to nuclear in their energy portfolios. They will not want to be left behind if it turns out that nuclear energy is cost-effective, reliable, and safe—all of which are possible judgments—and their scientists and engineers may well feel challenged to compete globally. On balance, environmental considerations also push in this direction. However, the long lead-times for nuclear construction and the high capital costs mitigate against a sudden dramatic surge. Besides, a significant proportion of existing facilities will reach the end of their projected life within the next two decades.

For our current purposes, we therefore suppose a considerable increase in the number of new countries that will be weighing the pros and cons of nuclear power, and we assume that all countries

already possessing nuclear reactors will consider whether or not to expand. Probably this will lead in the next two decades to an increase in the number of countries using nuclear power, but not to an enormous increase in the number of reactors.

If these suppositions prove to be approximately correct, it seems likely that there will be a demand for all three types of MNA considered in the Pellaud Report. That report, as we have said, has covered in considerable detail possible improvements in market mechanisms, and therefore we do not dwell on that further. Instead, our object is to work out in comparable detail what shared ownership might look like.

Obviously, every case will have its own special circumstances. Some cases may be regional, cultural, or political; others will be commercial and financial; still others will have to do with which part or parts of the fuel cycle are concerned especially (but not exclusively) with enrichment, reprocessing, or long-term storage and whether any of the prospective partners already possess such facilities. With that said, and allowing for the need to negotiate each MNA separately, we believe that the generalized model we sketch below will give useful guidance irrespective of which part of the fuel cycle is at issue; this will do as well for the multilateralization of existing facilities (Type 2 in the Pellaud Report) as for building new multilateral facilities from scratch (Type 3).

Political Will

We have already shown that multilateral projects in principle have important advantages, especially for countries with medium or small nuclear power projects and for countries that lack abundant sources of capital or technology. Against that must be weighed the difficulties inherent in any international project: How much control does each participant have? Who has the final say? Are their professional standards compatible? How are disputes to be resolved? These are all problems that have been and can be satisfactorily managed, but an international partnership on such an ambitious project is like marriage: it is not to be entered into lightly or unadvisedly. Unless there is a political will strong enough to overcome problems, it is probably better not to begin.

Exclusive Commitment

Political will is on trial from the beginning since it will be essential (with some exceptions) for participants to promise not to set up new national plants in parallel with the MNA plants. For example, if the MNA is to be a shared enrichment facility, the participants should undertake not to establish enrichment facilities on their soil or under their national control. This is partly to prevent the theft of technology, partly to avoid conflict of interest, and partly for nonproliferation reasons. It applies particularly to the host country but as far as practicable should apply to all participants. It would not, however, be practicable to apply it retrospectively to participants who already own national enrichment facilities—unless they were contributing these to the MNA—nor would it bar a country from investing in more than one MNA.

Form of Agreement

Political will is also a factor in the question of what sort of agreement to negotiate. A treaty is best because, if achievable, it does most to secure political commitment and it is a natural type of agreement between governments. The form of a treaty may not be indispensable, but comprehensiveness and clarity are. It will be simplest if the partners are all governments, but we do not want to rule out the possibility of participation, whether from the outset or later, by one or more commercial companies. However, we advise against allowing commercial participation unless the responsible government or governments, both legally and as a political matter for the company concerned, are as fully and legally committed as the directly participating governments. The treaty must provide machinery for the settlement of disputes.

Decision Making

In the same line of thought, the treaty (or whatever other form of agreement is adopted) must exclude the possibility that any one participant could exercise a degree of control that could override the wishes of the others. This raises the delicate issue of the position of the host government. Inevitably this government will have advantages and burdens that are somewhat different from those of the other participants. For example, although the host government will operate like the others on a commercial basis, it will probably on that basis have some advantage in terms of costs and probably also in terms of employment and the import of capital. Against this, it will have to agree that the installations of the partnership have the extraterritorial benefits of an embassy and that the foreigners employed by the partnership have rights modeled on customary diplomatic rights.

It will be prudent to recognize the special position of the host government by providing in the treaty that it has the right to require the partnership to leave its territory provided (1) that an appropriate amount of time is allowed, say three years; (2) that the host government pays the costs thus incurred; (3) that an explanation is formally made public.

Such action by the host government will not automatically cause the partnership to terminate. On the contrary, it should give the other participants the right to buy out the host country and continue without it.

Similarly, it should be stipulated that no participant may sell or assign its participation without the consent of all the others. New participants may be inducted by unanimous invitation.

Membership and the Nuclear Non-Proliferation Treaty

Given what is said above about government responsibility, it will be logical and simplest to provide that all of the participating governments must be signatories of the NPT in good standing. However, we can imagine circumstances in which both non-NPT and NPT signatories see advantage in a deal allowing the former to become participants. The quid pro quo would be a formal agreement whereby the nonmembers, while not signing the NPT itself, committed themselves to observing the provisions of its first six articles.

The Organizational Structure of an MNA

It would be a mistake to insist that all MNA have identical structures. After all, experience may suggest improvements. Yet a worked-out model structure will help to reveal the strengths and problems of the MNA concept. We suggest the following.

Allowing for the foregoing points (e.g., no participant can dominate the others), a commercial model seems best. The participants would be shareholders in a formal organization set up by treaty. Both the contributions of capital and the distribution of profits would be in proportion to their shares. Each participant with at least X% (perhaps 5%) of the shares would be entitled to appoint at least one director of the organization. The directors on behalf of their governments would be responsible for establishing and overseeing policy, for financial control, for discussions with governments, and also for hiring and overseeing a management company that would be responsible for the day-to-day operations of the business. This company may well need to be formed ad hoc for this purpose since it will need to have an international character and a high level of professional expertise. Theoretically, the directors could run the business themselves, but since many people of different nationalities and diverse talents will have to be hired, it is probably better that experienced professional management run the operations while freeing the board of directors from the operational details in order to concentrate on large policy issues and government relations.

The IAEA

The board will need a close relationship with the IAEA, yet the two bodies must remain separate and at arm's length. The IAEA should become (with the consent of the board of governors) the "regulators" for MNA. It is the agency obviously best fitted to monitor operations to ensure that there is no diversion of materials from specified procedures and purposes. (It would make no sense to set up a new agency to do what the IAEA already does well.) Close relations are desirable to ensure that the facilities are designed (for example, in their piping and valves) to facilitate monitoring. At the same time, there will need to be a firm and formal agreement between the MNA and the IAEA to ensure that the latter will be in a position to provide material and services (for example, fuel or storage) to countries in good standing with the NPT who are prevented for political reasons from obtaining materials or services in the normal way.

Commercial Considerations Crucial

The MNA should be run on commercial lines with politics, so far as possible, kept at bay. Thus, the compensation for the management company would be comparable to that of peer enterprises, and the pricing of the product and services would be competitive. MNA would no doubt benefit from drawing the large sums necessary as starting capital from governments or government- backed funds, but they would not be directly subsidized. Management decisions, including investment in research and development, would be grounded in commercial calculations.

If, over the long run, an MNA fails to make a profit, it may have to be wound-up. Provisions for winding-up must be included in the founding treaty.

Buying or Leasing Equipment

If the MNA is Type 2 (i.e., it incorporates existing facilities), the arguments for leasing are strong. If the enterprise was wound-up, the equipment would then return automatically to its owners. The same would hold for equipment brought in to replace the original incorporated equipment. The move from one to the other would be made on commercial grounds, and there would be no problem of factoring in sunk costs. Leasing would probably also be preferable for political reasons. In the case of a Type 3 MNA (one which started from scratch without existing facilities), the board would have choices between whether to own outright or to lease goods and services. Again, com-

mercial considerations would normally outweigh political ones. The land on which the facilities stand should probably be owned by the MNA with a provision that it could not be sold or leased except to the host government.

Personnel

We have determined the international composition of the board of directors above. The management company would also be internationally manned. Expertise would be the first requirement so the numbers from different nationalities would not necessarily be proportionate to shareholding, but all participants would be represented. Moreover, the manning for each shift in the technically sensitive operational areas would always represent at least three different nationalities, and when repairs or adjustments had to be made that would reveal commercial or proliferation secrets, only personnel licensed by the appropriate manufacturers would be allowed to participate. Without this restriction (which would in any case be necessary on nonproliferation grounds) there would be no chance that the MNA could buy or lease the most advanced equipment and techniques. The nonproliferation advantages of international manning are discussed below.

Sites for MNA

Safety must be the prime consideration. In general, earthquake-prone sites are not desirable, but this need not rule out whole countries. For long-term storage, geological stability is crucial. Ease of transport is both a safety and a commercial consideration, but this should not exclude the possibility of upgrading existing infrastructure or even new building if the site is otherwise suitable. Regional considerations and especially the geographical relationships of the countries involved will often point to potentially suitable sites.

Participants are already committed by Article IV, paragraph 2, of the NPT to favor "the developing areas of the world." (That paragraph reads in part: "Parties to the Treaty in a position to do so shall also cooperate in contributing alone or together with other States or international organizations to the further development of the application of nuclear energy for peaceful purposes, especially in the territories of Non-Nuclear Weapon States [NNWSs] Party to the Treaty, with due consideration for the needs of the developing areas of the world.") Subject to safety and some commercial considerations, sites in developing areas in NNWSs ought normally to be picked.

Nonproliferation Considerations

The NPT is the basic international agreement assuring its members (the whole world minus India, Israel, and Pakistan) of equitable access to the peaceful benefits (mainly in power and medicine) of nuclear technologies. Unfortunately, the international regime based on the NPT is beginning to unravel for political reasons. All will suffer if the process continues, but that does not ensure that the political problems will be overcome. Those who can strengthen the regime would be irresponsible not to do so, starting with the five NWSs and especially the United States and Russia. To prepare the ground for a successful outcome at the 2010 Review Conference of the NPT, they need to take urgent steps toward fulfilling their obligation to eliminate their nuclear arsenals.

There is a parallel obligation on the NNWSs to avoid any step that could promote proliferation; this is important because it is the counterpart to their right to technology. MNA, as we have stated above, can play a significant role in preventing proliferation. Multilateral facilities are inherently less open than national ones to the diversion of materials or to threats to "go nuclear" in a military sense. In addition, they can provide a safe setting for the absorption of existing national facilities that may be seen as threatening, for example, the Iranian enrichment facility at Natanz. So it behooves all members of the NPT to support the concept of MNA and to make them in practice as attractive and as effective as possible.

One important step to this end is to enhance the IAEA's capabilities so that it may play the role outlined above both in promoting nuclear energy and in safeguarding the process. Another is that care should be taken with the manning of the management company to make it as professionally competent as possible and also proliferation-resistant. Nothing works better than having trusted people working in close collaboration so that any cheating quickly becomes apparent. (For further discussion see the Annex.) A third important step might be to incorporate technical safeguards into the machinery to protect it against espionage and to destroy or disable it in the unlikely event that the host country used force to expropriate the facilities. (This, too, is discussed in the Annex.)

In conclusion, two general points must be recognized. One is the impossibility of guaranteeing that proliferation can be prevented under all circumstances. This being so, the second point becomes crucial: the most effective way of reducing the risks is to make it "unthinkable" for each government to acquire weapons. This can be achieved by restoring and bolstering the international nonproliferation regime.

Annex

Organizational and Technical Safeguards

Technical safeguards, if appropriate at all, will vary with the type of facility concerned (e.g., conversion plant, reprocessing, long-term storage, etc.). No doubt the same will be true to some extent with organizational safeguards. Accordingly, in a short paper, there is limited usefulness in elaborating on what might be required. For most readers, the treatment above should suffice. However, there may be some who want to delve deeper. For those we reproduce below our thoughts on what might be done in the specific case of a multilateral enrichment facility in Iran with British, Dutch, French, and German participation (hence the use of the term *Western*).

"Technical" Safeguards

It is generally accepted that an economically viable enrichment plant should have a capacity of at least 5 million Separative Work Unit (SWU)-kg/yr. Even if the most advanced centrifuge design is used, thousands of advanced centrifuges will be in-country when the plant reaches its final capacity. During installation, and perhaps at other times, there will be a large number of centrifuges that are not mounted in their permanent positions, and the host country might divert or examine them for reverse-engineering purposes. However, it is possible to mount "so-called" active radio frequency identification (RFID) permanently on the outer casings of each centrifuge that monitors acceleration and motion, both while they await installation and after they have been permanently mounted. Once installed, the rotors would also be protected by the casing's RFID. Until then, the rotors would be kept in their shipping boxes that are protected by seals and their own active RFID.[1]

A common concern with building a multinational enrichment facility using advanced centrifuges in a host country that does not have the same level of technology is the possibility of the facility being "nationalized." However, technical measures can be taken to lengthen the time it would take the host country to get the facility up and running after such nationalization.

We believe that both safe and reliable self-destruct and disabling mechanisms[2] 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 pose a risk to workers in the course of 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 set off 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.[3] 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, it 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.

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 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.

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."[4] When that happens, the induction magnet spinning the centrifuge would lose 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 on which the centrifuge sits. A catastrophic crash would clearly disable the centrifuge 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 definitive answer to the question of worker safety can be given.) It is also possible that this reversing of phases could be done in a way as to ensure 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 program. However, we are 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.

The self-destruct mechanism should be effective enough to keep the centrifuges from being used again. However, it would, given enough time, be possible to rehabilitate centrifuges that had been disabled using the mechanism outlined above. We can estimate how long it would take to restore a single centrifuge to operation assuming that no time is taken to develop the techniques necessary to remove the electronic-key circuit—remembering that the host country has not seen the inside of the centrifuge and is planning simply on the basis of fundamental design principles—and that no mistakes are made. Of course, the host country could have a number of teams working in parallel and so could reconstitute a number of centrifuges at the same time. We arbitrarily assume 75 such teams.

We assume each centrifuge will take a day to disassemble and that this is labor-intensive, so each

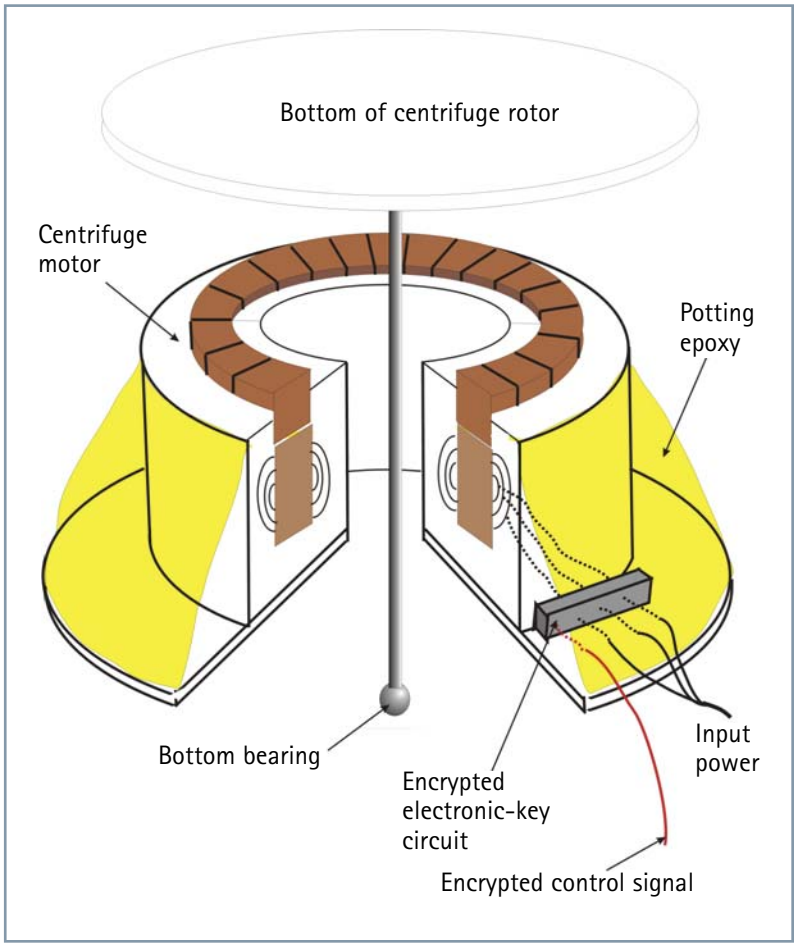

Figure 1. *A centrifuge motor with an encrypted electronic-key circuit embedded in its power train.*

team can only disassemble one centrifuge at a time. The next day is spent dissolving the epoxy in which the motor is potted. This is not labor-intensive, and the team could disassemble another centrifuge at the same time. At this point, the host country could choose to simply replace the motor, either with a reverse-engineered duplicate or an indigenously designed replacement, or it could unwind the motor, remove the circuit, and then rewind the motor.

We believe that the fastest approach would be for the host country to opt for the wind/rewind approach. We therefore estimate that each motor would take a week to unwind and another week to rewind. This is labor-intensive but probably only requires a single team member. Finally, it would take another day to repot the motor and a final day to reassemble the centrifuge. Thus, a two-man team could rehabilitate two centrifuges in 19 days. These time estimates are probably independent of the centrifuge design. While it is possible to speed the rehabilitation of a single centrifuge by working multiple teams around the clock, it would not shorten the time needed to reconstitute a cascade since different teams could be working on different machines in parallel.

If the centrifuges are the new Urenco TC-21 design, which is reported to have approximately 100 SWU-kg/yr enrichment capacity, then 75 such teams could reconstitute a 150-machine cascade in 38 days. Such a cascade could enrich enough weapons-grade uranium for approximately two bombs per year. If Russian centrifuges are used—which are much shorter than Urenco designs—and if they are the same type as sold to China with an enrichment capability of 2.5 SWU-kg/yr, it would take considerably longer to reconstitute enough for a cascade capable of a single bomb's worth of weapons-grade uranium.

Endnotes

[1] It might be a problem to tag all the centrifuges in a large cascade hall with RFID because of the difficulties associated with sending signals through the forest of metal centrifuges. However, there are possible workarounds to this. One possibility that the US national labs are developing is microwave-based RFID that are much less sensitive to any shielding effects such a cascade might represent.

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

[3] "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 takes a considerable amount of time.

[4] 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.

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LOOKING BACK: Carter's 1978 Declaration and the Significance of Security Assurances

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John Steinbruner

In terms of operational practice as distinct from political rhetoric, institutionalized security policy in the United States is based on two presumptions: that imperial aggression is the principal form of threat and that the countervailing threat of deterrent retaliation is the most decisive method of protection. This formulation was established during the Cold War and has been retained in its aftermath. Because no country can plausibly threaten immediate imperial aggression against U.S. territory, the formulation is now justified as a hedge against the rise of an unnamed peer competitor. For many other countries, however, the United States itself is the most credible potential embodiment of such a threat.

Although most prefer not to dwell on that practical fact, it does make the security assurances first issued by the Carter administration 30 years ago a matter of immediate interest. In the traditional formulation, a reliable deterrent should be based on the capacity to retaliate under all circumstances, not merely on the expressed intention to do so. Capacity displayed in immediate operational capability is considered to be more credible and less subject to deception or rapid change than are expressed intentions. That hard standard is far more readily achieved by the United States than by any other country. Because most countries do not have and cannot reasonably acquire unquestionable nuclear deterrent capability, they are dependent on agreed restraint and forced to rely more heavily on judgments of intention. As a result, the authoritative declarations of intention embodied in security assurances have greater global significance than is usually assumed in U.S. discussion of the topic.

Historical Declarations

The declarations of greatest significance are those issued in connection with the nuclear Nonproliferation Treaty (NPT). Those countries who agreed not to acquire nuclear weapons under the terms of the treaty had reasonable expectation that they would in return receive protection from the five states allowed to retain nuclear weapons. That basic rule was not included in the treaty text, however, because it was difficult to reconcile with U.S. and Soviet alliance commitments. By the time the NPT was negotiated in the late 1960s, the original principle of the UN Charter that each member state would be protected by all the others had been superseded by Cold War arrangements whereby protection was preferentially provided to formal alliance members. The United States believed at the time that the defense of Western Europe against conventional attack might require initiating the use of nuclear weapons against non-nuclear-weapon state-parties to the

attack might require initiating the use of nuclear weapons against non-nuclear-weapon state-parties to the treaty that belonged to the opposing Warsaw Pact. U.S. officials considered it imperative to extend the same commitment to Japan and South Korea as well.

Unable to include the expectation of general protection directly in the treaty language, the non-nuclear-weapon states resorted to UN Security Council Resolution 255, passed on June 19, 1968. The resolution "recognizes" that aggression with nuclear weapons against a non-nuclear-weapon state-party to the treaty would create an immediate obligation for action under the UN Charter and "welcomes the intention expressed by certain states" to provide assistance under those circumstances. That language suggests not merely the promise not to attack (negative assurance) but also to provide active defense if someone else did (positive assurance). By virtue of the Security Council vote, the concept was implicitly accepted by all five NPT nuclear-weapon states, although France abstained from the vote, stating that declaratory assurances would be inadequate without corresponding disarmament provisions.

In 1978, eight years after the NPT officially entered into force and 10 years after approval of Resolution 255, the United Nations convened its first special session on disarmament, and the United States used the occasion to issue an authoritative statement of intention. Speaking to the special session on behalf of President Jimmy Carter, Secretary of State Cyrus Vance stated:

The United States will not use nuclear weapons against any non-nuclear- weapon state party to the NPT or any comparable internationally binding commitment not to acquire nuclear explosive devices, except in the case of an attack on the United States, its territories or armed forces, or its allies, by such a state allied to a nuclear weapon state, or associated with a nuclear-weapon state in carrying out or sustaining the attack.[1]

That statement of negative assurance, endorsed by all succeeding administrations and reiterated at the 1995 NPT review conference that indefinitely extended the treaty, has come to be regarded as the standard formulation of U.S. declaratory policy. Its main feature is that the United States reserves the right to initiate the use of nuclear weapons in response to an attack of any sort as long as another nuclear-armed state is somehow implicated in the attack.

That qualified assurance had earlier been given formal legal standing for those states adhering to the nuclear-weapon-free-zone treaties for Latin America, the South Pacific, and Africa. In the Latin American case, the United States signed and subsequently ratified protocols to the treaty of Tlateloco extending negative security assurances to the states-parties to the treaties; but, as part of the ratification process, President Richard Nixon issued a proclamation laying out the qualification that was subsequently issued more generally but less formally in the 1978 statement.

Then, in 1996 with a Soviet invasion of Europe no longer a plausible concern, an aide to President Bill Clinton introduced additional qualifications at a White House press conference announcing that the United States had signed the corresponding protocol to the Treaty of Pelindaba, which sought to establish an African nuclear-weapon-free zone. He stated that attacks by other weapons of mass destruction would be justifying conditions for nuclear retaliation, and that was understood but not directly stated to mean chemical or biological agents. In Senate testimony two weeks earlier, Secretary of Defense William Perry had also implied that the use of nuclear weapons would be considered in responding to a chemical weapons attack. Neither statement addressed the central question as to whether the uniquely destructive power of nuclear weapons could be appropriately applied to substantially lesser forms of "mass destruction."

In citing the doctrine of belligerent reprisal as justification for the additional qualifications, Clinton administration officials evoked a traditional legal rule holding that the provisions of one treaty would be suspended if those of related one were violated. Hence an attack using chemical or biological agents in

violation of the 1925 Geneva protocol by a party to the Pelindaba treaty would invalidate its protection against a nuclear response.[2] They generally did not mention, however, that the doctrine would allow only for a response that could be demonstrated to be necessary and proportionate.

The evident efforts of Nixon, Carter, and Clinton to minimize legal limitations on U.S. deterrent operations all reflect an underlying institutionalized commitment to preserve as much uncertainty as possible in the minds of all conceivable opponents as to how far the deterrent effect of nuclear weapons might be extended. The incremental supplement to deterrence supposedly achieved against a willful aggressor by that deliberate ambiguity outweighed the legitimate interest of the non-nuclear-weapon states in establishing categorical security assurances, an interest on which they have repeatedly said their continued adherence to the treaty ultimately depends.

The U.S. extended deterrence doctrine has been emulated and thus reinforced by France, Russia, and the United Kingdom, all of whom have advanced similar qualifications to the security assurances they have issued.[3] Because the nuclear arsenals of Russia and the United States contain more than 95 percent of the nuclear weapons believed to exist, those two countries together effectively set the global standard. There is, however, a meaningful difference between them. Russia, whose conventional force capabilities are not competitive with those of NATO, has far more reason to rely on the extended deterrent effect of nuclear weapons for its own defense than does the United States. In fact, with the world's most capable military establishment and least vulnerable national territory, the U.S. doctrine is especially subject to serious moral and practical questions.

Those questions are implicitly posed, moreover, by China's nuclear weapons policy. China has historically had potentially antagonistic security relationships with Russia and the United States and is entangled in one of the world's most significant remaining disputes over sovereign jurisdiction: the question of the ultimate status of Taiwan, which could become a trigger for active confrontation. China has nonetheless maintained the most limited deployment of the five official nuclear powers and has proclaimed the most restricted doctrine of use. China has repeatedly issued categorical assurance that it would not to be the first to use or threaten to use nuclear weapons at any time or under any circumstances, and those assurances are reflected in its deployment pattern. The most authoritative information indicates that China has less than 100 operational nuclear delivery systems, less than 25 of which could reach the United States and none of which are ever brought to immediately available alert status. Academic speculation aside, nothing in the historical record suggests that this minimal deployment posture and exclusive doctrine of retaliation has provided inadequate deterrent protection for China, despite the fact that it had the most demanding burden during its formative period and arguably still has.

Fundamental Issues

The extended deterrence doctrine has acquired nearly axiomatic status in U.S. security culture, to an extent that even its most glaring defects are generally ignored. Although few if any individuals seriously believe in the existence of an implacable aggressor held in check only by the threat of massive retaliation and poised to exploit any ambiguity of resolve, the continuation of deterrent operations designed against a hypothetical threat of that sort is considered prudent beyond question. That the resulting operational coupling of large U.S. and Russian alert forces creates the possibility of inadvertent catastrophe is dismissed as a negligible risk despite the directly applicable folk wisdom embodied in Murphy's law: if something can go wrong, it eventually will.

Even more remarkably, the fact that large dispersed deployments increase the risk that terrorists might seize a weapon or an equivalent amount of explosive material is accepted despite frequently articulated fears of exactly that possibility. Current mainstream discussion appears willing to consider reducing active deployments to the 1,500-warhead level but not below 1,000. That latter figure might begin to impose

meaningful constraint on the destructive potential of the U.S. deterrent force, but the former would not. There is no prominently articulated support for emulating China's categorical assurances even from those who have recently advocated the elimination of nuclear weapons as an ultimate goal.

Despite its impressive hold over the U.S. security establishment, however, the extended deterrence doctrine is not assured indefinite reign. It has been undermined within the security bureaucracy by a radical assault from an intense minority faction promoting decisive military superiority as an ultimate substitute for deterrence. Successfully evoking the authority of President George W. Bush, they have advanced a doctrine of preventive war euphemistically labeled pre-emption. In an address to the West Point graduating class in 2002 and in an ensuing review of nuclear weapons policy, Bush reserved the right to initiate the use of force, including nuclear weapons if necessary, to prevent the acquisition of nuclear weapons by states considered to be inherently hostile to the United States.[4] In his 2002 State of the Union address,[5] Bush named Iran, Iraq, and North Korea as instances; in the perception of the world, he implemented the doctrine in the 2003 invasion of Iraq, unjustifiably as it turned out. Meanwhile, his administration issued a series of military planning documents proclaiming the intention to dominate space for national military advantage and began integrating both long-range precision strike weapons and ballistic missile defense into nuclear weapons operations, all of which projects a serious intention to engage in preventive operations.[6]

In the estimate of attentive military planners in China and Russia, the prevention/pre-emption doctrine backed by a rate of military investment that far exceeds their own is an inherent threat to their own deterrent forces, not merely to the named adversaries. If they come to believe that the doctrine has been established in the United States, they will be forced to counteract it in some fashion. That in turn is a threat to those in the professional core of the U.S. establishment who understand that the doctrine is inherently unrealistic and dangerously provocative. It is the unsustainable political project of an ideological minority whose actions have been discredited in Iraq and whose domination can be expected to diminish within the U.S. political system whatever the outcome of the election.

It is distinctly possible that adverse international reactions to the prevention/pre-emption doctrine will ultimately catalyze an accommodating revision of U.S. security policy that sweeps aside the traditional doctrine of extended deterrence as well. That outcome would be a bitter irony for the advocates of decisive superiority, but the threat of terrorist access to nuclear explosives provides a major incentive for that to occur. Admittedly, any hostile nuclear explosion anywhere in the world might trigger an insensate U.S. political reaction, reinforcing the aspiration for military dominance and giving it longer political life. Such an event would not render the aspiration achievable, however, and belligerent emotion would have to yield eventually to implacable fact.

Fortunately, it is more likely that some breach-of-security incident will command sufficient attention to give standing to the obvious common sense solution, namely, an arrangement whereby all nuclear weapons are removed from active operational deployment to secure storage where they can be continuously monitored and accurately counted. Because they could be reactivated if necessary, that arrangement would preserve all of the deterrent effect plausibly required and would essentially eliminate the inherent danger of inadvertent catastrophe. It would also provide much more reliable protection against terrorist exploitation, especially if all weapons-grade nuclear explosives are subjected to the same monitored storage conditions. Under such an arrangement, conveying reassurance of responsible management would be the principal objective. Preservation of a residual deterrent effect, readily achieved by the existence and operational potential of the stored weapons, would be subordinate to that objective.

The relentless underlying reality is that the process of globalization has rendered massive imperial aggression against any of the major established states virtually infeasible but is subjecting all of them to the disruptive threat of dissident violence emanating from the breakdown of legitimate authority in fragile jurisdictions.

Common interest in preventing severe disruption of the global economy gives all major states strong reason to established higher standards of control over nuclear explosives and other menacing technologies. Those common interests are more significant than any residual threat of imperial aggression or coercive projection of influence. The imperatives of the situation require extensive collaboration for mutual protection rather than belligerent competition for national advantage. The ultimate implication is that reassurance replaces deterrence as the central purpose of security policy.

Defenders of the U.S. extended deterrence doctrine will be quick to point out that it plays an important role in conveying reassurance, as indeed it does for formal allies. Under emerging circumstances, however, it will be vitally important to recognize that extended deterrence does not require and cannot tolerate the initial use of nuclear weapons under any circumstance and that its legitimacy depends on global rather than culturally preferential application. To sustain the traditional doctrine in appropriately subordinated form, the United States will not only have to issue categorical negative security assurances, as China has done, but also globally inclusive positive assurances. It will have to indicate it is prepared to protect any country from unprovoked imperial attack and that it will not itself undertake pre-emptive attack without international authorization. That is the only viable way of justifying the degree of military superiority it will retain for quite some time.

Practical Observations

The U.S. political system does not concentrate executive authority to the degree that would be required to change operational security doctrine. The president and other authoritative agents can and do make doctrinal pronouncements, but institutionalized implementation depends on consensus created by seminal formative experience and lengthy evolution. The Cold War formulation still largely prevails because the United States has not yet encountered a comparably powerful formative experience. Unfortunately, it is an open question whether institutionalized policy can be appropriately altered in response to fundamental changes of circumstance without the motivating and organizing focus of global war, real in the case of World War II and widely imagined during the ensuing Cold War period.

It is not evident that entanglement in civil conflict and fear of associated terrorism will alone drive a fundamental reformulation. The threat involved is much smaller in scale in any given instance and different in character but not so different as to compel consensual reformulation. Nonetheless, current agonies of policy in Iraq and Afghanistan will clearly be formative experiences of some enduring consequence, and the lessons eventually drawn are likely to feature the importance of global collaboration. It is very unlikely that acceptable stabilization can be achieved in either instance without constructive engagement with Iran and significant assistance from Russia and China in accomplishing the degree of engagement required. That in turn will require fundamental accommodation with all three countries involving categorical negative assurances and substantial positive ones as well. Most immediately, however, that process will probably be burdened by the Russian action in Georgia, which is actually a localized event resulting from the failure of accommodation but is being depicted by defenders of the established doctrine as an ominous indication of broader imperialist impulse.

It is more likely that the consequences of global warming will eventually become imposing enough to force fundamental accommodation and the reformulation of policy necessary to accomplish it. Reliably effective action requires a massive transformation to energy generating technologies that do not emit carbon gases, which is unlikely to be accomplished on sufficient scale without substantial expansion of nuclear power generation. That in turn could not be safely or practically accomplished without new reactor designs, much more secure management of the fuel cycle, and intimate collaboration between the sources of finance and technology—primarily the European Union, Russia, and the United States—and the leading venues of application—China, India, and the developing world generally. Fundamental security accommodation would be an indispensable precondition.

Whatever the degree of accommodation eventually achieved, it is reasonable to expect that negative and positive security assurances will have increasing prominence in the regulation of security relationships. The disparities in military investment and resulting operational capability between the United States and everyone else virtually preclude equitable restriction of military capabilities and therefore make credible restraint on behavior essential. It will be increasingly incumbent on the United States to convey reassurance about the rules and circumstances under which its military establishment operates. It will be incumbent on potential adversaries to accept restrictions on behavior that preclude justification of coercive action. It will be incumbent on all to work out routine documentation of compliance more continuous and more convincing than traditional methods of adversarial verification. That is a predictable trend, however discouraging immediate events and traditionally interpreted history may appear to be.

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ENDNOTES

1. "Statement of Secretary of State Vance: U.S. Assurance on Non-Use of Nuclear Weapons, June 12, 1978," *Department of State Bulletin*, August 1978, p. 52, ACDA, *Documents on Disarmament*, v. 1978, p. 384.
2. George Bunn, "The Legal Status of U.S. Negative Security Assurances to Non-Nuclear Weapon States," *Nonproliferation Review*, Vol. 4, No. 3 (Spring-Summer 1997), pp. 1-17.
3. A conceptual distinction is often made between extending the deterrent effect from one state to another and extending it to forms of attack other than nuclear weapons. The operational doctrines of France, Russia, the United Kingdom, and the United States all include both forms of extension.
4. Office of the Press Secretary, The White House, "President Bush Delivers Graduation Speech at West Point," June 1, 2003.
5. Office of the Press Secretary, The White House, "President Delivers State of the Union Address," January 29, 2002.
6. Nancy Gallagher and John D. Steinbruner, "Reconsidering the Rules for Space Security," American Academy of Arts and Sciences, 2008, pp. 25-29.

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Consensual security

The disaster in Iraq is a harbinger for a changing global order, one that increasingly defines national security in terms of global cooperation.

BY JOHN STEINBRUNER

The invasion of Iraq will likely prove to be a seminal event in the evolution of international security. Legal order has evidently been shattered throughout the country, and the occupying forces have been able to contain but not eliminate the resulting pattern of predatory violence. At the outset of the conflict, the United States forfeited the critical asset of legitimacy necessary to establish and maintain consensual rule, and the continued presence of the United States undermines the indigenous institutions it is attempting to nurture. Similar breakdowns have occurred in other parts of the world, and the consequences have been tolerated over extended periods of time. Somalia is a notable example, as is the Darfur region of Sudan. Because of timing, location, and the entanglement of the United States, however, intractable violence in Iraq will have much stronger global resonance. U.S. forces alone are not likely to be able to master the situation, but neither can they withdraw without intensifying internal violence and extending it into an already volatile region. The potential consequences of that dilemma are ominous, but for that reason the situation presents opportunity as well as danger. Calamity is sometimes a catalyst for greater wisdom.

Within the United States, disengagement from Iraq promises to be a riveting issue in the forthcoming presidential election, but the formulae advanced for accomplishing that are unlikely to be realistic and even less likely to be constructive. The U.S. political process is still in the early stages of absorbing the magnitude of disaster in Iraq and has not yet acknowledged the probable implications. To have any hope of achieving a tolerable outcome, an effective stabilization and reconstruction process would have to be established and sustained long enough for a viable government to form from a fractured social base—at least a decade presumably, perhaps even a generation. The United States would have to transfer responsibility for that effort to a broadly representative international consortium that might be able to command the consensual cooperation the United States alone will never be able to achieve. U.S. military capability, which will remain necessary to prevent external incursion and to limit the scale of internal conflict, would have to be subordinated to the authority of that consortium. Intensely reluctant governments would have to be induced to participate in the consortium and would have to be compensated for their efforts. Members whose independence from the United States gives them the greatest potential for commanding acceptance within Iraq would have to be credibly reassured about the use of U.S. military power. Those implications lie well outside the bounds of political acceptability at the moment and will not be prominently discussed during the course of the election. Less demanding alternatives have not yet been exhausted.

With the inauguration of a new administration in 2009, however, the public can expect some process of fundamental reconsideration, whoever is elected. The new U.S. president will undoubtedly begin this reconsideration with the inherited Iraq situation, but his or her thinking cannot be confined to that. If a president is to achieve a viable result during the course of an eight-year term, global implications will have to be addressed, and the fundamentals of policy will have to be engaged.

In the broader context of security policy, the Iraq venture has become a test for those who have argued for primary reliance on national military advantage achieved through adroit utilization of advanced technology, a project they have labeled transformation. They have claimed that opposing military forces can be decisively defeated rapidly and at tolerable cost by superior combined arms operations, as was demonstrated in the initial assaults in Afghanistan and Iraq. They officially intend to use superior military capability preemptively both to prevent the acquisition of weapons of mass destruction by hostile governments and to alter the character of those governments before they present imminent threats of any sort. The less explicit but widely perceived implication is that transformation is to be undertaken exclusively by the United

States, thereby enabling global military dominance. Agony in Iraq vividly demonstrates the central fallacy of that project. Security ultimately depends more on inducing adherence to consensual rules than on wielding coercive force. Global dominance is not a legitimate objective and cannot be expected to command consensus.

Consensual allegiance was the principal determinant of security even during the Cold War and the much earlier era of colonialism, as is better appreciated in retrospect than it was during those times. It is yet more compellingly vital under the circumstances of globalization. The more intense and more consequential interactions now occurring among human societies change the scale and character of threats and make collaboration for mutual protection far more important than competition for national advantage. That emerging fact will require governments to transform the basic purposes and organizing principles of their security policies as well as the resulting international relationships—a fundamental reconceptualization of vital interest.

Conceptual adjustment of that scope is admittedly difficult to achieve, yet some of the reasons why it is likely to be necessary are nonetheless evident. Human societies are organized in separate jurisdictions prone to mutual distrust. Virtually all individuals identify with some segment of the population and not with the species as a whole. Many are actively hostile to those people they set beyond the boundaries of their identity, and the central purpose of security policy has primarily been to provide preferential protection against hostile intrusion. The process of globalization runs across all national jurisdictions, however, and transcends the control of any of them. It also imposes common interests that are potentially more significant than divisive ones to which security policy has traditionally been directed. All human societies face the increasingly demanding problem of acting effectively on behalf of common interests beyond the bounds of their primary emotional and legal affiliations, a process that pits circumstance against sentiment.

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The defining feature of globalization is a spontaneously occurring increase in the scope, range, and intensity of human interactions. If it is indeed occurring as now commonly imagined, and if we were able to measure it with precision, we would presumably observe that commodities, money, and information have all been flowing in recent years over greater distances at increasing volume with increasing velocity; that these transactions involve an increasing proportion of the world's population; and that they affect the social attitudes on which national jurisdiction is based. Some part of those expectations we can observe—exponential increases in international financial transactions, for example, and more linear increases in commodity trade. Other aspects are considerably more obscure, but most of those who study the matter nonetheless believe that economic activity in particular is globalizing and is escaping the effective control of any national government.

The highly inequitable pattern of growth associated with the globalizing economy is also fairly evident: Gains in standards of living are heavily concentrated among the affluent, while population increases are occurring almost exclusively among the poor. The empirical relationship between equity and legitimacy is not well understood, nor is the empirical connection between economic equity and civil violence. It is prudent to assume, however, that these relationships are important even though they are not well measured. The process of globalization poses a threat to national governments because it escapes national borders and because it appears to be undermining social consensus on which political legitimacy and social cohesiveness depend.

Moreover, whether or not it is considered a defining characteristic, the term globalization also refers to the increasingly evident fact that aggregate human activity affects basic features of Earth's ecology, most notably the atmospheric concentration of greenhouse gases on which all forms of life depend. Without the warming effect of those gases—which absorb and re-radiate infrared radiation emitted from Earth's surface—Earth would be too cold to support organic life. But as with several other features of the physical universe, this benign, enabling effect occurs only within specific limits. Increases beyond historical limits in the atmospheric concentration of greenhouse gasses that are occuring as a result of human activity—especially energy generation—are capable of altering global weather patterns to an extent that might threaten the viability of many, if not all, contemporary societies. At the moment, effects of that sort can be credibly outlined, but scientists cannot precisely specify their exact character, probability, timing, or magnitude. If ever they can be specified to exacting scientific standards, the momentum of the effects in question is likely to make them irreversible as a practical matter. That situation requires standards of prudence and international coordination far beyond historical antecedents.

Nations base their prevailing security policies, which were forged primarily during the Cold War, on principles of active confrontation. Despite the rhetorical accommodation that occurred in the aftermath of that period, they have not fundamentally altered these legacy policies. The countervailing deterrent operations of U.S. and Russian nuclear forces still dominate international security arrangements in operational reality, if not in public consciousness. Although the United States and Russia have declared reductions in the inventories of those forces, they are essentially as lethal as they ever have been and as actively deployed. Both countries continuously maintain several thousand nuclear weapons on alert status, and they are programmed to initiate massive bombardment within minutes and to complete it within hours. As an objective matter, that situation presents what is by far the greatest physical danger to both of the societies in question and to all others as well. According to the doctrine of deterrence, the threat provides decisive protection against deliberate assault, but it also creates the possibility of a catastrophic accident—a significant fact that is heavily discounted by disciples of the doctrine.

With regard to conventional forces, the active confrontation associated with the Cold War has disappeared, leaving U.S. forces embedded in their alliance arrangements with dominance over any military operation large enough to contest sovereign control over national territory. The traditional principle of confrontation remains in the sense that U.S. forces pose an implicit threat to any country not formally allied, are not credibly balanced by any independent force, and are not reliably restrained by any formal agreement. This presents an inherent security problem to all countries outside of U.S. alliances. Most of those countries plausibly judge that cross-border aggression is not likely to occur on the scale experienced during the last century, in significant part because any such exercise would threaten economic performance—the dominant imperative of the globalization era. Nonetheless, some countries do have reason to worry.

Within the United States, and to a lesser extent within its alliances, public fear of terrorism inspired by the events of September 2001 replaced concern for these traditional forms of threat—massive nuclear bombardment and cross-border aggression. The rest of the world shifted its focus less dramatically, but most nations generally accept that addressing smaller scale, more broadly dispersed forms of violence will become an increasing priority of security policy. Most of the violence in Iraq and elsewhere arises from unresolved problems of civil conflict, and most terrorism is embedded in one or more of those conflicts. If one credits what its leaders say, even Al Qaeda's violence is intended to contest control over the Islamic world, which it considers to be its legitimate territory.

Most informed analysts recognize that unresolved or unmitigated chronic civil conflict generates a threat to global order that could be increasingly serious, even if the conflicts themselves remain contained. That threat could become truly compelling if the extreme antagonism generated in unresolved conflicts converges with instruments of mass destruction. Mercifully, that has not yet occurred, despite rampant speculation. The more advanced barriers to this type of disaster that are technically possible, however, have not been constructed, and have not yet even been specifically designed. Meanwhile, nations barely acknowledge the looming security implications of global warming—a source of threat of yet larger scale and yet more radically different character than the traditional concerns.

The more intense and more consequential interactions now occurring among human societies change the scale and character of threats and make collaboration for mutual protection far more important than competition for national advantage.

It is, of course, virtually impossible to determine with any confidence how these fundamental changes in the scale and character of primary security threats might play out over an extended period of time. There are many outcomes that can plausibly be imagined, yet there are some commonsense suggestions as to how it *ought* to play out. Aspirations are easier to formulate than predictions.

Security policy responsive to the emerging circumstances of globalization would make the defense of global legal order its primary objective and would therefore elevate common interest over national advantage. Why? Because the coordination required to operate a global economy across divided jurisdictions can only be achieved by equitable legal principles that can command sufficiently broad allegiance to make enforcement possible. With global economic coordination a priority, nations would need to adjust their thinking on other matters of national importance. They would have to subordinate all forms of confrontation to direct collaboration and, in particular, subordinate the practice of deterrence to reassurance, which has always been a companion principle.

Active monitoring of weapons arsenals, development efforts, and deployment patterns would become the principle method of protection. This would involve the organized exchange of information to set and enforce basic standards of behavior—a technique that can be extremely powerful if appropriately applied, in part because it would provide the legitimizing context for any use of force. Security relationships in such an arrangement would generally be inclusive rather than divisive, and would transform the legacy policies of confrontation among the United States, Russia, China, and India, in particular. Territorial sovereignty would remain, but its protection would primarily be a common enterprise.

Those who can only think of what history has so far revealed will undoubtedly find that image of general security transformation to be implausible. Those with some sense of what globalization means are likely to find it more interesting. Wherever on the spectrum of receptiveness one might fall, however, most would concede that any transformation of security policy that does occur is unlikely to be an exercise of general design and is more likely to be the emergent result of reactions to specific problems. Of the many broad issues that might play a catalytic role in an evolutionary process of transformation, four are especially significant: the management of nuclear explosive materials, the oversight of biotechnology, the regulation of space activities, and the mitigation of global warming. These can and will be seen as

separate issues, but there are significant connections between them.

Nuclear explosives. "Nuclear explosive material" refers to any combination of radioactive isotopes that can generate an explosive chain reaction. There are nine principal isotopes that have this characteristic, of which uranium 235 and plutonium 239 are the most extensively produced and applied. Governments have assertively and exclusively subjected these two explosive isotopes to national jurisdiction more than any other human-produced commodity. They manage them with separate national accounting and physical security systems that are largely opaque to each other. As a result, the U.S. government's estimate of the total number of nuclear weapons in existence has an uncertainty range of 5,000, and the estimate for total explosive materials is even more uncertain.

Each single weapon and each amount of material equivalent to a weapon (48 kilograms of uranium 235 and 10 kilograms of plutonium 239 for the bare sphere critical masses) is of strategic significance given the devastation that can be caused in an urban area. During the Cold War, when deterrence was embodied in upwards of 10,000 weapons in each of the two principal opposing arsenals, uncertainty about a single weapon appeared to be insignificant. If we assume that a dedicated terrorist might attempt to gain access to a nuclear weapon or an equivalent amount of explosive material, then managerial control of every single unit becomes a matter of high priority. Current national accounting and physical security systems cannot assure control of every single unit, particularly not the internally burdened system that Russia inherited from the Soviet Union.

Given inherent uncertainties about historical production of explosive nuclear isotopes, it would take decades for an advanced accounting and physical security system to know that each unit of material is under control, and many specialists believe that standard can never be achieved. Governments could achieve much higher standards than now prevail, however, if they gave managerial control greater priority than deterrence. They could substantially improve protection against terrorist diversion and virtually eliminate the risk of a catastrophic operational accident while still preserving all of the deterrent effect that is reasonably required. That the nuclear weapons states have not made this adjustment since the end of the Cold War and the advent of globalization is an indictment of their stewardship that could readily become a massive political scandal.

It is technically feasible to devise a common accounting and physical security system for all nuclear weapons and materials that over time would approach the standard of assuring control over every single nuclear unit while reliably preserving exclusive national jurisdiction over the details of weapons design and location. Advanced information technology would support such a system. It is reasonable to expect that fear of terrorism will drive insistent political demand for such an arrangement. It is also reasonable to presume that achieving such an arrangement will require nations to terminate active nuclear force operations. That would be a dramatic improvement in safety that can be achieved with little if any reduction in the underlying deterrent effect.

Biotechnology. The second of the candidate catalytic issues—protective oversight of biotechnology—is comparable in terms of the magnitude of danger posed but fundamentally different in most other respects. Progress in the fundamental science of molecular biology enables, in principle, a range of extremely consequential interventions in basic life processes. These promise the eradication of at least some of the common diseases that have long plagued human societies. Depending on how it is utilized, however, the same basic knowledge can be used for devastating destruction as well as for powerful therapies, the former being generally easier than the latter. New applications threaten the creation of diseases substantially more destructive than those that have naturally evolved. Scientists now widely acknowledge that possibility, which was generally doubted a decade ago. The inherent power of molecular biology gives human society as a whole an enormous stake in how the science is applied, and that transcendent interest almost certainly means that independent oversight procedures will have to be devised for the fundamental research process itself. Societies apply oversight to virtually all matters of high social consequence. No one is allowed to manage large sums of money without audit. No single individual is ever allowed exclusive control over a nuclear weapon. Governments or independent bodies will have to develop robust oversight procedures for those areas of biological research that pose large inherent danger.

To be effective, oversight procedures would have to be globally applied and, thus, would have to be globally devised. Biomedical research is globally distributed and has achieved a degree of momentum that exceeds the ability of any sovereign entity or limited coalition to exercise control. The research cannot be isolated from daily life to the extent that the production of explosive nuclear isotopes can be and has been. With no serious prospect of exercising exclusive national control over the biomedical research process, inclusive international collaboration is the only realistic option. When practicing scientists, the general public, and the governments that attempt to serve them all absorb the implications, as they will eventually, devising mutually protective oversight procedures will be a powerful incentive for security collaboration.

Some suggest that a nihilistic terrorist dedicated to mass destruction would logically choose an advanced biological pathogen as the agent of choice. Though this threat is currently exaggerated, the barriers to access for pathogens are nothing like what they are for nuclear weapons and explosive nuclear isotopes. They will have to be made more significant.

Space activities. At the moment, assets in space do not directly threaten mass destruction on Earth; the 1967 Outer Space Treaty prohibited the deployment of weapons that would, and that rule has not recently been contested. Space assets do contribute

substantially, however, to nations' emerging capabilities to undertake sudden precision attacks at very long range. The United States dramatically displayed this capability in November 2003, when an unmanned Predator aircraft destroyed a car traveling in the Yemeni desert that was said to be carrying a leading terrorist figure. U.S. officials controlled the aircraft remotely and are believed to have used space communications relays and navigation services.

Neither Yemen nor any other nation protested the summary execution of an alleged terrorist outside sovereign jurisdiction, without a trial or any other documented form of deliberation, but repeated exercises of that sort would certainly be contested, especially by the United States, if other nations acted similarly. The potential for that type of capacity to spread will assuredly lead to demands for legal regulation, and those demands will predictably focus on the utilization of space assets. Those assets may not be necessary for all forms of coercive intrusion, but in principle they provide greater reach and greater menace. Given the inherent vulnerability of space assets, they also provide a natural target for retribution.

In recent years the United States has officially articulated an extremely provocative doctrine of space development, asserting the intention to dominate the military use of space for decisive national advantage and to deny comparable capability to any other country. It has rejected efforts by virtually the entire international community to initiate negotiations on rules that would prevent the introduction of conventionally armed weapons in space, suggesting that it intends itself to introduce such weapons. Although the declared U.S. aspiration for space dominance is unrealistic in technical and economic terms, nations appreciate the potential scope for advanced forms of coercion along these lines, and such operations will eventually generate international demands for legal regulation. Since protective regulation is in the U.S. interest and is likely to emerge from formal negotiations on the subject, such talks will provide an occasion for working out more advanced principles of security collaboration.

GLOBAL WARMING. During the past decade, the Intergovernmental Panel on Climate Change forged consensus within the scientific community on the basic features of global warming. The panel's scientists determined that the concentration in Earth's atmosphere of those carbon gas molecules that absorb and re-emit infrared radiation has been increasing as a result of aggregate human activity since the Industrial Revolution and that the average surface temperature of Earth has increased by 0.4–0.8 degrees Celsius during the past century as a result. They estimate that this temperature would increase an additional 1.5–6 degrees Celsius if the current pattern of carbon dioxide emission continues for an additional century. They note that these temperature changes are very large and very rapid in comparison to the geological record and are in principle capable of triggering fundamental changes in Earth's climate pattern. Again, current science cannot establish with confidence the exact character, magnitude, timing, probability, or consequence of those changes but can warn that they might be catastrophic for human societies. And as also previously noted, by the time a catastrophic threat could be identified with precision and confidence, the process generating it is likely to be irreversible on any timescale of human interest.

It is technically feasible to mitigate the inherent danger by changing the prevailing pattern of energy generation and consumption, but that would require a global policy initiative of unprecedented scope and consequence. In addition to introducing incentives for greater efficiency, governments and industry would have to develop to the level of market viability those technologies capable of providing energy in the amount required to support equitable economic development, and they would have to assertively deflect the current trajectory of global energy markets to induce these technologies' adoption. The increase in concentrations of carbon dioxide in the atmosphere would have to be halted by 2050 at a level of 450 parts per million or below to achieve a prudent standard of protection. There are only five basic technologies that could plausibly provide carbon-free energy in amounts sufficient to meet this standard while also accommodating rising global demand to the extent required to support basic standards of equity: wind, solar, biomass, carbon sequestration, and nuclear fission. All will presumably have to be developed and applied to some extent, although advocates of the favored option, carbon sequestration, have yet to demonstrate its long-term viability and might not be able to meet the burden of proof that should be imposed.

The significance for security policy rests primarily on the degree to which the response to global warming depends on nuclear power generation. Global energy requirements might in principle be achieved by some combination of the other methods, but that

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It is technically feasible to devise a common accounting and physical security system for all nuclear weapons and materials that over time would approach the standard of assuring control over every single nuclear unit, while reliably preserving exclusive national jurisdiction over the details of weapons design and location.

Consensual security

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cannot be assumed at the outset. Officials will have to seriously consider (and probably undertake) a dramatic expansion of nuclear power. That in turn will require radical revision of current reactor designs, fuel cycle management practices, and fundamental security relationships. Expanding nuclear power generation under other circumstances would be unsustainably dangerous, especially in the context of prevailing deterrent practices and confrontational security relationships. The incentive and opportunity for hostile diversion of nuclear explosive isotopes could not and would not be tolerated. The safe expansion of nuclear power generation in response to global warming would require intimate collaboration among China, the European Union, India, Japan, Russia, and the United States that can be expected to include top officials in all of the governments concerned. When these parties absorb all of the technical and institutional implications of negotiations, they will give strong impulse to the conceptual transformation of security policy.

Dealing with Iran's efforts to produce nuclear materials is likely to be the focus of this transformation's important initial stages. Iran is entangled in the internal violence in Iraq and simultaneously presents the most immediately troublesome threat of nuclear weapons proliferation. Recent reports indicate that Iran did conduct a clandestine nuclear weapons design effort before terminating it in 2003. Although it denies any intention to acquire nuclear weapons, it continues to defy a U.N. resolution demanding that it suspend its efforts to enrich uranium and produce plutonium, thereby providing potential justification for an attack on the facilities in question before they are able to produce a sufficient amount of material to fabricate nuclear weapons. U.S. forces could carry out such an attack without undertaking the burden of a ground invasion, and the Iranian president's inflammatory political statements appear to invite it. The lessons emerging from Iraq clearly suggest, however, that this course would be a disaster for all concerned. It would retard but not destroy the Iranian program and would presumably provoke an extended process of terrorist retaliation. Again, credible danger provides a strong incentive for devising constructive alternatives.

The formula for an alternative is readily apparent. It would involve an agreement by Iran not to engage in uranium enrichment or plutonium production on sufficient scale to enable fabrication of nuclear weapons and to document its compliance with those restrictions by accepting International Atomic Energy Agency monitoring under the Additional Protocol. In exchange, Iran would receive legally binding U.S. security assurances, ratified by the international community generally, that it would not be attacked if it did not initiate attack. Compliance with those assurances would be documented in some manner roughly comparable to Iranian documentation of the materials production restrictions. The international community would also assure Iran of access to fuel cycle services for nuclear power generation at equitable market rates without political conditions. That is the basic formula being applied in North Korea. Iran could not reasonably refuse this arrangement if it were credibly offered and accompanied by a U.S. commitment to normalize political and economic relations.

Engaging Iran in extensive, substantive discussion and adjusting prevailing political attitudes to apply that formula to Iran would support the broader program of conceptual transformation not only by mitigating emotional resistance but also by demonstrating the significance of the principles involved. In requiring both Iran and the United States to accept standards of behavior and to document their compliance through the systematic exchange of information, this arrangement would illustrate the practice of systematic reassurance. In a world of intense antagonisms and dispersed threats where small operations can have catastrophic consequences, all major states are likely to discover the value and consequence of systematic reassurance. That principle supported by advanced information technology can be expected to emerge as the necessary foundation for international security under the circumstances of globalization. ■

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The bureaucracy of deterrence

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The next U.S. president must remember that nuclear strategy is as important as trade policy. Bush Sr. was known for doing the heavy lifting needed to achieve foreign policy goals, especially if they were bold and potentially controversial. Clinton, by contrast, was wary of engendering conflict with the military, the Pentagon, and Congress—and his wariness left subordinates to fight their battles alone, without enough political muscle to prevail.

Another piece of advice: Seasoned professionals, loyal to the president yet respected by careerists, stand a far better chance of defusing bureaucratic resistance than outsiders who come in seeking to impose aggressive—and unfamiliar—agendas on institutions that prize the familiar. Staffing a new administration wisely at the outset could be decisive for later endeavors.

The next commander-in-chief must also support appointees. Leadership is the art of superintending change. Presidents need to demonstrate their commitment to specific, high-priority strategic outcomes, state that these outcomes are nonnegotiable, and be prepared to intervene personally when the process encounters trouble. Tactics for implementation can be left to subordinates who can count on the president's full backing.

Finally, the president must realize that wholesale institutional change may be necessary to enable a new president to

THE COST STRUCTURE OF INTERNATIONAL URANIUM ENRICHMENT SERVICE SUPPLY

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Abstract

This paper develops an economic model of the international uranium enrichment supply market. With information from planned and operating enrichment facilities, we estimate econometric models of construction cost and labor requirements as exponential functions of facility size. These models are used to estimate Separative Working Unit (SWU) costs of all major enrichers. This allows the tracing of the international SWU supply curve. In a competitive market, the highest cost producer sets the market price. When inefficient gaseous diffusion plants are retired, the SWU price should decline. This could reduce profits for all suppliers and might decrease incentives for future investment in this industry. However, higher prices could encourage potential enrichers to enter the international market. Therefore, to discourage proliferation of enrichment technology, some form of international *market* intervention might be necessary to control SWU prices, in addition to *political* interventions under discussion in the international community to control SWU supply.

Keywords: Gaseous Diffusion, Gas Centrifuge, Separative Work Unit, nuclear power economics

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1. The International Uranium Enrichment Services Market

To increase the percentage of fissile uranium, natural uranium oxide is converted to uranium hexafluoride (UF6, a gas above 56º C), then enriched to a higher percentage of the fissile isotope U^{235}. Enrichment is done commercially using two methods: gaseous diffusion and gas centrifuge. With gaseous diffusion, the UF6 is forced through a series of barriers that allow the smaller U^{235} to penetrate more easily than the larger U^{238}. Given that the difference in weight is small, this process requires pumping UF6 through hundreds of barriers to achieve an enrichment of 3-5% for nuclear reactor fuel. With centrifuge technology, the UF6 is separated through a centrifugation process. Both processes operate in a cascade arrangement where different separation stages are tied together with intricate piping systems. Due to the higher separation factor per stage, a smaller number of centrifuge stages are required to achieve the same level of enrichment than with gaseous diffusion.

Historically, France and the United States dominated the enrichment market with gaseous diffusion. But firms using centrifuge technology, such as the Russian Rosatom and the British-Dutch-German Urenco, have captured an increasing share of the market. The U.S. Enrichment Corporation's (USEC's) share declined from 39% in 1995 to 17% in 2005, as 1940s and 1950s era diffusion facilities (at Oak Ridge, TN, and Portsmith, OH) were retired (Rothwell, 2003).

On the other hand, centrifuge capacity is being built in France and the United States. In France, Eurodif (a member of the Areva group) has partnered with Urenco to produce centrifuges. In the United States, the Department of Energy (U.S. DOE) has helped USEC develop a new generation of centrifuges to replace USEC's diffusion capacity. Testing of the first cascade began in September 2007. Also, Urenco is building centrifuge capacity in New Mexico, and Areva has announced plans to build another centrifuge facility in the United States.

Further, the Brazilian INB (Indústrias Nucleares do Brasil) is building a small enrichment facility at its Resende integrated-nuclear-fuel-cycle site to assure fuel supply of its two nuclear power plants. Argentina, which has two small, de-activated enrichment facilities, is now considering re-activating them. South Africa is interested in refurbishing and expanding its uranium enrichment facility at Pelindaba. Australia is considering building an enrichment facility (possibly using laser enrichment technology) to increase the value added to its uranium resources. With huge diffusion facility retirements and new centrifuge facilities under construction, market capacity and price will be uncertain during the coming transitional decade.

The Appendix forecasts marginal costs for enrichment services, measured in Separative Work Units (SWU). We develop a cost engineering model of four currently planned centrifuge enrichment facilities, and statistically estimate scale parameters from available data. Using long-run levelized cost as a proxy for long-run marginal cost, we calculate marginal costs and construct SWU supply curves for 2005 and 2015.

We show that industry profits could fall with the retirement of the diffusion plants, if prices are determined by competitive markets. This could lead to a lack of investment in the international uranium enrichment industry by profit-making companies in "fuel-cycle" states. If market power is used to sustain higher prices, small new entrants could believe they might be able to compete in the enrichment market. New entry by "non-fuel-cycle" states implies the proliferation of uranium enrichment technology. Because the proliferation externality associated with enrichment is not reflected in the price of enrichment services, free markets do not necessarily lead to socially optimal outcomes. Hence, some form of *market* intervention could be necessary to insure non-proliferating capacity investment and prices near production cost.

2. The Supply Curves of Existing and Future Enrichment Services

We can apply the results of the Appendix to approximate the supply curve for the existing international commercial uranium enrichment services. See Figure 1 for 2005 and Figure 2 for 2015. In Figure 1 we assume that Russian production is limited such that the Novouralsk facility (with 9 M SWU per year) is not competing in the international market (due to agreements associated with blending down weapons grade highly enriched uranium and domestic commitments). See Mikhailov (1995). In Figure 1, about one quarter of the international enrichment market is low cost (less than $50), one quarter is moderate cost (between $50-$100), and one half of the market is high cost (more than $100). With requirements at 40 million SWU (approximately 120,000 SWU per GW per year), the market price is determine by the highest cost producer (USEC) at approximately $135/SWU. (Of course, cheaper producers could under cut Eurodif's and USEC's price in long-term contracts.) With a price of $135/SWU and quantity of 40 M SWU, total industry annual revenues at Fourth-Quarter-2006 prices were about $5,400 M.

With the retirement of the world's diffusion capacity and no constraints on Russian participation in the market, the supply curve for enrichment services will shift between now and 2015 to a situation more similar to that in Figure 2 (which includes Brazilian capacity, in the top right-hand corner). At 2005 quantities (40 M SWU) world requirements could be satisfied by all enrichers, and total revenues would be approximately $3,200 M. If requirements do not grow between 2005 and 2015, then the Japanese (Rokkasho) facility would set the spot market price at least $80/SWU in 2006 dollars: A price drop of 41%, and big savings to consumers of nuclear generated electricity, i.e., $2,200 M.

To understand the implications of these changes, consider economic profits in 2005 versus 2015 (economic profits are net revenues after payments to debt and a reasonable rate of return on equity; accounting profits are net revenues after payments to debt, see Rothwell and Gomez, 2003, p. 25). In Figure 1 the "Russian" box represents Russian economic profits, equal to ($135 ─ $31) (9 M SWU), or about $900 M (not including profits from other facilities and services). In Figure 1 the "Urenco" box represents Urenco's economic profits, equal to ($135 ─ $70) (8.1 M SWU), or $525 M. In 2015 the profit situation changes: In Figure 2 the "Russian" box represents Russian profits, equal to ($80 ─ $40) (19 M SWU), or about $760 M (taking a weighted average across all facilities) and the "Urenco" box represents Urenco's economic profits, equal to ($80 ─ $62) (8.1 M SWU), or $145 M.

Therefore, as uneconomic diffusion capacity is retired and all Russian capacity enters the international market, Russian economic profits could decline 16%, but Urenco's profits could decline by 72%! Because of their more mature technology, Eurodif's George Besse II and Urenco's NEF could earn economic profits, but USEC's APC, might not earn significant economic profits (e.g., $30M per year on an investment of $3,000 M). This situation could make private financing for private enrichers difficult to acquire capital at costs that will allow them to be competitive.

Additional enrichment capacity might be built in Russia, since their centrifuge technology and costs are lower than the comparable Western European centrifuges. One technique of increasing enrichment market share is the creation of an International Uranium Enrichment Center (IUEC) in Angarsk in western Siberia. The Angarsk enrichment and conversion plants have been combined with Kazakhstan's uranium supplies, since Kazakhstan has joined the IUEC as an equity partner. A fuel pellet plant operating in Kazakhstan might be

upgraded to provide fabrication services. In this way the IUEC could provide nuclear fuel at a lower market price, increasing its nuclear fuel market share, and thus its enrichment market share. (The concept of taking equity partners in an enrichment facility to reduce the lead country risk and capital contribution was done to finance the Eurodif facility in France; France might finance the second stage of the George Besse II facility in a similar way.)

3. Conclusions

With the retirement of diffusion technology during the next decade, the artificially high price of enrichment services could fall. (It is "artificially" high due to entry barriers: had a free market developed in enrichment, new cheaper capacity would have forced the retirement of the diffusion technology much earlier). The enrichment industry is now being more closely watched with the discovery of a Pakistani enrichment smuggling network, Braun and Chyba (2004). Thus, entry of new participants into the enrichment market is constrained by nonproliferation considerations, as well as by commercial interests. The enrichment industry response could be the formation of a cartel to maintain artificially high prices. Unfortunately, high prices could encourage entry by countries like Argentina, Australia, Brazil, Iran, South Africa, and others.

Without market intervention, prices could fall to competitive levels. This implies there would be no economic profits in this industry for new entrants. For this reason, the financial outlook of uranium enrichers has been bleak, prompting a Standard and Poor's analyst to write:

"On 29 September 2006, Standard & Poor's Ratings Services affirmed its 'A-/A-2' long- and short-term corporate credit ratings on Europe-based uranium enrichment company Urenco Ltd . . . The enrichment market is undergoing very drastic changes, as TENEX (Rosatom)—which controls roughly 50% of global enrichment capacity but only 24% market share among end-customers—is looking to increase its share of direct sales to end-customers. The extent to which this will affect Western enrichment suppliers—USEC Inc. (B-/Negative/--), Areva (not rated), and Urenco—over the medium term remains to be seen, but will be strongly influenced by ongoing political and trade negotiations . . . The other major industry change is an expected phase-out of the non-economical gaseous diffusion plants used by USEC and Areva, both of whom are expected to build centrifuge plants in the medium to long term."

A- implies that Standard & Poor's believes that the "economic situation can affect finance" and "it is likely to be… downgraded (negative);" B- implies a likely downgrade of non-investment grade (junk) bonds where "financial situation varies noticeably," i.e., USEC's must pay junk bond rates on its debt, while trying to finance a new, First-of-a-Kind technology. On the other hand, the U.S. Congress has recently approved $2,000 M in loan guarantees to USEC.

Therefore, assuring adequate enrichment capacity over the long term (e.g., the planning horizon of countries like Brazil) will be problematic without some market intervention. This could take the form of an internationally-recognized uranium enrichment regulator that would guarantee a reasonable rate of return on new enrichment facility investments at a price that would not encourage entry by marginal countries attempting to assure their own country's nuclear power industry enrichment requirements, as claimed by Iran. On the other hand, fuel cycle states could guarantee a profitable price for uranium enrichers, tax the enrichers, and use these taxes to subsidize enrichment services to non-fuel cycle states. Whatever the solution, assuring adequate investment in a centrifuge technology non-proliferation regime will be problematic for any single country to achieve.

Another observation can be made: Any program for assured nuclear fuel supplies to compensate countries willing to give up uncompetitive domestic enrichment facilities should be coupled with lower international enrichment prices to discourage new entrants. The fuel bank proposals should be encouraged, but few of these proposals discuss reasonable prices for the fuel bank services, or whether a fuel bank would be necessary if the SWU price were set artificially low (through subsidies). A subsidized SWU price should be low enough to eliminate any commercial incentive for new enrichment entry. Setting an unreasonably low price might be possible in a regulated or cartel setting, but is unlikely in a "free" market. Because of the

externality associated with nuclear weapons technology proliferation, markets in enrichment do not necessarily lead to a social optimum. Subsidies to enrichers to lower enrichment prices to below competitive levels, while increasing capacity, would signal countries considering nuclear power plants that they would never be able to produce fuel at costs below the low-volatility, subsidized price. However, setting an artificially low SWU price would encourage inefficient uranium consumption (i.e., pressure to raise the tails assay); therefore the tails assay must also be set with the price to insure economic efficiency.

Appendix: Cost Models of International Enrichment Facilities

Paul J.C. Harding, the Managing Director of Urenco (Capenhurst) Ltd (UCL), described production at his plant in 2005 (to explain his plant's dependency on non-interruptible power):

"• 40% of Urenco's total current enrichment capacity is at UCL
- UCL has 390 employees
- Annual electricity consumption is 180,000 MWh (~ 20MWe continuous demand)
- Once started, aim is never to stop gas centrifuge machines
  - Need no maintenance
  - Low failure rate
  - Oldest machines at site have run continuously since 1982!
  - If machines are stopped, risk is they will not start again"

To account for the capital, labor, electricity, and other expenses in enrichment services, let total annual cost in 2006 dollars, TC, of producing total annual SWU be $p_K K + p_L L + p_E E + p_M M$, where K is the total capital investment cost (TCIC, defined in EMWG 2008) measured in millions, M, of 2006 dollars, and p_K is the annual capital charge rate; L is the number of employees at the facility, and p_L is annual (burdened) salary of an employee; E is the electricity input MWh, and p_E is the price of electricity in dollars per MWh; M represents the cost of materials consumed in the enrichment process, and p_M is the price of materials.

We assume that (1) M is a linear function of K, and (2) p_M is expressed in percent per year of K (this is similar to setting p_M to the physical depreciation rate). Let $p_{KM} = p_K + p_M$. The Levelized Cost, or Long-Run Average Cost, AC, is

$$AC = \Sigma \left(p_{KM} K + p_L L_t + p_E E_t\right) (1 + r)^{-t} / \left[\Sigma SWU_t (1 + r)^{-t}\right], \quad (1)$$

where the summation is over the commercial life of the facility, all construction costs are discounted to the commercial operation date and r is the appropriate discount rate. (We implicitly assume, following Harding, 2005, a constant annual capacity factor of 100 percent.)

The remainder of this Appendix proposes and estimates econometric models of overnight costs, k, and labor, L, for new centrifuge capacity. Overnight cost, k, is transformed into total capital investment cost, K, with the addition of Interest During Construction and contingency, i.e., $K = (1 + c) \cdot k$, where c is a percentage mark-up for IDC and contingency. We forecast electricity cost as the product of electricity price and kWh/SWU. With these costs we project long-run marginal cost, and graph supply curves for enrichment services; see Section 2 above.

A.1. Estimating New Centrifuge Enrichment Facility Costs

Overnight construction cost, k, for new centrifuge facilities is estimated with information on four recently announced facilities in the United States, France, and Brazil:

(1) The American Centrifuge Plant (ACP) is being built in Ohio by USEC, using a U.S. DOE-USEC developed 320 SWU/year centrifuge. USEC estimates the first stage will cost $2,300 M in 2007 dollars (about $2,230 in 2006 dollars) for a capacity of 3.8 M SWU. The first stages should be producing by 2009 and the facility should be completed by 2012 (USEC, 2007).

(2) The Urenco New Enrichment Facility (NEF) facility in New Mexico with a 3 M SWU per year capacity is based on Urenco technology (TC-12 machines) with a separative capacity of 50 SWU per centrifuge per year. Construction started in August 2006 with the first set of stages

to operate in 2010, and full capacity operation expected in 2013. The overnight cost has been estimated at $1,500 M (in 2006 dollars); see Schnoebelen (2006).

(3) The new George Besse II enrichment facility, with a capacity of 7.5 M SWU per year, near Tricastain, France, is also based on Urenco's TC-12 centrifuges. This facility is being built by Eurodif, a member of the French Areva group. The estimated cost is € 3,000 (2003) M (or $3,275 M 2003 dollars, or $3,700 M 2006 dollars); Autebert (2006).

(4) The Brazilian government is building an enrichment facility at Resende to supply 203,000 SWU by 2015 for its Angra 1 and 2 nuclear power plants. They are using an indigenously developed centrifuge design. The estimated overnight cost is about 550 M 2006 Brazilian Real, or about $253 M 2006 dollars (Cabrera-Palmer and Rothwell, 2008).

Before analyzing this information, we caution that the following cost-engineering -econometric model is based on three centrifuge technologies at different maturities: The Urenco TC-12 centrifuges have been in commercial operation for more than a decade and can be reproduced at N^{th}-of-a-Kind cost. The smaller Brazilian centrifuges are in their First-of-a-Kind commercial deployment. The ACP larger centrifuges are being scaled up from prototype to commercial size. Therefore, these are conditional estimates and should be revised when more cost information is publicly available.

With this information we estimate an exponential model of k (overnight cost in millions of 2006 dollars) as a function of annual SWU capacity (SWU in thousands of SWU per year), i.e., the Ordinary Least Squares (OLS) parameter estimates are

$$\ln(k_i) = \underset{(0.38)}{1.62} + \underset{(0.05)}{0.73}\ln(SWU_i) \qquad (R^2 = 0.99,\ F = 228.54), \tag{2}$$

where values in parentheses are standard errors. All indications are that this equation is well estimated, see graph in Figure A.1. From these results, we conclude there are increasing returns to scale in capital (with a scale factor of 0.73 and a standard error of 0.05, there is 99 percent confidence that the scale factor is not equal to 1.0, as it would be under constant returns to scale).

In industries where there are increasing returns to scale, the largest producer can undercut the price of smaller producers. This can lead to the creation of market power and to prices higher than costs. On the other hand, in the enrichment industry, increasing returns to scale provides a barrier to entry, thus increasing the proliferation resistance of the industry, and therefore reducing the social cost of the proliferation externality. Increasing returns to scale in enrichment reduces both proliferation and market price discipline. Hence, there is a tension between profits (under high prices, which encourage proliferation) and non-proliferation (under low prices).

The difference between overnight costs (k) and total capital investment costs (K) is the addition of Interest During Construction (IDC) and contingency. IDC discounts construction expenditures to the start of commercial operation. It is a function of the cost of capital and the construction length. Because centrifuge enrichment facilities can be built in modules, IDC is charged over the lead time of module construction. We assume this lead time is 3 years. At a cost of capital of 5 percent, IDC adds 7.48 percent to the cost of the project. Following EMWG (2008), we assume a contingency of 10%. So $K = (1 + 0.0748 + 0.10)\, k = 1.1748\, k$.

The price of capital, p_K, is the annual capital charge rate. Following Cabrera-Palmer and Rothwell (2008), we assume a 5 percent *real* cost of capital with centrifuge economic plant lives of 30 years, i.e., $p_K = 0.0651$. (The real cost of capital is equal to the nominal cost of capital minus the expected inflation rate; with expected inflation at 3 percent, the nominal cost of capital

would be 8 percent, i.e., one appropriate for a regulated utility.) Also, we assume that the annual physical depreciation cost is 1 percent of overnight costs, i.e., $p_M M = 0.01\ k = 0.01/1.1748\ K = 0.0085\ K$). So, $p_{KM} = 6.51\% + 0.85\% = 7.4\%$. (Although EMWG, 2008, recommends financing plant decommissioning through a sinking fund, because the throughput of these facilities is so high, the decommissioning cost per SWU is low enough to be ignored at this level of analysis.)

Second, regarding labor, *L*, the announced projected staff size of the ACP is 500 employees (USEC 2004), the staff size of NEF has been announced to be 210, and the staff size of Resende is estimated to be 100 (Cabrera-Palmer and Rothwell 2008). Also, while not a new facility, there are 390 employees at Urenco's Capenhurst facility (producing 3.4 M SWU per year). This provides a benchmark and another observation. With this information we estimate an exponential model of *L* (staff size) as a function of size (*SWU* in thousands of SWU per year). The OLS parameter estimates are

$$\ln(L_i) = \underset{(1.22)}{2.16} + \underset{(0.16)}{0.46}\ln(SWU_i) \qquad (R^2 = 0.80, F = 7.91), \tag{3}$$

where values in parentheses are standard errors. This equation is not as well estimated as Equation 2, see graph in Figure A.2. However, the equation does well at forecasting the staff size at Capenhurst. We conclude there are increasing returns to scale in labor. (With the scale factor equal to 0.46, and a standard error of 0.16, there is 98 percent confidence in rejecting constant returns).

Further, we assume a "fully burdened" average annual salary is $60,000 in Brazil, based on a base salary of approximately $35,000 per year (Cabrera-Palmer and Rothwell, 2008) and a 70 percent burden rate (EMWG 2008). Also, we assume a burdened average annual salary in France and the United States is $120,000, based on information in the annual reports of the ETC

(Enrichment Technology Corporation, a joint venture between Urenco and Areva to produce centrifuge equipment): The 959 employees at ETC in 2006 were paid €65.943 M, or €69,000/employee/year (ETC, 2007), which is approximately twice the salary paid in Brazil.

Third, the electricity consumption for Urenco and ACP centrifuges is from INL (2007), i.e., 50 kWh/SWU. The electricity consumption for Resende centrifuges is from Cabrera-Palmer and Rothwell (2008), i.e., 100 kWh/SWU. Further, following Cabrera-Palmer and Rothwell (2008), we assume $92/MWh (or $0.092/kWh) as the delivered price of electricity (in 2006 dollars) for all centrifuge facilities, which includes transmission and distribution fees (generally, generation is one-half of total costs, i.e., the generation cost is approximately $46/MWh).

Table I presents the estimated levelized cost per SWU for the new centrifuge facilities assuming a real 5 percent cost of capital. The capital intensity of centrifuge enrichment technology yields an annual capital charge that is 2/3rds of the total annual cost. Labor is about 1/6th of total costs, and electricity and materials make up the remaining 1/6th. The Urenco technology facilities (NEF in New Mexico and George Besse II in France) will likely have lower costs than the USEC's ACP. The levelized cost of Brazil's small facility will likely be twice as much as cost at the ACP, and almost three times as much as cost at the Urenco facilities. Next, we apply this economic model to estimate costs of the existing enrichment facilities.

A.2. Projecting Replacement Costs of Existing Centrifuge Facilities

Next, we approximate the cost structure of the existing commercial centrifuge facilities owned by Urenco, JNFL, and Rosatom. See Tables II and III. Urenco has three production facilities at Capenhurst, the UK, with 3.4 M SWU; Almelo, the Netherlands, with 2.9 M SWU; and Gronau, Germany, with 1.8 M SWU. Using Equation (2), we estimate the overnight replacement cost (in 2006 dollars). Because these facilities have already been built and some of

the capital has been depreciated, we assume that there is no contingency or IDC, i.e., that total capital investment cost (K) is equal to the estimated overnight replacement cost (k). (This assumption reduces the levelized capital costs at older facilities by 10 percent.) We assume that Urenco and JNFL determine their annual capital charge using a real 5 percent cost of capital. The Urenco facilities yield levelized costs in the same range as the new facilities in the United States. Costs at Rokkasho, Japan, are higher due to the lack of scale economies in capital and labor (also Japanese levelized costs could be much higher given lower capacity factors at Rokkasho.)

The same analysis is applied to estimate the costs at Rosatom's centrifuge-based facilities in Novouralsk (UEKhK, Sverdlovsk Oblast) with 9 M SWU, Zelenogorsk (EKhZ, Krasnoyarsk Kray) with 5 M SWU, Seversk (SKhK, Tomsk Oblast) with 3 M SWU, and Angarsk (Irkutsk Oblast) with 2 M SWU. (See Bukharin 2004.) Again, we assume the replacement values of the facilities can be modeled with Equation (2) and labor requirements with Equation (3). In determining appropriate parameter values, we follow Bukharin (2004, p. 199): "large separative capacities and low production cost – possibly on the order of $20 per SWU (compared to approximately $70 per SWU in the United States) – which is made possible by the use of highly-efficient centrifuge technology, and access to low-cost electricity, materials and labor, make the Russian enrichment enterprise highly competitive." Therefore, we assume (1) that the real cost of capital is 2.5%, leading to a capital recovery factor of 4.78% (versus 6.51% for the other centrifuge facilities), (2) the burdened cost of labor is $60,000 equal to that in Brazil, and (3) a cost of electricity of $46/MWh (implicitly assuming that the cost of transmission and distribution is zero). See Table III. The estimated levelized cost in 2006 dollars is between $31 for the largest facility and $48 for the smallest facility, lower than at all other international facilities. It is possible that costs are even lower, as assumed in Bukharin (2004).

A.3. Projecting Costs of Existing Diffusion Facilities

Finally, we apply our economic model to approximate the cost structure of the existing commercial diffusion plants owned by USEC and Eurodif. See Table IV. Of course, this is a different technology (however, nearly 85% of the cost of diffusion enrichment is determined by the cost of electricity, so all other costs, which we are approximating with our model of centrifuge technology, are of second order). Using the same technique for projecting investment costs as above, we find that the current investment costs (*replacement value*) for each diffusion plant is about $4,000 M. We assume a 2.5% cost of capital to determine the annual capital charge. We assume that Eurodif's newer diffusion plant (completed in 1982) operates at 2,200 kWh/SWU, whereas the older USEC plant (Paducah, completed in 1954) operates at 2,500 kWh/SWU. Because of the size of these facilities, we assume dedicated electricity generators at $46/MWh (i.e., again, implicitly, the transmission and distribution costs are zero). This high use of electricity makes the gaseous diffusion plants the highest cost producers in the international enrichment industry (with almost half the world's capacity). These two plants are due to retire by 2015. We use these results to trace supply curves in Section 2 to determine how the retirement of gaseous diffusion capacity could influence prices in this market.

A.4. Estimating the long-Run Average Costs of Centrifuge Facilities

Given the high cost of the small plant and the similarity of costs for the large plants (indicating the possibility of declining scale economies), we use a reciprocal functional form to model the relationship between average cost (AC) and size (SWU): $AC = \gamma + \delta (1 / SWU)$. Average cost is calculated for various plant sizes at costs of capital of 5% and 10%. These calculated costs are compared to the inverse of plant size. This relationships presented in Figure A.3. (Here, economies of scale are nearly exhausted at 2.5 million SWU.) So, if a plant had a

capacity of 1 million SWU per year with r = 10%, the levelized average cost would be approximately $69.59 + $18.93 = $88.52/SWU. This information is used to graph the supply curves in Section 2.

FIGURES

Figure 1. Supply of Uranium Enrichment Services, 2005

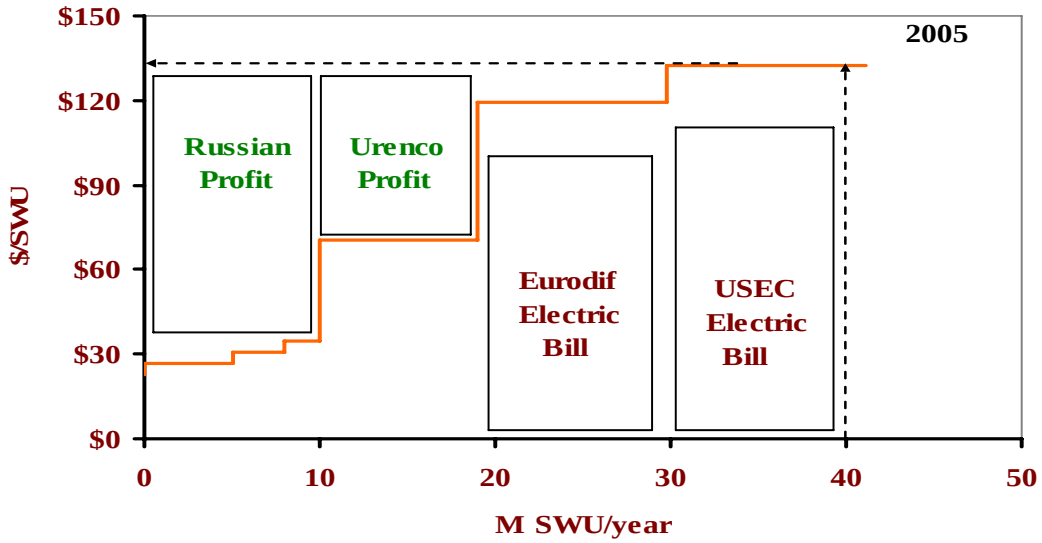


Figure 2. Supply of Uranium Enrichment Services, 2015

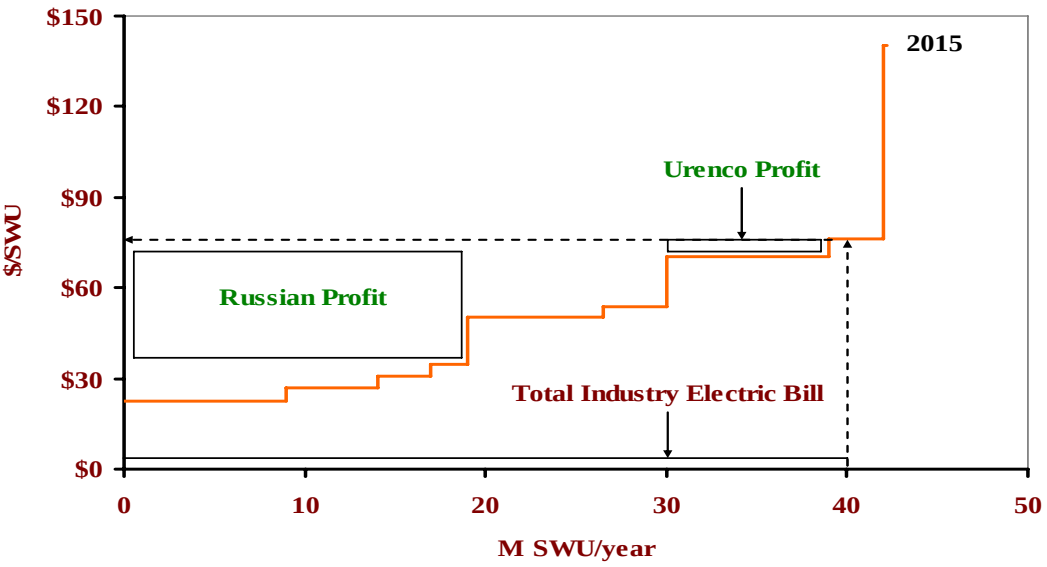


Figure A.1. Estimated Overnight Cost, Centrifuge Technology (2006 dollars)

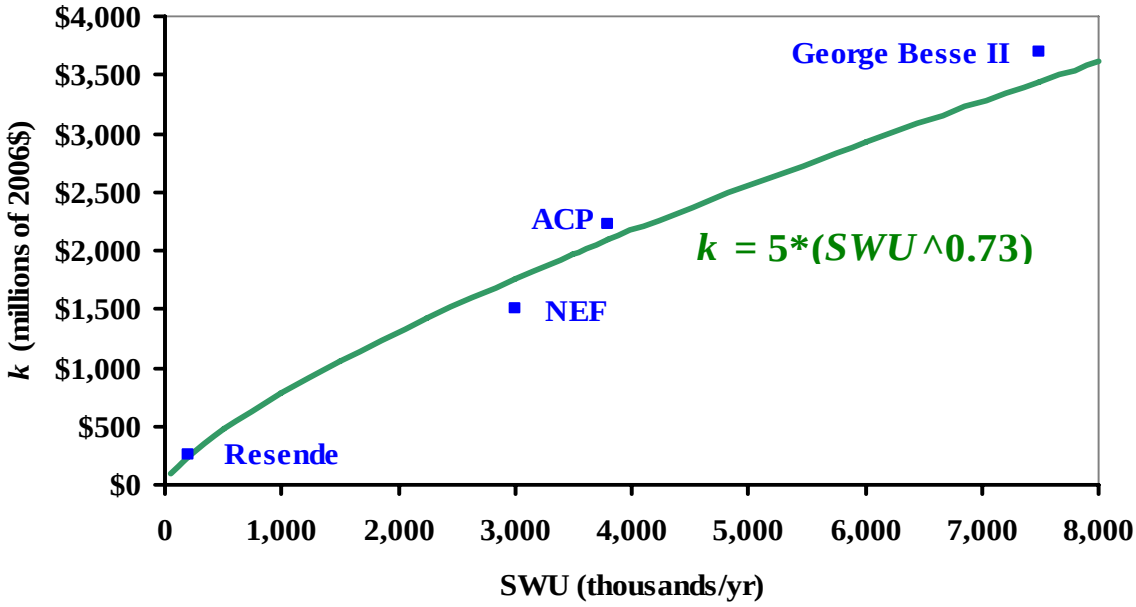


Figure A.2. Estimated Labor, Centrifuge Technology

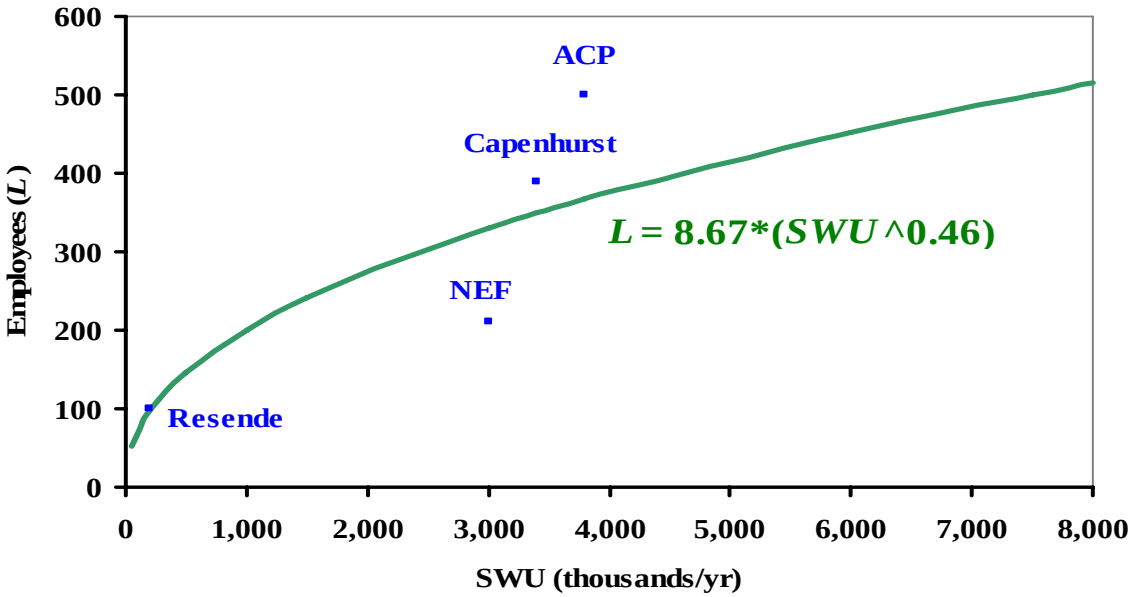
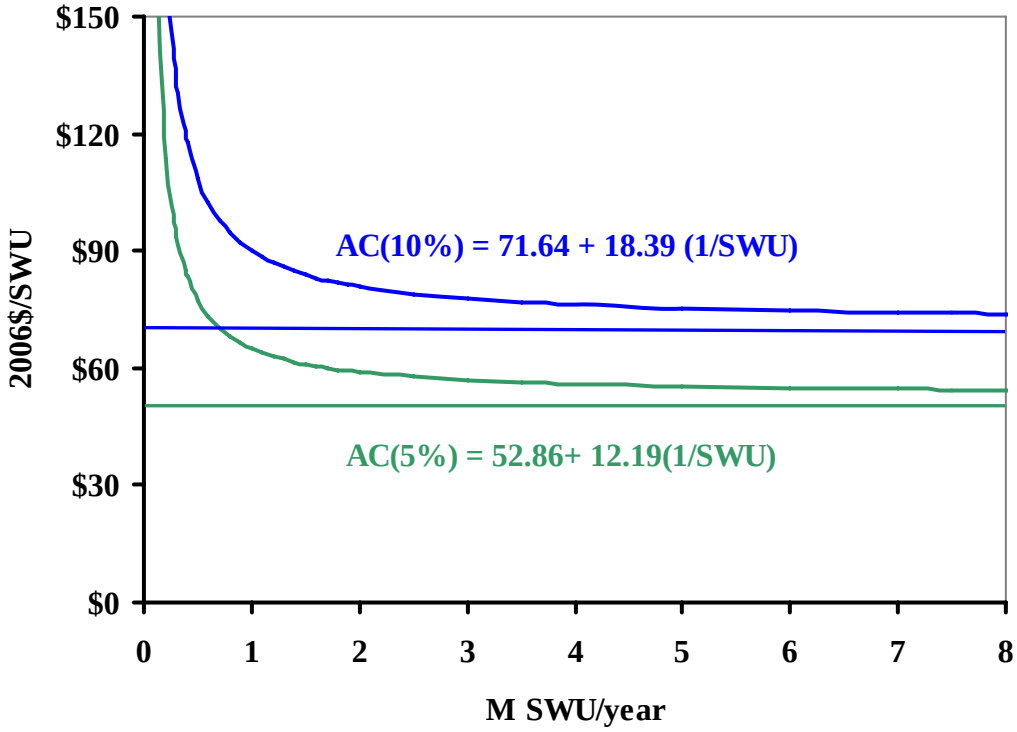


Figure A.3. Estimated Cost Curves, Centrifuge Technology



TABLES

Table I. Levelized SWU Costs, New Centrifuge Capacity
(5% cost of capital, 6.51% Capital Recovery Factor, +7.48% IDC, 10% Contingency)

Firm **Facility**	(2006 $)	**USEC** **ACP**	**Urenco** **NEF**	**Eurodif** **Besse II**	**INBrazil** **Resende**
Plant Capacity	k SWU/yr	**3,800**	**3,000**	**7,500**	**203**
Overnight Cost (*k*)	$M	**$2,230**	**$1,500**	**$3,700**	**$253**
Total Capital Invest Cost (*K*)	$M	**$2,645**	**$1,779**	**$4,389**	**$300**
Annual Capital Charge	$M	**$172**	**$116**	**$286**	**$20**
Staff Size (L)	people	500	210	525	100
Annual Fully Burden Salary	$k/yr	$120	$120	$120	$60
Annual Labor Cost	$M	**$60**	**$25**	**$63**	**$6**
Electricity Consumption	kWh/SWU	50	50	50	100
Electricity Price	$/MWh	$92	$92	$92	$92
Annual Electricity Cost	$M	**$17**	**$14**	**$35**	**$2**
Annual Materials Cost	$M	**$22**	**$15**	**$37**	**$3**
Annual Total Costs	$M	**$272**	**$170**	**$420**	**$30**
Levelized SWU Cost (*AC*)	$/SWU	**$72**	**$57**	**$56**	**$147**

Table II. Levelized SWU Costs, Existing Centrifuge Capacity (Europe and Japan)
(5% cost of capital, 6.51% Capital Recovery Factor, +0% IDC, 0% Contingency)

Firm **Facility**	(2006 $)	**Urenco** **Capen-hurst**	**Urenco** **Almelo**	**Urenco** **Gronau**	**JNFL** **Rokkasho**
Plant Capacity (in millions)	k SWU/yr	**3,400**	**2,900**	**1,800**	**1,250**
Overnight Cost (*k*)	$M	**$1,892**	**$1,685**	**$1,189**	**$911**
Total Capital Invest Cost (*K*)	$M	**$1,892**	**$1,685**	**$1,189**	**$911**
Annual Capital Charge	$M	**$123**	**$110**	**$77**	**$59**
Staff Size (L)	people	**365**	**339**	**273**	**230**
Annual Fully Burden Salary	$k/yr	$120	$120	$120	$120
Annual Labor Cost	$M	**$44**	**$41**	**$33**	**$28**
Electricity Consumption	kWh/SWU	50	50	50	50
Electricity Price	$/MWh	$92	$92	$92	$92
Annual Electricity Cost	$M	**$16**	**$13**	**$8**	**$6**
Annual Materials Cost	$M	**$19**	**$17**	**$12**	**$9**
Annual Total Costs	$M	**$201**	**$181**	**$130**	**$102**
Levelized SWU Cost (*AC*)	$/SWU	**$59**	**$62**	**$72**	**$81**

Table III. Levelized SWU Costs, Existing Centrifuge Capacity (Russia)
(2.5% cost of capital, 4.78% Capital Recovery Factor, +0% IDC, 0% Contingency)

Firm		**Rosatom**	**Rosatom**	**Rosatom**	**Rosatom**
Facility	(2006 $)	**Novouralsk**	**Zelenogorsk**	**Seversk**	**Angarsk**
Plant Capacity (in millions)	k SWU/yr	**9,000**	**5,000**	**3,000**	**2,000**
Overnight Cost (*k*)	$M	**$3,851**	**$2,507**	**$1,727**	**$1,284**
Total Capital Invest Cost (*K*)	$M	**$3,851**	**$2,507**	**$1,727**	**$1,284**
Annual Capital Charge	$M	**$184**	**$120**	**$83**	**$61**
Staff Size (L)	people	**571**	**436**	**345**	**286**
Annual Fully Burden Salary	$k/yr	$60	$60	$60	$60
Annual Labor Cost	$M	**$34**	**$26**	**$21**	**$17**
Electricity Consumption	kWh/SWU	50	50	50	50
Electricity Price	$/MWh	$46	$46	$46	$46
Annual Electricity Cost	$M	**$21**	**$12**	**$7**	**$5**
Annual Materials Cost	$M	**$39**	**$25**	**$17**	**$13**
Annual Total Costs	$M	**$277**	**$183**	**$127**	**$96**
Levelized SWU Cost (*AC*)	$/SWU	**$31**	**$37**	**$42**	**$48**

Table IV. Levelized SWU Costs, Existing Diffusion Capacity (U.S. and France)
(2.5% cost of capital, 4.78% Capital Recovery Factor, +0% IDC, 0% Contingency)

Firm		**USEC**	**Areva**
Facility	(2006 $)	**Paducah**	**Eurodif**
Plant Capacity (in millions)	k SWU/yr	8,000	11,300
Overnight Cost (*k*)	$M	**$3,534**	**$4,547**
Total Capital Invest Cost (*K*)	$M	**$3,534**	**$4,547**
Staff Size (L)	people	**541**	**635**
Annual Fully Burden Salary	$k/yr	$120	$120
Annual Labor Cost	$M	**$65**	**$76**
Electricity Consumption	kWh/SWU	2,500	2,200
Electricity Price	$/MWh	$46	$46
Annual Electricity Cost	$M	**$1,300**	**$1,093**
Annual Materials Cost	$M	**$35**	**$45**
Annual Total Costs	$M	**$1,569**	**$1,432**
Levelized SWU Cost (*AC*)	$/SWU	**$137**	**$130**

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Reforming the Nuclear Fuel Cycle: Time Is Running Out

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Fiona Simpson

Revelations earlier this decade about Iran's clandestine nuclear activities reignited global concerns that the spread of such sensitive fuel-cycle technology would lead to nuclear weapons proliferation. In a 2003 *Economist* op-ed, International Atomic Energy Agency (IAEA) Director-General Mohamed ElBaradei proposed that the time was right to re-examine multilateral approaches to the nuclear fuel cycle.[1]

Similar studies had already been undertaken in the 1970s and 1980s but had not produced concrete results.[2] Nonetheless, states responded with a plethora of proposals aimed at thwarting the unchecked spread of uranium-enrichment and spent fuel reprocessing technologies, for example, by suggesting means of assuring nuclear fuel supplies and establishing international nuclear fuel-cycle centers.

In June 2007, ElBaradei catalogued these proposals in the report "Possible New Framework for the Utilization of Nuclear Energy," delivered to the agency's Board of Governors. The report, which remains restricted, was designed to be of help to the board in considering the issue at a subsequent meeting, and ElBaradei later indicated that he was turning over the responsibility for leading the discussion to the IAEA's member states.[3] Subsequently, the Board of Governors has apparently not formally discussed any of the proposals, although about a half dozen of them have been refined during the year that followed. ElBaradei himself sees attaining credible assurance of supply as part of an ambitious multilateral effort that would culminate in all new, and then all existing, enrichment and reprocessing facilities being placed under multilateral control.

The next six months are likely to prove critical in determining whether any of these proposals becomes a genuine blueprint for a new approach to this issue or whether, like similar efforts three decades ago, they simply gather dust.

A Dozen Proposals

Twelve proposals were put forward by the time of the 2007 IAEA board report. They have been summarized elsewhere, including in a list extracted from the board report,[4] and are recapped briefly below before

turning to focus on those proposals that have been developed further. In addition, another possible new framework is noted that attempts to include, or to lend itself to incorporation by, many of the existing proposals.

As they stood in June 2007, the proposals varied widely. They included plans to establish a fuel bank, a fuel cycle center, or fuel services program; to initiate a mechanism providing different levels of supply assurances, a concept that also, in practice, incorporated the fuel bank idea; or to support these other proposals.

The creation of an independent fuel bank not linked to any particular fuel-cycle center option or other assurance of supply mechanism characterized two of the proposals, one made by the United States and the other by the nongovernmental Nuclear Threat Initiative (NTI). The U.S. proposal, as announced in September 2005, committed the United States to downblend 17.4 metric tons of highly enriched uranium (HEU) to low-enriched uranium (LEU), which would be made available to qualifying countries, i.e., those not presently pursuing indigenous enrichment or reprocessing technologies.[5] The NTI proposal, put forward a year later, comprised an offer of $50 million to allow the IAEA to create an LEU stockpile, which would be owned and managed by the agency. The release of the NTI funds would occur providing that, within two years, i.e., by the end of September 2008, the IAEA had taken the necessary steps to establish the reserve and an additional $100 million had been provided by member states, whether in funds or in an equivalent value of LEU.

A slightly different interpretation of the nuclear fuel bank idea was contained in the proposal by Austria in May 2007, which was more conceptual in nature and less of a "fuel reserve" than those envisioned by the NTI and the United States. Rather than establishing a bank simply as a storage site for a reserve of fuel, Austria suggested a two-track mechanism. The first would see states declare, to the IAEA and to each other, all existing nuclear programs, development plans, and activities and all transfers of nuclear material, equipment, and related technologies. The second track would place all nuclear fuel transactions and, eventually, enrichment and reprocessing facilities and nuclear fuel supply under the auspices of a Nuclear Fuel Bank.[6] ElBaradei himself has long believed and frequently stated that credible assurances of fuel supply should be the first step of an ambitious multilateralization effort, which would culminate in all enrichment and reprocessing being placed under multilateral control.

Broader efforts to establish a fuel cycle center or a consortium for fuel services lay at the heart of a U.S. proposal for the Global Nuclear Energy Partnership (GNEP); a Russian plan for a system of international enrichment centers, the first example being the International Uranium Enrichment Center at Angarsk; and a German proposal for a Multilateral Enrichment Sanctuary Project (MESP).

The GNEP idea was perhaps the most ambitious. As initially proposed, it contained both domestic and international components and technological as well as policy dimensions. Internationally, the program focused on the provision of reliable fuel services, especially the possibility of fuel leasing, where providers would be responsible for dealing with spent fuel. Technologically, the program emphasized the development and deployment of more advanced nuclear power reactors and, more controversially, the use of new spent fuel reprocessing technologies said to be more "proliferation resistant" than current methods because they would not produce pure separated plutonium.[7]

The Angarsk concept, like GNEP, was already well on the way to being realized by the time of the June 2007 board report. The proposal itself existed in two parts: a fuel cycle (enrichment) center and a fuel bank. By the time of the 2007 report, the Russian Duma had already approved enabling legislation that would grant participating countries the right to partake financially in the facility. In addition, Russia was also exploring a means through which a separate LEU stockpile could be set aside under IAEA safeguards and for the use of IAEA member states.

The German proposal favored the creation of a multilateral enrichment center under IAEA control and supervision and on a site that had been granted extraterritorial status. Under the MESP framework, the center would be a new entrant into the enrichment services market and could be established by a group of interested states.

The tiered approach to multilateralizing the fuel cycle characterized the ideas put forward by the World Nuclear Association (WNA), the industry trade group, and the Concept for a Multilateral Mechanism for Reliable Access to Nuclear Fuel, often known as the RANF proposal or the Six-Country Concept.[8] Both proposals envisioned the first, or "basic," assurance of supply mechanism as being the existing and normally operating market. The WNA proposal suggested that a second level of assurance could be provided by "collective guarantees by enrichers, supported by governmental and IAEA commitments."[9] Similarly, the RANF mechanism envisioned a second layer of assurance being offered by suppliers of enriched uranium agreeing to substitute for each other to cover certain supply interruptions.[10] A final, third layer of assurance in both proposals incorporated the fuel bank concept by suggesting governmental creation of enriched uranium stocks, either virtual or physical.

Finally, several of the proposals were intended to be supplementary to other efforts. The British proposal for an enrichment bond suggested a means of assuring states that if they met certain IAEA-determined criteria, they would be guaranteed enrichment services by national providers and would be provided with prior consent for export assurances.[11] The Japanese proposed increased transparency by way of an database, managed and dispersed by the IAEA and comprising information voluntarily provided by states on capacities for uranium ore, reserves, conversion, enrichment, and fuel fabrication.[12] In addition, the European Union submitted a nonpaper to the IAEA Secretariat and the 2007 nuclear Nonproliferation Treaty (NPT) Preparatory Committee (PrepCom) meeting.[13] Its inclusion among the other proposals is something of a misnomer, however, because rather than proposing a stand-alone mechanism, the nonpaper instead offered a list of criteria by which such mechanisms could be evaluated.

Refining the Proposals

Several of the proposals have undergone substantial further development since the June 2007 ElBaradei report. U.S. contractors have begun downblending the 17.4 tons of former military HEU, which Washington had pledged. This process is expected to yield 290 tons of LEU by the time the effort is completed in 2010. In addition, the potential consumer base for the fuel has been broadened, with U.S. companies also being permitted to buy fuel in the event of supply disruption, rather than it only being available internationally and to countries that are not pursuing enrichment or reprocessing. The United States would make the fuel available at the prevailing market price.[14]

The NTI offer of $50 million to establish an LEU reserve under IAEA auspices has made some notable progress over the past year. Although the required full amount of $100 million has not yet been raised, Congress pledged one-half ($50 million) to be allotted to this fuel bank and, as of August 4, 2008, had issued a letter officially donating the funds.[15] In addition, Norway has made a $5 million contribution, and it was recently announced that the United Arab Emirates (UAE) had pledged a further $10 million.[16] This leaves $35 million dollars still to be raised in order to meet the first of the NTI's conditions and, in turn, leaves the IAEA not yet able to meet the second condition and take the steps necessary to establish the reserve. ElBaradei has decided not to approach the IAEA Board of Governors for a decision until all funding has been pledged.[17] At that point and given that the NTI has indicated that it expects the IAEA to agree on a set of release criteria for the material, the fuel bank would become part of a broader and yet more complicated discussion in the board on terms and conditions for use.

The NTI proposal is the only one made in the context of an official deadline, originally requiring that both

conditions be met by the end of September 2008. At the request of the IAEA director-general and with the consent of the NTI, the deadline has now been extended to September 2009, which provides something of a cushion. Still, it is difficult to imagine that the money would be indefinitely earmarked, either by the NTI or by donor states, in the absence of other funds being raised, and thus some pressure would need to be brought to bear on other states to contribute funds toward the bank as soon as possible.

The GNEP proposal has also forged ahead, although not without setbacks and changes. GNEP was to be a consortium of nations with advanced nuclear technologies that would establish supply arrangements to provide nuclear fuel to and take back spent fuel from other participants. The GNEP International Partnership was established in September 2007, and GNEP countries soon thereafter established a steering group. That group then established two working groups, one of which was tasked with exploring reliable nuclear fuel services and making recommendations on practical measures in this regard.[18] The first meeting of this working group took place in April 2008. The proposed measures and the summary of work undertaken were to be summarized in a report to the GNEP Steering Group in May 2008 and to the partnership's ministerial-level Executive Committee in October 2008.

However, GNEP has encountered difficulties internationally and domestically. Internationally, the United States shelved initial plans to require countries that joined the partnership to forswear enrichment and reprocessing. Instead, the United States has chosen to rely on a set of other bilateral incentives, such as help with financing, infrastructure, and workforce issues, as levers to convince countries to sign a bilateral memorandum of understanding (MOU) pledging to rely on the global nuclear fuel market instead of developing sensitive technology. For example, during the first half of 2008, three of the six states of the Gulf Cooperation Council (Bahrain, Saudi Arabia, and the UAE) signed MOUs with the United States. A draft MOU between the United States and Qatar, presumably with a similar undertaking on the part of Qatar, is currently under consideration. Although U.S. officials express hope that other suppliers, such as France, will follow their lead, Paris has made no explicit commitment to do so.

Domestically, since the Democrats gained control of Congress in 2007, the program has seen its funding cut on Capitol Hill and its effort limited to research. At the end of June, the House Appropriations Committee expressed its skepticism of GNEP in a very visible fashion, by "zeroing out" international fiscal year 2009 funding for the program and sharply curtailing funding for domestic research. In its report, the panel stated that the "initiative to reprocess spent nuclear fuel...undermines our Nation's nuclear non-proliferation policy."[19] With the Bush administration only months away from leaving office and the future of GNEP under a new administration by no means assured, GNEP is, as one recent article has observed, in "limbo."[20]

Nonetheless and almost contradictorily, efforts at expanding GNEP are continuing, with invitations soon to be extended to 25 countries to join the partnership. To be sure, joining GNEP merely requires a state to sign the partnership's Statement of Principles, which is not legally binding. Nor are any sort of financial "dues" required to join the club, so a simple expansion of the membership is less indicative of GNEP's health than it might otherwise appear.

Russia's proposed international enrichment center at Angarsk was legally established in September 2007 as a joint stock company. By the time shares were issued in November 2007, a deal had already been signed with Kazakhstan, which purchased 10 percent of the shares. At that time, Armenia indicated its interest in joining, a step that was taken through an exchange of notes in February 2008. In order to address concerns regarding the spread of technology, the International Uranium Enrichment Center (IUEC) will be structured ("black-boxed") in such a way that no access to enrichment technology or classified knowledge will be accessible to the foreign participants. Traditionally, black-boxed technology has been in place in cases where the host state is to be prevented from accessing the technology. Russia, for instance, constructed a black-box centrifuge plant for China in 1995. In such cases, the obvious concern stems from a possible takeover of the facility by

the host state. The fact that the host state is, in this case, also the technology holder allows this concern to be assuaged, although it still remains to ensure that physical access to the technology and know-how is nonetheless restricted and that the black box is indeed opaque. Any IAEA member state that also meets "the established nonproliferation criteria" is eligible to participate in the IUEC, although it has previously been indicated that members should also not be "envisaging the development of indigenous sensitive nuclear technology."[21]

In December 2007, the Russian government took the decision to include the nuclear material in the enrichment center in the list of facilities it is willing to submit to IAEA safeguards. Safeguards are also to be applied to the 120-ton LEU stockpile that is to be set aside, separately, as a fuel bank in the event of a supply disruption for political reasons unrelated to nonproliferation. Although an agreement between the IAEA and Russia on the safeguards arrangements was originally expected to be concluded in the first half of 2008,[22] such an agreement has not yet been finalized and appears likely to be held up for at least another few months. It is therefore likely to land on the board's plate while the future of the NTI proposal and GNEP are likewise coming to a head.

The German proposal for a multilateral enrichment center is also being actively pursued. Such efforts followed an initial delay, which was apparently the consequence of internal disagreements. Germany made a presentation at the IAEA in February 2008, which gave further details regarding the proposal, and the German government also initiated and ultimately co-hosted a conference in Berlin in April 2008 with the Netherlands and the United Kingdom on nuclear fuel assurances. At that time, it was noted that the three states also stood ready to undertake further development of the enrichment bond concept.

The proposal, as developed thus far, has recommended that the host country for such a center should not already possess enrichment capabilities. Although the IAEA would have responsibility for oversight of such a center, the MESP idea also wisely confers responsibility for day-to-day management and operation of the center to a private firm rather than to an international organization. The IAEA also would not have any other means of access to sensitive technology or know-how.

One of the most difficult aspects of the MESP idea is finding a host country. In addition to requiring that the country is not already a current supplier of enrichment services, the MESP proposal also notes the need for the host country to have a suitable infrastructure and political stability, adhere to safeguards agreement, and be in good standing with the NPT. It is not yet clear how difficult it will be to find a willing host and, once found, how acceptable that host country will be to possible participants in the center.

Of all the proposals made, however, the MESP concept is perhaps the most explicitly welcoming to all interested parties, including those who might wish to develop an indigenous enrichment technology, by noting that they would "remain free" to do so if they so chose "and circumstances require."[23] This inclusiveness is sure to increase the appeal of the MESP idea, particularly to states who have long been concerned that participation in multilateral ventures was dependent on not pursuing indigenous enrichment and reprocessing activities. It remains unclear, however, whether the "circumstances required" for states to explore their own capabilities while participating in the center will be identified or formalized in any way. If so, this might be viewed as limiting the MESP's apparent inclusiveness. If not, such inclusiveness might then come at the expense of the proposal's nonproliferation value.

A working paper, providing still more detail on the MESP idea and suggesting next steps for this and other proposals, may be presented by Germany to ElBaradei in September 2008. This would serve to provide an interesting backdrop to the NTI-GNEP-Angarsk developments.

Another Possible Framework

Finally, another framework that makes use of the three-layer approach contained in the WNA proposal and Six-Country Concept has been noted. Like the others, the first level of such a mechanism is simply the current market and its existing supply arrangements. The second level, again much like that suggested by the WNA and in the Six-Country Concept, would be based on the existence of backup commitments that would be undertaken by suppliers and the relevant governments of enrichment services and of fuel fabrication. In the event of any failure in the current market and assuming that the IAEA director-general considered that certain predetermined criteria were met, this second layer of assurance would be enacted. As a final guarantee, a third level consisting of a physical or, more likely, a virtual LEU fuel bank could be created. Under this framework, which would be open to all IAEA member states, the LEU reserve would be stored "in one or several separate locations and made available to consumer states through a set of arrangements and agreements, involving the IAEA and supplier states and companies."[24]

Selected Remaining Issues

Several of the proposals made on fuel assurances foresee the IAEA's involvement in deciding when services may be supplied or fuel from a fuel bank released. It is often assumed that criteria would be agreed on in advance by the Board of Governors and that the director-general would therefore, at the time of the request, need only to approve it on the basis of whether it met or failed to meet these criteria. This would seem to be the only way that potential recipients could have confidence that the supply they require would be timely and would not be waylaid by debate in the board. It follows that, as ElBaradei has stated, such criteria would have to be "non-political" and "applied in a consistent and objective manner."[25] This would allow the director-general to check the request against the list of conditions for release, which would proceed as a last-resort supply in the event of denial of services for political reasons not related to proliferation concerns.

Conditions agreed to in advance would likely require that the consumer state be in good standing with its IAEA safeguards obligations, as indicated in the agency's Safeguards Implementation Report. Whether the state would have to have been in good standing for only the most recent year or for a predetermined number of previous years would also need to be agreed. Naturally, safeguards would be applied to the material supplied.

Those safeguards, however, would almost certainly not include the 1997 Model Additional Protocol, which provides further legal authority beyond the required NPT safeguards agreement, allowing the IAEA to draw conclusions regarding the absence of undeclared nuclear materials and activities. After all, the additional protocol remains voluntary, and until the Board of Governors takes a decision to the contrary, many states feel strongly that the protocol should not be required as a criterion for supply. This does not sit well with some other states, who not only support the universalization of the protocol, but who may have domestic legislation in place requiring a recipient state to have an additional protocol in place as a condition of bilateral supply. Whatever conditions are proposed, perhaps the only sure conclusion is that the agreement of nonpolitical advance criteria in a forum that has become increasingly political over the past few years will be a difficult task.

Such politicization has been reflected in the concerns and suspicions regarding eligibility criteria. The questions of which states are able to participate and what, if anything, those states would have to give up in order to do so have been a running theme in the discussions. As initially introduced, several of the proposals, such as the Six-Country Concept and GNEP, were understood to place requirements on potential consumers not to pursue indigenous enrichment or reprocessing activities. This triggered fears that the current supplier countries were attempting in effect to establish a cartel, despite the fact that, as stated by South Africa, some nonsupplier states "might choose to pursue sensitive fuel cycle activities in a limited way or only for research activities."[26] Although efforts have been taken by the supplier states to assuage these concerns, many other states, some of whom, Brazil and Japan, for instance, have expressed interest in eventually being suppliers

themselves, retain their misgivings and continue to be concerned that multilateral approaches to the fuel cycle might serve to curtail their Article IV rights under the NPT to the research, development, production, and use of nuclear energy for peaceful purposes. It remains to be seen whether this skepticism can be overcome.

The ability of fuel assurance mechanisms to address the back end of the fuel cycle and, in particular, to resolve the issue of spent fuel is also a cause for concern. The return of spent fuel is traditionally a controversial idea, being politically and often legally difficult. Accordingly, the establishment of regional or international spent fuel storage or disposal facilities has proved to be a tough sell. A mechanism that provides for a take-back of spent fuel, however, would certainly hold greater appeal to states whose nuclear power programs are in their early stages. It would also provide greater nonproliferation assurance against the possibility of reprocessing the spent fuel for plutonium. The taking back of spent fuel to the country of origin is actually envisioned under GNEP, and unsurprisingly, this aspect of the proposal has proven to be one of its more controversial elements among such GNEP members as Australia and Canada, its nonproliferation benefits notwithstanding.

Conclusion

More than a year has now passed since the report to the Board of Governors. Although the likelihood of successfully implementing a multilateral approach to the nuclear fuel cycle is by no means assured, recent events have indicated that greater progress to this end has already been made than was possible during the 1970s and 1980s. In terms of assurance of supply, however, it appears that the remaining months of 2008 will be indicative of how much the proposed mechanisms will be able to accomplish in practice.

The ultimate goal of the exercise envisioned by the director-general, of all enrichment and reprocessing activities being under multilateral control one day, seems a longer-term prospect to say the least and remains deeply unpalatable to many states for the time being. Although the complementarity of the proposals is often noted, the MESP and NTI ideas (and supported by the enrichment bond principle), hold a vision of an IAEA-administered fuel-cycle center or fuel bank that, of all the proposals that have been refined over the past year, is perhaps the most in keeping with the spirit ElBaradei's long-term vision. If attained, they would serve as an important departure from the traditional approach to enrichment and reprocessing.

Nonetheless, several significant hurdles remain. The sponsors of these proposals currently appear to have the necessary political will to push them forward, although this will be not be sufficient without the concomitant political will on the part of other IAEA member states. The momentum that has been generated on fuel assurances and on multilateral approaches to the nuclear fuel cycle cannot be sustained indefinitely. The recent UAE contribution of $10 million to the NTI fuel bank is an encouraging sign, as is the extension of the deadline. The safeguards approach to Angarsk is apparently soon to be agreed, albeit nearly a year later than originally expected. There are indications that the MESP proposal may soon be put forward for formal discussion.

Still, GNEP is suffering from funding difficulties. The director-general who revived and argued in favor of the new fuel-cycle arrangements will soon head into the final year of his tenure. More than a year has now passed since the June 2007 report to the Board of Governors identified the board as the appropriate forum for the next considerations of the issue. If the board does not take up the discussion soon, whether because sufficient funding has been raised for the fuel bank or on the basis of draft agreements or release criteria suggested by member states, it seems increasingly possible that the project will go the way of those that preceded it, 30 or so years ago.

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Unfinished Business for the NSG

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- India
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- Nuclear Suppliers Group
- Focus Editorial

Daryl G. Kimball

In an unprecedented move that will undermine the value of the Nuclear Suppliers Group (NSG) and the already beleaguered nuclear Nonproliferation Treaty (NPT), the NSG reluctantly agreed Sept. 6 to exempt NPT holdout India from its guidelines that require comprehensive international safeguards as a condition of nuclear trade.

The decision is a nonproliferation disaster of historic proportions that will produce harm for decades to come. It severely erodes the credibility of global efforts to ensure that access to nuclear trade and technology is available only to those states that meet global nuclear nonproliferation and disarmament standards. India does not.

Furthermore, foreign supplies of nuclear fuel to India's civil nuclear sector will reduce or eliminate India's need to sacrifice electricity production to produce weapons-grade plutonium. This would enable India to increase the rate of fissile material production for bombs and worsen nuclear arms competition in Asia.

Compounding the error, the Bush administration rebuffed efforts by a group of responsible NSG states to incorporate into their decision provisions in U.S. law that severely restrict transfers of sensitive nuclear fuel-cycle technologies to India and mandate a cutoff of nuclear trade if India resumes nuclear testing.

When the NSG meets again in November, the United States and other participating governments will have an opportunity to close one of the loopholes of their India-specific exemption: barring the transfer of uranium-enrichment and spent fuel reprocessing technologies to states that have not joined the NPT or agreed to an additional protocol to their safeguards agreement, which gives international inspectors broader authority.

Tougher NSG standards on sensitive fuel cycle technologies are long overdue. In India's case, enrichment and reprocessing cooperation could actually help its nuclear bomb production program because international safeguards cannot prevent the replication or use of such technologies for weapons purposes.

In practice, it is unlikely that suppliers will transfer enrichment or reprocessing technology to India anytime soon. The NSG waiver for India maintains that NSG states must continue to "exercise restraint" with respect to transfers of sensitive dual-use technologies and enrichment and reprocessing technologies to India or any other state. And, according to the Bush administration, no NSG participating government intends to transfer

enrichment or reprocessing technology to India. Yet, India continues to demand "full" access to the nuclear fuel and technology market, and supplier states intentions could change, especially if they smell a profit.

Before agreeing to consider the U.S.-Indian nuclear cooperation agreement last month, the House and Senate should have demanded that the United States win support for tougher NSG guidelines on enrichment and reprocessing transfers. Under heavy political pressure to rush the flawed deal through, they failed to do so.

In exchange for quick House approval of the India agreement, however, Secretary of State Condoleezza Rice acknowledged the NSG loophole in a personal commitment to Howard Berman (D-Calif.), chair of the House Committee on Foreign Affairs. Rice promised that the United States will make its "highest priority" to achieve a decision at the next NSG meeting to prohibit the export of enrichment and reprocessing equipment and technology to states that are not party to the NPT.

NSG discussions on the matter predate the proposal for opening nuclear trade with India and are ripe for a decision. In 2004 the United States proposed a complete ban on sensitive fuel-cycle technology transfers to states without such capabilities. Many NSG states objected and suggested a criteria-based approach, but the United States said no.

Just ahead of the May 2008 NSG meeting, the United States adjusted its position and threw its support behind a proposal that would bar enrichment and reprocessing technologies to states that:

- have not signed the NPT;
- have not agreed to an additional protocol to their International Atomic Energy Agency safeguards agreement;
- are not in compliance with their NPT or safeguards obligations; or
- are located in regions in which such transfers might promote proliferation or undermine security.

However, Washington also demanded that if enrichment or reprocessing transfers do occur, they should be executed only via "black box" technologies, wherein only the supplier can access and own the technology. Canada opposed this provision, thereby blocking consensus on the package.

If Washington and Ottawa can resolve their differences and if Brazil can be prevailed on to drop its misguided opposition to the additional protocol criterion, the NSG can adapt tougher enrichment and reprocessing transfer guidelines. This would plug one of the gaping holes in the September NSG waiver for India and ensure that other suppliers are more in line with U.S. policy.

The Bush administration must now follow through and rally NSG support for tougher NSG guidelines that would help mitigate some of the damage caused by the waiver for India.

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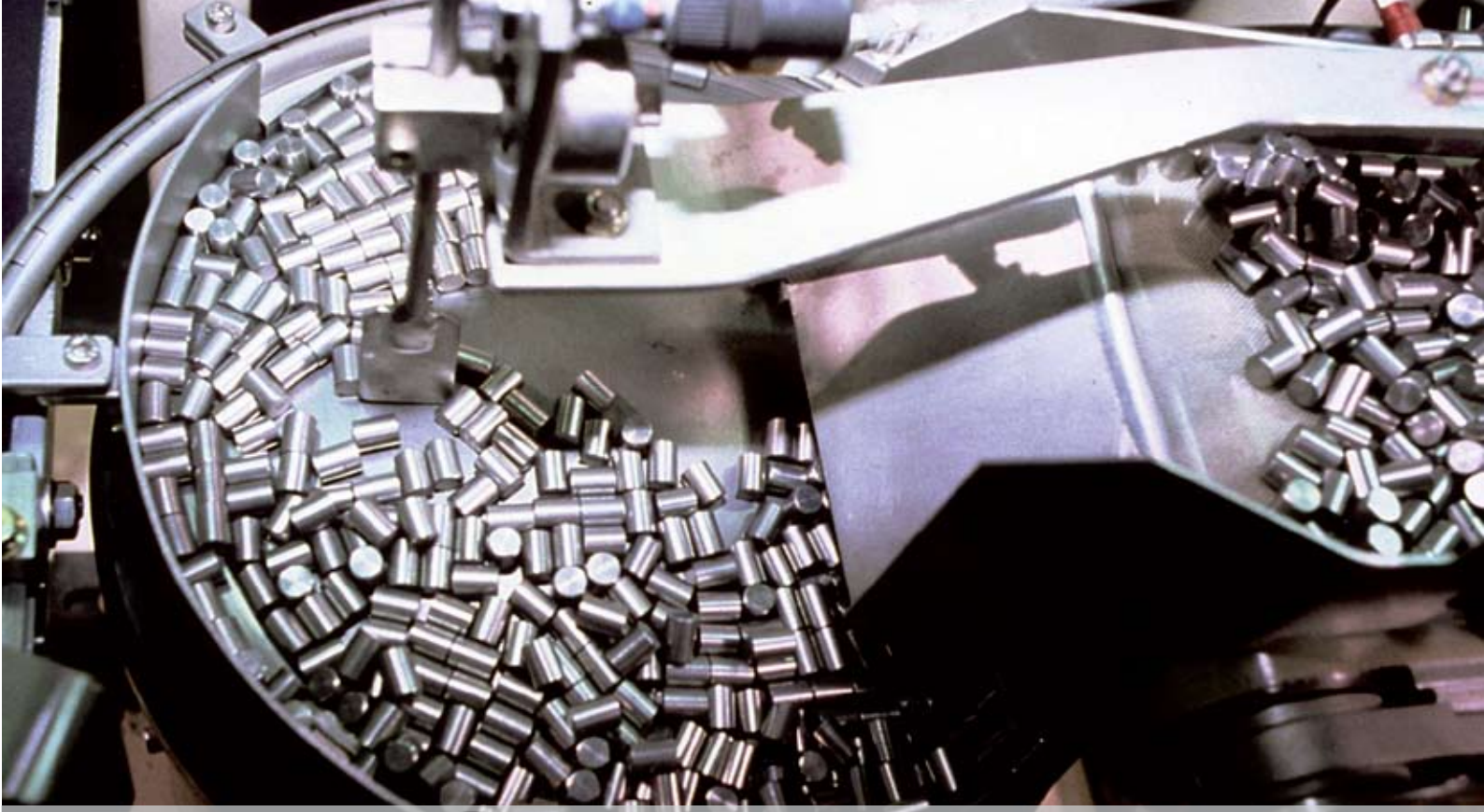

Fuel for Thought

by Tariq Rauf and Zoryana Vovchok

A multilateral approach to the nuclear fuel cycle would help cope with the expected expansion of nuclear power use and strengthen the nuclear non-proliferation regime.

The increase in global energy demand is driving a potential expansion in the use of nuclear energy and over the last few years there has been a growing interest in the possible development of a new, multilateral approach to the nuclear fuel cycle. This is widely believed to be a key measure to cope with the expected expansion of nuclear power use and, at the same time, strengthen the nuclear non-proliferation regime.

The establishment of a new framework that is equitable and accessible to all users of nuclear energy acting in accordance with agreed nuclear non-proliferation norms would be a complex endeavour that needs to be addressed through a series of interlinked, progressive steps.

The first step would be to establish mechanisms for assurances of supply of fuel for nuclear power reactors — and, as needed, assurance of supply for the acquisition of such reactors. The second step would be to have future enrichment and reprocessing through multilateral operations. The third step would be to convert existing enrichment and reprocessing facilities from national to multilateral operations. In this context, it will be crucial to negotiate and implement a global, internationally verifiable treaty on the prohibition of fissile material production for nuclear weapons (FMCT).

Photo: Nuclear fuel pellets in production.
Credit: Melox

IAEA Special Event

There are, at present, 12 mutually complementary proposals for a multilateral approach to the nuclear fuel cycle that have been put forward. The scope of these proposals ranges, inter alia, from providing backup assurances of supply to establishing an IAEA-controlled low enriched uranium (LEU) reserve and to setting up international uranium enrichment centres.

At the IAEA General Conference in September 2006 a special event on a new framework for the nuclear fuel cycle to focus on the existing proposals took place. Experts from many States and from all relevant fields discussed ways and means to move forward.

The summary of the report on the special event, submitted to the 2006 IAEA General Conference mentioned, in part, that the recent proposals for assuring supplies of uranium-based nuclear fuel can be seen as one stage in a broader, longer-term development of a multilateral framework that could encompass assurance-of-supply mechanisms for both natural fuel and LEU, as well as nuclear fuel and spent fuel management. In this context, establishing a fully developed multilateral framework that is equitable and accessible to all users of nuclear energy is a key consideration for the IAEA and its Member States.

The summary also pointed to why an assurance of supply mechanism is needed. This could address two specific challenges. The first is to deal with the possible consequences of interruptions of supply of nuclear fuel due to political considerations that are not related to non-proliferation and not related to commercial or other aspects in terms of fulfillment of contractual obligations. Such interruptions might dissuade States from initiating or expanding nuclear power programmes. At the same time, such a mechanism would reduce the vulnerabilities that might create incentives for States to build new national enrichment and reprocessing capabilities, rather than opting for reliance on the international nuclear fuel market and supply assurances.

Déjà vu all over again

More than fifty years after the 1953 Atoms for Peace initiative, the time has come not only to think of but to implement a new framework for the use of nuclear energy — a framework that accounts for both the lessons learned and the current realities. This new framework potentially could include: innovative nuclear technology that is inherently safer, proliferation resistant and more economical; universal application of comprehensive safeguards and the additional protocol; concrete and rapid progress toward verified nuclear disarmament; a robust international nuclear security regime; and an effective and universal nuclear safety regime.

The Baruch Plan of 1946 eerily warned that "Behind the black portent of the new atomic age lies a hope, which seized upon with faith can work our salvation... Science has torn from nature a secret so vast in its potentialities that our minds cower from the terror it creates. Yet terror is not enough to inhibit the use of the atomic bomb. The terror created by weapons has never stopped man from employing them." Baruch envisioned an internationalization of the nuclear fuel cycle that was ahead of its time. Three decades later, the 1976 International Nuclear Fuel Cycle Evaluation (INFCE) considered multilateral approaches to the nuclear fuel cycle but could not agree on the way forward. Another 30-years later, in 2006, the IAEA special event fostered discussion on assurances of enrichment services, international fuel centres and multilateral control over all fuel cycle facilities and paved the way for further action.

In the global discussion on clean energy options, there is now increasing talk about a potential nuclear renaissance. For the past couple of decades, some 16% of the world's energy has come from nuclear sources, and this percentage has remained relatively stable. But over the next couple of decades, the projections are that nuclear power capacity will increase. As the world's energy requirements increase exponentially, and the pressures of reducing carbon emissions become even more pressing on governments, there is expected to be an increasing reliance on 'clean' nuclear energy. Furthermore, if there is to be this nuclear renaissance, there will be a major new demand for nuclear energy inputs, both in terms of reactors, but also in terms of fuel supply. The question then is where will the new nuclear fuel supply come from? Will it remain in the hands of the few existing suppliers who might then perhaps expand their capacity? Would new States develop their own national indigenous enrichment and reprocessing capabilities? The vision of a new framework is that all new enrichment and reprocessing should be exclusively under multinational control and eventually all such sensitive nuclear fuel cycle technologies are operated multilaterally together with an assurance of supply mechanism.

New Framework for the Nuclear Fuel Cycle

The main challenge now is to find a framework that draws upon the common elements of the existing proposals and thus outlines a possible framework for assurances of supply.

It has become abundantly clear that different States will choose different policies and solutions for their energy requirements. These will depend on their specific situation such as geography, technical abilities, national priorities and choices. Thus, in this context, it is of the utmost importance to retain flexibility and not try and suggest solutions that are

perceived to be imposed, particularly on the consumer States. This was made absolutely clear at the IAEA special event on the nuclear fuel cycle.

Hence, an assurance of supply mechanism would be envisaged solely as a backup mechanism to the operation of the current normally functioning market in nuclear materials, fuels, technologies and services. This would not be a substitute for the existing market, nor would it deal with disruption of supply due to commercial, technical or other failures. And in this context, an assurance of supply mechanism would be available to all States that abide by agreed nuclear non-proliferation norms. No State would be asked or expected to give up or abridge any rights under the nuclear Non-Proliferation Treaty (NPT) or the IAEA Statute.

A possible new framework for the nuclear fuel cycle can be established on three levels. The first level is the existing market, based on existing commercial and other arrangements. The second level would rely on backup commitments provided by suppliers of enrichment and fuel fabrication services and their respective governments to assure nuclear fuel supply in cases of political disruptions when predetermined conditions and criteria are met. This can be viewed as a combined virtual enrichment and fuel fabrication reserve mechanism. In the event that some States still might not be fully assured by the first two levels, a third level is essential. The third level would be a reserve of LEU stored in one or several separate locations and made available to consumer States through a set of arrangements and agreements, involving the IAEA and supplier States and companies. A virtual reserve based on supply guarantees, could also provide assurances of supply and would avoid the need to tying up LEU in a physical reserve. Extended assurances could include fuel fabrication services as well. All assurance of supply frameworks under the Agency's auspices should be open to participation by all Member States of the Agency on the basis of accepted criteria.

The release of material under any framework for the assured supply of nuclear fuel would be determined by criteria established in advance and applied in a consistent manner without prejudice to any State's future options regarding its fuel cycle in the context of multilateral approaches.

The framework would envision that once a request for supply is received from a consumer State experiencing a political supply disruption, the IAEA Director General would consider the request and decide whether it meets the established criteria. And, if the decision is positive, the supply framework would be triggered.

Possible criteria for a workable assurance of supply framework, though neither definitive nor exhaustive, could include: a disruption of supply for a political reason (as defined previously); a safeguards agreement in force that covers the material to be supplied; a conclusion drawn by the Agency for the consumer State on the non-diversion of declared nuclear material in the most recent available Safeguards Implementation Report (SIR); no safeguards issues relating to the consumer State under current consideration by the Board of Governors, in respect of the consumer State; and, other relevant criteria such as nuclear security and nuclear safety requirements based on applicable Agency standards. Such criteria would need to be agreed in advance and applied uniformly. States would continue to have the option of participating or not participating in the new framework without prejudice to their nuclear fuel cycle options.

As regards legal authority, under its Statute, the IAEA already has the required authority to provide fuel cycle related services to its Member States and has been assisting Member States upon request for many years through IAEA programmes. The IAEA therefore is in a position to facilitate an assurance of supply framework through international nuclear fuel centres and virtual or actual nuclear fuel banks.

The Way Forward

A multilateral approach to the nuclear fuel cycle has the potential to facilitate the continued and expected increased use of nuclear energy for peaceful purposes. It has the potential to provide the benefits of cost-effectiveness and economies of scale in the use of nuclear technologies. And, it also can provide additional assurance to the international community that the sensitive parts of the civilian nuclear fuel cycle are less vulnerable to misuse for non-peaceful purposes. Thus, nuclear energy, non-proliferation and economic considerations can coincide and be mutually reinforcing, while providing security of supply of nuclear fuel to consumer States.

The way forward points to consultations involving interested Member States, the nuclear industry and other stakeholders, on the common themes and the elements of multilateral approaches to the nuclear fuel cycle.

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12 Proposals

Over the past few years a number of proposals have been made regarding as

1. Reserve of nuclear fuel

USA. The USA announced in Vienna in September 2005, at the 49th regular session of the General Conference, that it would commit up to 17 metric tonnes of high enriched uranium (HEU) to be down-blended to LEU "to support assurance of reliable fuel supplies for states that forego enrichment and reprocessing".

(Ref: INFCIRC/659, September 2005)

2. Statement on the Peaceful Use of Nuclear Energy

Russian Federation. Vladimir Putin, President of the Russian Federation, outlined a proposal that included "the creation of a system of international centres providing uranium enrichment services, including enrichment, on a non-discriminatory basis and under the control of the IAEA".

(Ref: INFCIRC/667, February 2006)

3. Global Nuclear Energy Partnership (GNEP)

USA. One of the elements of GNEP is a proposed "fuel services programme to enable nations to acquire nuclear energy economically while limiting proliferation risks. Under GNEP, a consortium of nations with advanced nuclear technologies would ensure that countries who agree to forgo their own investment in enrichment and reprocessing technologies will have reliable access to nuclear fuel".

(Ref: "Department of Energy Announces New Nuclear Initiatives", USDOE, 6 February 2006)

4. Ensuring Security of Supply in the International Nuclear Fuel Cycle

World Nuclear Association. A working group, including representatives of the four principal enrichment companies, proposed a three-level mechanism to assure enrichment services:

(1) basic supply security provided by the existing world market;

(2) collective guarantees by enrichers supported by governmental and IAEA commitments; and

(3) government stocks of enriched uranium product.

(Ref: WNA Report, May 2006)

5. Concept for a Multilateral Mechanism for Reliable Access to Nuclear Fuel

France, the Federal Republic of Germany, the Netherlands, Russian Federation, UK and USA. The six enrichment services supplier States proposed essentially two levels of enrichment assurance beyond the normally operating market. At the "basic assurances" level suppliers of enriched uranium would agree to substitute for each other to cover certain supply interruptions to customers in States that had "chosen to obtain supplies on the international market and not to pursue sensitive fuel cycle activities". At the "reserves" level, participating governments could provide physical or virtual reserves of LEU that would be made available if the "basic assurances" were to fail.

(Ref: GOV/INF/2006/10, June 2006) (restricted access)

6. IAEA Standby Arrangements System for the Assurance of Nuclear Fuel Supply

Japan. Japan proposed an information system to help prevent interruptions in nuclear fuel supplies. The system, to be managed by the Agency, would disseminate information contributed voluntarily by Member States on their national capacities for uranium ore, uranium reserves, uranium conversion, uranium enrichment and fuel fabrication. The proposal is described by Japan as complementary to the concept of reliable access to nuclear fuel as proposed by the six countries and described under paragraph 5.

(Ref: INFCIRC/683, September 2006)

7. Nuclear Threat Initiative

The Nuclear Threat Initiative offered to contribute $50 million to the Agency to help create an LEU stockpile owned and managed by the Agency that could be made available should other supply arrangements be disrupted. The offer is contingent on the following two conditions being met within two years from when the offer was made:

(1) that the Agency takes the necessary actions to approve establishment of the reserve; and

(2) that one or more Member States contribute an additional $100 million in funding or an equivalent value of LEU.

Every other element of the arrangement — the structure, its location, the conditions for access —

fuel cycle c

On The Table

ssurance of supply and the establishment of international fuel cycle centres.

would be up to the Agency and the Member States to decide (In December 2007, the US Congress authorized a US$50million contribution, and in February 2008, Norway pledged $5million).
(Ref: NTI Letter, September 2006)

8. Enrichment Bonds
United Kingdom. The UK proposed a "bonding" principle that would, in the event that the Agency determines that specified conditions have been met:
(a) guarantee that national enrichment providers would not be prevented from supplying enrichment services; and
(b) provide prior consent for export assurances. Germany and the Netherlands are cooperating with the UK in the development of the enrichment bonds concept.
(Ref: INFCIRC/707, June 2007)

9. International Uranium Enrichment Centre at Angarsk
Russian Federation. Following adoption of the necessary enabling legislation in January 2007, the Russian Federation will establish an International Uranium Enrichment Centre (IUEC) at the Angarsk Electrolysis Chemical Combine "to provide guaranteed access to uranium enrichment capabilities to the Centre's participating organizations". On 10 May 2007 the first agreement in the framework of the IUEC was signed by the Russian Federation and the Republic of Kazakhstan.

A mechanism is being developed to set aside a stockpile of LEU which might contribute to a broader assurance of supply mechanism, and "a regulatory basis will be developed in the sphere of export control such that the shipment of material out of the country at the request of the Agency is guaranteed". (In June 2007, Russia offered to set up an LEU reserve of 120 MT under Agency auspices, and stored under safeguards at Angarsk, for use by IAEA Member States.)
(Ref: INFCIRC/708, June 2007)

10. Multilateralizing the Nuclear Fuel Cycle
Germany. Germany proposed the creation of a multilateral uranium enrichment centre with extraterritorial status, operating on a commercial basis as a new supplier in the market, under Agency control, providing enrichment services. From there, potential users could then obtain nuclear fuel for civilian use under strict supervision. Such a plant could also help assure the supply of enriched uranium to qualifying States (Germany has proposed a "Multilateral Enrichment Sanctuary Project" for an international enrichment centre established by a group of interested States, on an extra-territorial basis in a host State.)
(Ref: INFCIRC/704, May 2007)

11. Multilateralisation of the Nuclear Fuel Cycle
Austria. Austria proposed a two-track multilateral mechanism. The first track would "optimiz[e] international transparency going beyond current IAEA safeguards obligations". The second track would place all nuclear fuel transactions under the auspices of a "nuclear fuel bank" to "enable equal access to and control of most sensitive nuclear technologies, particularly enrichment and reprocessing."
(Ref: INFCIRC/706, May 2007)

12. Nuclear Fuel Cycle
European Union (EU). The EU non-paper noted that flexibility would be appropriate in considering an approach to fuel supply options and proposed criteria for assessment of a multilateral mechanism for reliability of fuel supply. These criteria included, inter alia:
a) proliferation resistance — minimization of the risk of unintended transfer of sensitive nuclear technology;
b) assurance of supply — reliability of long term supply arrangements;
c) consistency with equal rights and obligations — obligations of suppliers, companies, consumer States and the IAEA; and
d) market neutrality — avoiding any unnecessary disturbance or interference in the functioning of the existing market.
(Ref: EU non-paper, June 2007)

Note: This list is taken from GOV/INF/2007/11 which is a restricted access document.

centres

URENCO'S VIEWS ON INTERNATIONAL SAFEGUARDS INSPECTION

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ABSTRACT

The Urenco group has operated uranium enrichment plants, using the gas centrifuge process, for over thirty years in Europe. Throughout this whole period, the plants have been subject to a rigorous regime of safeguards inspection by Euratom – and since the late 1970's, the plants have been inspected by IAEA also. This paper describes the regime of inspection by international safeguards organisations at Urenco's enrichment plants. It also gives an insight into Urenco's views on this inspection regime and specifically touching following topics: the value of international safeguards to the nuclear industry; IAEA objectives in safeguarding gas centrifuge enrichment plants; the need to take account of safeguards requirements in the design of facilities; the secrets of success for new inspection techniques; the conflicts involved with the protection of sensitive technology; the meaning of effectiveness and efficiency; and future trends.

Key Words: centrifuge, enrichment, safeguards

Disclaimer: This paper expresses the views of Urenco and not necessarily those of the Troika governments.

INTRODUCTION

It is over 20 years since Urenco last gave a presentation[1] at the *International Conference on Facilities Operations - Safeguards* Interface. Much of that paper is still relevant today – but here I explain about what's happened over the last 20 years, give Urenco's views on the safeguards inspection regime and give our thoughts of the future of international safeguards. Whilst the focus of the paper is on international safeguards applied to uranium enrichment plants, some of the views are relevant to other types of facilities in the nuclear fuel cycle.

URENCO

Urenco operates uranium enrichment plants at three sites: Almelo in the Netherlands, Gronau in Germany, and Capenhurst in the UK. All of the plants use the gas centrifuge process for enrichment; all of them produce only low enriched uranium (LEU), currently at up to either 5 to 6% U235 enrichment. This is used only to make fuel for nuclear power stations. We do not make enriched uranium for military or defence uses.

Urenco also operates a small centrifuge facility at Almelo for separation of isotopes of elements other than uranium: the so-called stable isotopes production. Urenco also has a 50% stake, along with Areva, in the Enrichment Technology Company (ETC), which develops centrifuges, manufactures them, and builds plants. But this paper does not cover any of these areas.

In 1976, Urenco began commercial operations at Almelo (in the Netherlands) and Capenhurst (in the UK). In 1985, the site at Gronau (in Germany) started production. Urenco has increased capacity gradually every year. By end 2007, the capacity at all three sites combined had reached 9,600 tonnes of separative work (tSW). Urenco is also building the National Enrichment Facility (NEF) at Eunice in Lea County, New Mexico, USA – this will start production next year. By 2012 Urenco expects to have 15,000 tSW of capacity in operation.

SAFEGUARDS INSPECTION REGIME IN URENCO PLANTS

Urenco is very familiar with international safeguards, as all of our plants and all of the nuclear material held on the sites have been inspected for many years by two international safeguards organisations: the European Commission Nuclear Safeguards Directorate (Euratom), based in Luxembourg and carrying out inspection in Europe; and the International Atomic Energy Agency (IAEA), based in Vienna and carrying out inspection world-wide. Euratom began carrying out safeguards inspections on Urenco sites right back in the early 1970's when there were only small pilot plants. By 1979, IAEA joined the inspections, initially on an ad-hoc basis. Ever since then, inspections at the sites have been by a *joint team* consisting of both Euratom and IAEA inspectors.

From 1980 to 1983, Urenco participated in the *Hexapartite Safeguards Project* (HSP), involving Australia, Euratom, the IAEA, Japan, the USA and the "Troika" consisting of

Germany, the Netherlands and the United Kingdom (UK). This looked at how best to carry out safeguards inspections in centrifuge enrichment plants. When that was concluded, full scope safeguards inspections began at all Urenco sites, based on the principles of HSP, including access to cascade halls. *Facility attachment* agreements were concluded between IAEA, Euratom and our governments: these describe precisely the inspection regime taking place at our plants, and they are legally binding on Urenco.

Urenco's experience of international safeguards is immense. Urenco has calculated that between 80 and 90% of all the enrichment production in the world which has been subject to IAEA verification has been Urenco production. None of the plants of Urenco's major competitors (operated by Areva, USDOE/USEC and Minatom/Rosatom) have been subject to IAEA safeguards inspection (other than a small amount of production in the early 1980's in the fledgling centrifuge enrichment plant in USA). It is estimated that IAEA and Euratom have each carried out over 8,000 man-days of inspections on Urenco sites - that's over 16,000 man-days of inspections over the last 30 years. Urenco has seen more of IAEA nuclear safeguards inspectors than any other enrichment company in the world – and probably more than any other company.

TYPES OF SAFEGUARDS INSPECTIONS IN URENCO PLANTS

A *joint team* of Euratom and IAEA inspectors carries out the following inspections at each of the European sites (Almelo, Capenhurst and Gronau):

- Routine inspections, one week in every month, at which the main activity is the verification of flow: i.e. uranium hexafluoride (UF_6) newly received onto site, and newly produced enriched and depleted UF_6.
- An annual *physical inventory verification* (PIV), to verify the entire stock of nuclear material on site.
- *Design information verification* (DIV), to confirm that the plants are built in line with what has been declared in the *design information* documents submitted to the inspectorates: these DIVs are normally carried out once on a new plant and repeated up to once a year thereafter.
- *Limited frequency unannounced access* (LFUA) inspections, to verify that the cascade pipework has not been modified, for example to introduce feed points and product take-off points. These LFUAs take place inside cascade halls, several times each year.
- *Complementary access* visits, as required by the *additional protocol* agreements between our governments, Euratom and the IAEA. These are unannounced, and mainly take place at ETC locations adjacent to our plants. There are a few such visits per year.

SAFEGUARDS INSPECTION TECHNIQUES USED IN URENCO PLANTS

Most of the inspection activity concerns the verification of flow of nuclear material and the inventory of nuclear material on Urenco sites. Urenco submits inventory change reports and lists of inventory items, which are verified by inspectors as follows:

- checking the weights of cylinders, either with the inspectors' load cells or Urenco weigh scales, and at the annual inventory check on process plant station load cells,
- verifying the U235 enrichment of the UF_6 in the cylinders which are due to be used in the plants or have recently been produced, by non-destructive analysis (NDA) techniques, by hand-held gamma detectors of either germanium or sodium iodide crystal type,
- taking samples of UF_6 gas from cylinders, or sometimes from the gas flow in the plants, for analysis by mass spectrometry, and
- visually checking identity numbers of cylinders (on labels or nameplates), to make sure that the cylinders in stock are those that are declared.

Various types of seals are used: metal cap seals are used on cylinders and other equipment; for short-term use there are paper seals; on two plants, electronic seals are used in combination with camera surveillance, to ensure continuity of knowledge of on-line cylinders during the physical inventory verification.

Design information verification is carried out by visual observation: inspectors examine the process pipework and equipment to make sure that the plant is as declared, and look carefully inside cascade halls to make sure that cascades, pipework and connections are not modified to produce or take off *high enriched uranium* (HEU), which is defined by IAEA as having a U235 content of 20% or more.

Note that a fuller description of all of the above inspection measures is given in reference 1.

The inspectors use the *continuous enrichment monitor* (CEMO) on two Urenco plants. this equipment monitors the enrichment level in the gas in the product pipe as it is being produced, and is designed to give a rapid alarm signal direct to Vienna and Luxembourg if either HEU is detected or if the equipment is not working properly. CEMO has in the main operated reliably, but it has falsely indicated HEU on two occasions, to the consternation of Urenco and the inspectorates.

The *complementary access* visits to ETC centrifuge manufacturing and assembly areas mainly involve visual observation. These are aimed at making sure that there are no undeclared activities in these areas, such as carrying out enrichment production. Access to these areas is allowed carefully, to avoid compromising sensitive technologies.

ENVIRONMENTAL SAMPLING

The inspectors carry out e*nvironmental sampling* in Urenco plants: this is a technique which was introduced into safeguards in the mid 1990's. They take swipes many times each year at many locations, and these swipes are analysed in their analytical laboratories (IAEA Network and Seibersdorf) for the isotopic composition of uranic particles. *Environmental sampling* trials began in Urenco plants around ten years ago. These trials showed that the technique is immensely powerful, in that it detects all kinds of information about the enrichments produced – no matter whether such production had taken place recently or several years previously. An impressive example of the results that can be obtained by e*nvironmental sampling* was given in a paper to INMM in 2000[2]: this included the detection only two weeks after the start of production at a new, enrichment level. If Urenco were making HEU (of course, Urenco has no intention of doing so!), then there would be a very high chance of finding this out from *environmental samples*.

THE VALUE OF INTERNATIONAL SAFEGUARDS

Urenco really believes that the regime of international safeguards verification of the civil nuclear fuel cycle facilities and the nuclear material they use is very important for the world, for the following reasons:

- By reassuring the public: by demonstrating that civil nuclear programmes do not lead to the development of nuclear weapons.
- By helping international trade, because many countries will not buy uranium or nuclear fuel cycle services from countries which don't have international safeguards inspection, or will not sell to such countries. It seems clear that if one's nuclear plants are subject to international safeguards verification, then it increases the chance of doing business around the world.
- By helping the expansion of nuclear power worldwide. Many new countries are now thinking of building nuclear power stations and a thorough implementation of IAEA safeguards in all countries would assist that expansion.

IAEA SAFEGUARDS OBJECTIVES FOR CENTRIFUGE ENRICHMENT PLANTS

The IAEA has declared[3] that there are three objectives to be achieved in safeguarding a gas centrifuge enrichment plant (GCEP):

- To detect diversion of declared nuclear material. This is traditional safeguards, as defined in INFCIRC 153. Urenco completely agrees with this objective and considers that the inspectorates meet this objective extremely thoroughly.
- To detect production of enrichments higher than the declared maximum, in particular HEU. The last three words are the ones that really matter, as HEU can potentially be used for the manufacture of nuclear weapons. But this target, which was originally set by the *Hexapartite Safeguards Project* (HSP) in the early 1980's, is not just the detection of enrichments above 20% U235, it is also the detection of enrichments between the declared maximum (normally 5% U235) and 20% U235. In their recent re-appraisal[3], IAEA conclude that such misuse of

an enrichment plant is unlikely because it would have the disadvantages of both being open to detection in a declared plant and requiring further enrichment at an undeclared plant to produce HEU, and in any case this acquisition path would be covered by measures covering the three main paths. Urenco agrees with this reasoning. The wording of the objective should surely be revised, to make it clearer that it is just the detection of HEU production which is meant.

- To detect production using undeclared uranium. This objective is completely new in the IAEA model approach. The IAEA currently seems very excited about being able to detect undeclared enrichment production - using undeclared uranium. But Urenco can't understand why a proliferator would ever want to do that. If I wanted to produce HEU for nuclear weapons, why should I make secret LEU in a plant under the spotlight of IAEA, and then further enrich this in a completely separate, but secret enrichment plant? That doesn't make sense at all, since this is far too complicated, and there would be two opportunities for the IAEA to discover this. It would be far simpler to just enrich secret supplies of uranium in a secret plant. There would be less chance of being found out.

DESIGN OF PLANTS

Urenco believes that any new nuclear plant built should take account of the requirements of IAEA safeguards, preferably when it is being designed, i.e. before it is built. This is no problem for an operator like Urenco, with established plants and an established inspection regime. Urenco thinks its plants are quite well designed to take account of the needs of safeguards inspection – and that includes the National Enrichment Facility in New Mexico, which is in most respects a copy of the newest plants in Europe. Urenco has learnt lessons, and has simplified the design of its plants over the years. But if one is new to safeguards, it's very difficult to design a plant to take account of safeguards requirements, because they aren't published, and a dialogue with the IAEA might not start until it's almost too late to take account of their wishes. It could even be that by the time that IAEA has decided that they are going to safeguard a plant, it has already been built! Another problem is that from time to time, IAEA changes its requirements.

So IAEA should issue design guidelines. These could be quite brief: just one or two pages would suffice for each type of plant. For example, for gas centrifuge enrichment plants it seems to us that there are two important design aspects:

- Outside the cascade halls, equipment containing UF6 (e.g. process gas pipework, valves and cylinders) should be readily inspectable. IAEA hates it if they can't gain access to equipment containing nuclear materials.
- Inside the cascade halls, there should be as little equipment as possible, because the operator will inevitably restrict access in these areas for reasons of sensitivity of technology. Centrifuge casings and cascade pipework should be visible to an inspector during a LFUA inspection.

NEW INSPECTION TECHNIQUES

There are many organisations - particularly in USA – currently aiming to develop new equipment and new techniques for safeguards verification purposes. But many of the developers (who might not have many contacts with IAEA or with operators experienced in safeguards implementation) seem to be too interested in the technology per se, and should give a lot more thought into the practicalities. Questions which need to be addressed include:

- Where will the equipment be installed? Does it require access to sensitive areas?
- Will the operator accept the equipment in his plant? Because if he won't and you don't understand why, then it's a waste of your time developing the equipment.
- What is the benefit for safeguards?
- What is IAEA's view? Does it see a need for the new technique?
- How would the new technique fit into the safeguards approach? If a new technique being introduced means that an existing technique can be phased out, then there would be a benefit. Otherwise, costs will simply increase.
- Will the equipment be reliable? What will be the consequences if it fails? If the equipment is not highly reliable, then it is probably useless. For example, the inspectorates hate having to respond to lots of false alarms, and an operator could take advantage of safeguards equipment if he knows it is not working.
- What will be the full cost: for developing the equipment, for buying it, for installation, for routine use, and for maintenance? You need to talk to the people who you expect to pay for all this.
- Can the operator bypass the equipment or sabotage it? A malicious operator could take advantage of any shortcomings of the equipment or technique.
- Will the equipment be easy to use by inspectors?
- How will inspectors be trained in the use of the equipment?

The difficulty found with equipment which is a one-off is that inspectors don't get enough opportunity to learn about it - standard equipment which is in world-wide use is much better.

In Urenco's view, the presence of a competent inspector on site provides more effective safeguards than the use of complex remote monitoring equipment.

PROTECTION OF SENSITIVE INFORMATION

Urenco's enrichment plants contain very sensitive centrifuge technology. Potentially, all visitors to the sites contribute to proliferation of sensitive information. Of course, this statement particularly applies to safeguards inspectors, for several reasons: they are the most frequent group of visitors, they are allowed to see much more of the plants than other visitors, and they come from a wider range of countries than other visitors.

That means that the safeguards verification regime has to be designed well, to avoid disclosure of sensitive information and technology: Urenco does not want its competitors to know what it is doing and especially Urenco does not want to help

potential proliferators. In practice IAEA and Euratom act very professionally in this regard: they are well aware of the sensitivities. Urenco has very careful security procedures agreed with IAEA and Euratom, and to Urenco's knowledge they've never divulged secrets.

EFFECTIVENESS AND EFFICIENCY OF SAFEGUARDS

In recent years, the IAEA has referred many times to improving the *effectiveness and efficiency of safeguards* – but it is strange that they have never properly defined either term. In Urenco's opinion:

- The *effectiveness* of a safeguards measure relates to whether an operator is deterred from carrying out illicit activities by it. If he's not, then it is not very effective.
- The *efficiency* of a safeguards measure relates to whether it gives value for money. One has to compare different measures and chose the one that gives best value for money.

But the IAEA - and to some extent Euratom also - seem to use the expression of *improving the effectiveness and efficiency of safeguards* to justify <u>any</u> extra measures. There really should be a more critical evaluation of existing and proposed new safeguards measures in order to choose the right ones. To keep on adding new safeguards measures on top of those in place is not good practice, as it merely increases costs - both for the plant operator and for the inspectorates (and therewith the international taxpayer) . There should be the aim of cutting back on those safeguards measures which are evaluated to have low effectiveness or efficiency.

FUTURE TRENDS IN SAFEGUARDS IN GAS CENTRIFUGE ENRICHMENT PLANTS

It is clear to Urenco that, in the coming years, there will be more centrifuge enrichment plants around the world subject to international safeguards inspection by IAEA. Urenco understands that the plant currently being built by Areva at Pierrelatte in France will be under IAEA safeguards and Urenco is pleased to hear that. In America, there may soon be not one but three new plants under construction: the National Enrichment Facility, the USEC plant and the Areva plant. Urenco understands that IAEA has not yet decided to inspect any of these plants. Urenco's view is that all three plants should be inspected by IAEA: all are being built as "commercial" plants, to provide LEU for fuel for electricity-generating nuclear reactors. The clear intention of the HSP agreement in 1983 was that all commercial centrifuge enrichment plants sited in HSP countries would be placed under IAEA safeguards. The whole basis of this agreement was so that the different companies would be operating on a "level playing field" in the commercial marketplace. Furthermore, if these three plants were under IAEA safeguards and could contribute their experience, it would enable the enormous wealth of technical expertise in USA to be better exploited in developing improved techniques for safeguards verification under real operational conditions, for IAEA to use world-wide.

In Russia, Urenco does not know what is happening regarding IAEA safeguards inspection at the "international enrichment centre" under development at Angarsk. Very little of any substance has been published on this matter, either by IAEA or by the Russians. However, it will be disappointing to Urenco if all that transpires is that a store containing a few cylinders of enriched UF_6 is inspected by IAEA. In no way would such a limited scheme meet any of the declared IAEA safeguards objectives for gas centrifuge enrichment plants. Are the Russians merely paying lip-service to the concept of international safeguards, and trying to use the good name of IAEA for marketing purposes?

But there will no doubt be new enrichment plants built in other countries around the world in the coming years.

CONCLUSION

It is physically possible to misuse enrichment plants, and it is important that they're properly safeguarded, to ensure that weapons-grade HEU is not produced illicitly. Urenco feels that IAEA should spend more time in guiding the development of new techniques, to make sure that the considerable expertise available is utilised wisely. Urenco hopes that IAEA will take an increasing role in leading the development and implementation of safeguards in all uranium enrichment plants worldwide, irrespective of whether in Nuclear Weapons States or in Non-Nuclear Weapons States: this is an important role which the IAEA is well placed to carry out.

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Mechanisms to increase Nuclear Fuel Supply Guarantees

Pierre Goldschmidt*

1. INTRODUCTION

Almost all non-nuclear weapons states have so far relied on the international nuclear fuel supply market to fuel their electrical nuclear power plants. This is particularly true for countries that depend on nuclear energy for more than 30% of their electricity production. Indeed, international supply sustains countries that rely on nuclear power for 50% or more of their electricity.
There is not a single example in history that I am aware of where a state that had a Comprehensive Safeguards Agreement (CSA) in force had to close down an electrical nuclear power plant because it was denied the delivery of nuclear fuel.

This being said, the nuclear fuel cycle industry is an oligopoly. Many electrical utilities have not forgotten that in the 1970's there was a cartel of uranium producers and that some suppliers of enrichment services did not accept new orders or imposed highly restrictive commercial conditions.

It is imperative for any utility that has invested in nuclear power plants to have the highest assurance that nuclear fuel will be supplied at fair market prices in time to keep their plants running without interruption.

However, the fact that states with less than impeccable non-proliferation records could argue that in order to meet this objective, they need to produce low enriched uranium (LEU) domestically, has recently raised new proliferation concerns. Indeed, once a country operates a uranium enrichment facility (e.g. based on the gas centrifuge process) and either has an indigenous conversion plant or a stockpile of UF_6, it is technically in a position to produce high enriched uranium (HEU) suitable for nuclear weapons. Such material could not be produced undetected in a commercial enrichment plant (i.e. one normally limited to produce uranium with less than 5% U-235) under IAEA safeguards. But such a plant could be reconfigured rapidly to produce HEU if the state where the facility is operating withdraws from the NPT. The risk also exists that a small undeclared replicate of the enrichment facility (based on the same domestic technology) could be operated in a concealed location. The fact that both Libya and Iran have been able to work over a period of 20 years on the development

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of centrifuge enrichment without being detected by the IAEA has significantly increased the awareness of the international community that this is more than a theoretical possibility.

It is therefore urgent to develop a concept that would guarantee a highly reliable fuel supply for nuclear power reactors in non-nuclear weapons states (NNWS) while providing maximum protection against nuclear proliferation.

Fuel supply guarantees would be particularly relevant in the very rare case where a country would have been found by the IAEA to be in non-compliance with its safeguards agreement and, in order to benefit from electrical nuclear energy while reassuring the world of its peaceful use, would agree, or be required to suspend for a period of time all its nuclear fuel cycle activities.

The following describes a mechanism that could form the basis of such a proliferation-resistant guaranteed fuel supply concept.[1]

2. PROLIFERATION-RESISTANT FUEL SUPPLY AGREEMENT

A "Supplier State" and a "Recipient State" would negotiate bilaterally the terms and conditions of a fuel supply contract including its duration, the quantities of fuel involved, the pricing mechanism and the relevant fuel performance guarantees. The supply contract would have two components, one related to the supply of fresh fuel assemblies (FF) and the other dealing with spent fuel (SF) management.

2.1. Delivery of Fresh Fuel Assemblies

a. The FF would be leased to a nuclear power plant (NPP) in the Recipient State, the supplier (in the Supplier State) remaining the owner of the FF and SF at any point in time.

b. FF assemblies would be delivered in transport containers sealed by the IAEA in the Supplier State, which would remain sealed until the loading of the FF in the reactor core or their storage racks inside the reactor containment building. The number of FF assemblies stored at the NPP would not exceed at any time 2 annual reloads.

2.2. Repatriation of Spent Fuel Assemblies

As is well known, SF assemblies contain plutonium that can be recovered through reprocessing and, depending on its quality, used to manufacture nuclear weapons or nuclear explosive devices. It is highly unlikely that SF under IAEA safeguards could be diverted in any significant quantity from a NPP without the Agency detecting it. But, once a state has accumulated SF assemblies and masters the reprocessing technology, it could, as the DPRK did in January 2003, withdraw from the NPT and recover the plutonium for military purposes. For this reasons, and particularly for a state that has been found by the IAEA to be in non-compliance with its safeguards agreement, highly

[1] See also "The Proliferation Challenge of the Nuclear Fuel Cycle in Non-Nuclear Weapon States" by P.Goldschmidt. "Institut Français des Relations Internationales"- Paris, 26April 2004

reliable fuel supply guarantees may be linked to the assurance that SF will not be accumulated in such a state.
Therefore under the fuel supply contract, SF would have to be returned to the Supplier State after a minimum cooling time (e.g. 2 years or less if technically possible and economically justified).If not, the delivery of additional FF assemblies would be suspended.
In addition, as a matter of good practice, and to guarantee to the Supplier State that the necessary funds will be available to cover future SF management costs, the following mechanism would be implemented:

For each kwhe produced by the NPP a specified amount of money (often expressed in USD mills per kwhe or "millage") would have to be paid monthly into a dedicated escrow account in order to cover all transportation costs of the SF to the Supplier State and all management, storage, conditioning and final disposal costs of the SF assemblies after their return to the Supplier State.
The account would have to be managed by an appropriate international organization such as the EBRD, the IMF or possibly the IAEA.

If the Supplier State is allowed by law to retain the SF without having to return any radioactive waste to the Recipient State, then the full amount of the corresponding millage would be released by the fund (with accrued interest) to the Supplier State after it has re-imported the SF.

In some cases however the supplier may be legally obliged to include in the contract provisions whereby the Recipient State would have to take back vitrified high level wastes (HLW) or any other properly conditioned form of HLW, in a quantity (and toxicity) equivalent to that of the fission products contained in the SF. This concept has been implemented by both COGEMA and BNFL for the customers of their reprocessing facilities. The return of these HLW would take place after an agreed period of storage in the Supplier State. That period could be either very short or up to 25 years or more.
In such a case only an agreed proportion of the millage would be paid to the Supplier State and the remaining (with accrued interest) to the Recipient State as and when the HLW is sent back to the Recipient State.

It is clear that the proposed fuel contract will be most attractive to the Recipient State if it resolves completely its SF and HLW management problem. This would likely be the case only in a Recipient Sate that has not yet accumulated a large amount of SF from electrical nuclear power plants.
Where a Recipient State has already accumulated SF from any research reactor, the removal by the Supplier State of such SF (under agreed upon terms) would further increase considerably the attractiveness of the supply agreement to the Recipient State. In contrast, if the Supplier State were to request that the vitrified HLW be sent back to the Recipient State, this attractiveness would likely be significantly reduced.

3. CONTRACTUAL CONDITIONS FOR FF DELIVERIES

3.1 FF deliveries would take place if and only if the Recipient State fulfils its contractual obligations and in particular:

a. SF is returned to the Supplier State within the agreed period of time;

b. The amount of assessed "millage" is paid monthly to the escrow account as required;

c. No FF or SF is removed from storage within the NPP site (and if possible from the containment building), except after the SF is loaded under IAEA surveillance immediately before its retransfer to the Supplier State in transportation casks sealed by the IAEA.

3.2. FF deliveries would be suspended in the following cases:

a. the Recipient State withdraws from the NPT.
In such a case all FF and SF owned by the Supplier State will have to be returned without delay. (cf. paragraph 4.1.a. below)

b. the Recipient State is found by the IAEA to be in non compliance with its safeguards agreements. FF supply would resume once the Agency has concluded that there is no undeclared nuclear material and activities in the Recipient State.

c. the IAEA has found anomalies or inconsistencies or has raised questions that have not been fully resolved within a given period not to exceed 12 months. The contract could include a provision requesting the IAEA to report any such case promptly to its Board of Governors.

4. FUEL SUPPLY GUARANTEES

If a Recipient State considers that it needs nuclear fuel supply assurances extending beyond usual contractual arrangements, e.g. for fear that the necessary export licences would not be granted for political reasons, the following arrangements could be considered in order to address this particular concern.

4.1. Guarantee by the Supplier State.

The Supplier State would grant to the Recipient State a binding long term generic export licence for all FF to be delivered under the supply contract as long as a number of conditions specified in the contract are satisfied.

These conditions could include the following:

a. The IAEA has confirmed that:

- the Recipient Sate has not issued any notice of withdrawal from the NPT
- The Recipient State has concluded with the IAEA an INFCIRC/66 type safeguards agreement for the NPP under consideration. This agreement would normally be subsumed under the Comprehensive Safeguards Agreement (CSA), but would be implemented in case the Recipient State

withdraws from the NPT, so that any FF or SF remaining in the Recipient State would always be subject to IAEA safeguards[2].

- the Recipient Sate has a CSA and an Additional Protocol (AP) in force
- the IAEA has drawn the conclusion, at least annually, that there has been no diversion of nuclear material (NM) placed under safeguards and that there is no undeclared nuclear material and activities in the Recipient State as a whole.
- the IAEA has not raised questions or found inconsistencies or anomalies concerning the State's nuclear programme that have not been resolved within a given period not to exceed 12 months.
- the SF has been returned to the Supplier Sate within the contractual timeframe
- no FF or SF has been removed from the NPP site, except in sealed SF containers being sent back to the Supplier State
- the NPP meets international (IAEA) safety standards and an adequate level of physical protection

b. The international organization (EBRD, IMF, or IAEA) in charge of managing the escrow account has confirmed that all "millage" monthly payments have been performed in accordance with the contract.

The IAEA would not need to be a party to the contract between the Supplier State and the Recipient State, but would be required, in order for the contract to enter into force, to provide its "concurrence" that all the above conditions are included in the contract. This "concurrence" by the IAEA would be similar to the concurrence required from the Euratom Supply Agency on all nuclear fuel supply contracts concluded by EU electrical utilities. Thereafter, before each FF delivery, the IAEA (and the financial organization in charge of managing the escrow account) would have to certify that all relevant conditions have been met.

c. In the very rare cases where a State has been found by the IAEA Board of Governors to be in non-compliance with its safeguards agreement, it may well be that some exporting countries would be prepared to grant a binding long term generic export licence for FF under the conditions stated above, if and only if, in addition, the Recipient State undertakes to suspend, at least during the term of the contract, any R&D, manufacturing, construction, testing or operation activities related to the nuclear fuel cycle (except for the storage and final disposal of low, medium and high level radioactive wastes).

   The IAEA could be requested to verify that the Recipient State complies with this commitment and, if it doesn't, to report without delay to the IAEA Board of Governors.

[2] A CSA remains in force only for so long as the state remains party to the NPT, whereas under a INFCIRC/66 type agreement all nuclear material supplied or produced under that agreement would remain under safeguards, even if the state withdraws from the NPT, until such time the IAEA has determined that such material is no longer subject to safeguards.

4.2. Additional guarantee by the IAEA.

As foreseen in Article III.A.1 of the IAEA Statute, as a back-up to the contractual arrangement described above, the Agency could provide further fabricated fuel supply guarantees in case the FF delivery is delayed by the Supplier Sate for more than [12] months after the contractual due date for any reason other than a failure by the Recipient Sate to meet its contractual obligations and the conditions listed in paragraph 4.1. above.
In such a case the IAEA would provide substitute FF assemblies to the Recipient Sate within a period of not more than [12] months.
The IAEA would be and remain the owner of the fuel elements (whether fresh or spent fuel) and would deliver them to the Recipient Sate under terms and conditions similar to those of the original contract with the Supplier State.

The IAEA could provide this additional guarantee as follows:

4.2.1. For the delivery of fresh fuel assemblies

a) Option N°1:

The IAEA could conclude long term agreements with a number of uranium, conversion, enrichment and fuel fabrication producers whereby they would commit to reserve at all times a specified percentage of their production capacity for the IAEA. These "drawing rights" would be exercised by the IAEA if and only if the Supplier State fails to meet its contractual obligations as described above and no other substitute fuel supply is readily available.
Such an option might however be complicate to manage in practice.

b) Option N°2:

Another option, simpler to manage, would be for the IAEA to become the owner of a stockpile of low enriched UF6. This stockpile could be transferred free of charge to the IAEA for example as part of an "off market" quantity of LEU resulting from the down blending of HEU in Nuclear Weapons States (NWS) as was recently suggested by the USA[3].
The UF6 would be stored on the site of one or more uranium enrichment companies. One could consider the possibility (and evaluate the merit) of creating on the site of the relevant enrichment plants an extra-territorial storage facility belonging to the United Nations, a concept similar to that of a foreign embassy.
The IAEA would conclude contracts with those enrichment companies for the storage of the material as well as for services to adjust (e.g. within one month), as and when necessary, the enrichment of the UF6 to the desired level (below 5% U-235).
In addition, the IAEA would conclude contracts with as many relevant fuel fabrication companies as possible[4], giving the IAEA the right to request at any time the fabrication of one or more reloads of fresh fuel elements, meeting pre-

[3] Cf. INFCIRC/659 – 29 September 2005
[4] In the specific case where the fuel would be of the VVER type, the only fuel manufacturers commercially available today are located in Russia and Spain.

determined specifications, within a period of [8] months maximum after the delivery of the necessary enriched UF6 owned by the Agency.
The States where the fuel fabrication facilities are located should furthermore grant to the IAEA, under an agreement approved by the Board of Governors, a generic export licence for the fabricated FF as long as the IAEA confirms that all the conditions listed in paragraph 4.1. above have been met by the end-user. This would provide the highest possible level of fuel delivery assurance, since it is unlikely that any supplier state would not honour an agreement concluded with the IAEA.

4.2.2. For the repatriation of spent fuel.

The IAEA would need to take the SF back from the Recipient Sate within the contractual timeframe.
For the time being, Russia is the only country that accepts, for LWRS, the repatriation of SF of Russian origin without having to send back HLW to the country that has used the fuel for electricity production.
Ideally, Russia could also agree to take back (at the contractual "millage" rate) SF belonging to the IAEA in the very unlikely event that this would be necessary. Other state may follow that example. In this regard it should be noted that the US is already repatriating spent HEU fuel of US origin used in foreign research reactors. The US should consider extending this policy to spent fuel owned by the IAEA in the very unlikely event considered here.

Other NWS should also undertake to take over SF owned by the IAEA if this were ever to be necessary, since such a situation would only occur in order to resolve a major nuclear proliferation concern, especially if it is in relation to a state that has been found in non-compliance and has agreed to suspend all fuel cycle related activities.

If the IAEA ever becomes the owner of SF, as a consequence of the fuel supply mechanism described above, it will need to have the guarantee that, at least one state will commit to take over the ownership of the SF for further storage, processing and final disposal. Without such assurance it is unlikely that the IAEA Board of Governors would agree to provide the fuel supply guarantees described in this paper.

5. CONCLUSION

It should be expected that, as in the past, almost all electrical utilities will be comfortable to relying on normal commercial practices to acquire the fuel required for their nuclear power plants, and will be wary of the involvement of any governmental or international organization. In some exceptional cases, a utility or a state may feel the need for increased fuel supply guarantees in order to be protected against the risk of fuel supply disruption for political reasons.
The mechanism developed in this paper should simultaneously provide this additional guarantee and maximum protection against nuclear proliferation.

Mechanisms to increase Nuclear Fuel Supply Guarantees

Addendum

The following clarifications are provided in response to questions that were raised with the author following this paper's release on November 8, 2005.

Delivery of FF assemblies (§2.1)

1. The question was raised whether by "leasing" the FF assemblies there was an implication that payment would be made over the "lease" term. The answer is, no, there would be an up-front payment for the total cost of the assemblies at the time of delivery.

2. The question was raised as to why the number of FF assemblies stored at the NPP would not exceed 2 annual reloads.
   The 2-year limit is suggested based on cost and practical considerations such as the need to adjust fuel enrichment levels over time. Proliferation concerns would not increase significantly if a Recipient State chose to maintain a larger reserve, provided the reserve remains under IAEA safeguards.

Additional guarantees by the IAEA (§4.2)

3. The question was raised as to the necessity for the Recipient State to wait 12 months before calling upon the IAEA back-up supply. It would **not** be necessary for the Recipient State to wait for any particular period once it becomes clear that FF delivery will be delayed by the Supplier State for any reason other than a failure by the Recipient State to meet its contractual obligations and the conditions listed in Section 4.1. In such case the Recipient State would inform the IAEA and request it to activate its fuel supply guarantee.
   Since it would take around 12 months for the IAEA to be in a position to deliver substitute FF assemblies, this period of time should be used to try to resolve the issue with the original supplier and to find out whether any other substitute fuel supply would be readily available.
   If the Recipient State has a reserve of FF assemblies sufficient to cover the operational needs of the NPP for at least two years, it would allow the IAEA back-up mechanism to be effectively implemented in time to guarantee the continuous operation of the electrical plant.

Magnitude of IAEA back-up fuel inventory

4. The question was raised as to how large the IAEA's back-up fuel inventory would have to be.

   It is unlikely that many utilities already operating electrical nuclear power plants for some years would feel the need to seek fuel supply guarantees other than diversifying as much as possible their sources of supply, concluding flexible fuel supply contracts and managing appropriate nuclear fuel inventories.

The fuel supply guarantee suggested in this paper could however be attractive for those states that, for any reason, feel that they do not have access to reliable and diversified sources of supply. The proposed mechanism would be most relevant in the very rare case where a country has been found by the IAEA to be in non-compliance with its safeguards agreement (i.e. Iraq, DPRK, Libya and Iran) and, in order to benefit from electrical nuclear energy while reassuring the world of the exclusively peaceful use of its nuclear programme, such country would agree, or be required, to temporarily suspend all its nuclear fuel cycle activities.
So far none of these states have a large scale commercial electrical nuclear power plant (NPP) in operation. The first and most urgent case to be considered is the VVER-1000 MWe at Busher, whose sole fuel supplier today is Russia. In this specific case, since the only VVER fuel manufacturing plant outside Russia is located in the European Union, the IAEA back-up low enriched UF6 stockpile should logically be stored on the site of one of the European commercial enrichment facilities.
In this case an initial inventory equivalent to one reload (approximately 30 t UF6 at 4% U-235) should be sufficient, considering the fact that as soon as this material would be used, the amount of money received should allow the IAEA to promptly buy a replacement quantity.
In a more global perspective, the IAEA would ideally store some of its back-up fuel inventory in all regions of the world possessing commercial enrichment plants: China, the European Union, Japan, Russia and the United States.
It is, however, recommended that implementation and testing of the proposed mechanism start on a modest scale, by addressing first the immediate need described above.

<u>What about funding?</u>

5. The question was raised as to what the financial implications of the proposed mechanism would be for the IAEA.

   The low enriched UF6 stockpile to be owned by the IAEA (initially equivalent to one annual reload or abut 30 tonnes of low enriched UF6 at a cost of around $ 25 million) should be “given” to the IAEA as suggested in Section 4.2.1.b, or the IAEA should be provided with the extra-budgetary resources necessary to buy the material.
   If a Recipient State calls upon the IAEA to deliver FF assemblies it would have to pay the IAEA the price fixed under the initial contract with the supplier. Depending on the evolution of the nuclear fuel market and the contractual pricing formula, this amount may be higher or lower than that necessary for the IAEA to fully reconstitute its stockpile.
   If it is less, then the IAEA should be provided with the additional extra-budgetary funds necessary. The possibility of establishing a special contingency fund for that purpose could be considered.

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Is There Any Fizz Left in the Fissban? Prospects for a Fissile Material Cutoff Treaty

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The pursuit of a multilateral ban on the production of fissile material, highly enriched uranium (HEU) and plutonium, for nuclear weapons has been one of the longest-running post-World War II enterprises of the international community and unfortunately probably among the most futile to date. It is a sobering fact for the disciples of multilateral diplomacy that 2007 marks the 50th anniversary of UN General Assembly Resolution 1148, which explicitly called for "the cessation of the production of fissionable materials for weapons purposes."

Why, despite the widespread support for the conclusion of a treaty to accomplish this goal, have negotiations failed to proceed? The present article will review the impediments to progress, discuss recent diplomatic efforts to promote negotiations, and examine options for starting work on a fissile material production ban in the future. As even the choice of acronyms to describe the treaty is a point of contention, between those who prefer FMCT (fissile material cutoff treaty, suggesting a focus on prohibiting production) and those who favor FMT (fissile material treaty, with its implication that past production will also be controlled), I will opt for the generic and more neutral contraction fissban to refer to the envisaged treaty.

Frozen by the Cold War

Although the goal of a fissban was already formally endorsed by the United Nations in the aforementioned General Assembly resolution of 1957, the massive nuclear build-up that characterized the Cold War period meant that little practical effect to this aspiration could be achieved during those decades.

The possibility of a fissban, however, appeared more promising with the end of the Cold War confrontation between the United States and the Soviet Union. As part of the general build-down of nuclear forces in the post-Cold War period, four out of the five recognized nuclear-weapon states under the nuclear Nonproliferation Treaty (NPT) indicated officially that they were no longer producing fissile material for weapons purposes. (China made no official announcement to this effect but informally suggested that it too had ceased such production.)

In 1993 the General Assembly passed by consensus a resolution calling for the initiation of multilateral negotiations on a fissban. In parallel, work on the issue within the 65-member-state Conference of Disarmament (CD) in Geneva, [illegible] with the appointment of Canada's Ambassador Gerald Shannon as

Disarmament (CD) in Geneva quickened with the appointment of Canada's Ambassador Gerald Shannon as special coordinator. Shannon's report and the mandate for negotiation contained therein were adopted by the CD in March 1995. Additional political momentum in favor of a fissban was imparted by the 1995 NPT Review and Extension Conference, which directed "the immediate commencement and early conclusion of negotiations" for a fissban in accordance with the Shannon mandate. This mandate was even operationalized, via an ad hoc committee of the CD, for a couple of weeks in the summer of 1998, but the negotiations could not be sustained.

Progress was blocked by the development in early 1999 of a gridlock situation with respect to the CD's program of work that pitted China and Russia as advocates of negotiations on outer space against the United States and those wishing to limit CD negotiations to a fissban. This dispute over what should be included in the CD program of work has persisted since then, and the resumption of fissban negotiations at the CD has remained an elusive goal despite its regular reaffirmation as a priority of the international community, including at the 2000 NPT review conference.

In the summer of 2004, a new complication arose when the Bush administration, in a sharp break with previous U.S. policy, announced that it had concluded pursuant to an internal review that the Shannon mandate's requirement for international and effective verification was impossible to achieve and that henceforth the United States would not support this part of the agreed mandate. Although the United States reaffirmed its commitment to a fissban and even tabled a draft mandate and treaty text at the CD, this break from the existing consensus around the Shannon mandate further complicated an already difficult situation.

Irrespective of the difficulties being encountered at the CD, international concerns over nuclear programs in Iran, Iraq, Libya, and North Korea as well as the classic nuclear arms race underway in the Indian subcontinent have all served to maintain a certain external pressure for pursuing the multilateral efforts for a fissban as one further firebreak against proliferation. Considerable creative diplomacy was evident in the last two years at the CD with the innovation of united platforms on the part of the rotating CD presidents, who hitherto had pursued individual and often uncoordinated agendas, that provided structured and focused discussion of a fissban and other key issues.

After an initial session (January to March) of intensive, informal discussions on all CD agenda items, this year's six presidents ventured so far as to put before the conference on March 23 a draft decision that sets out a work program on four core issues (nuclear disarmament, fissban, outer space, and negative security assurances) under the direction of four coordinators. This proposal provides for "negotiations, without any preconditions, on a non-discriminatory and multilateral treaty banning the production of fissile material for nuclear weapons or other nuclear explosive devices." The "without any preconditions" clause was devised to accommodate both the supporters and the opponents of the Shannon mandate by suggesting that the negotiations of a fissban would be open to all perspectives and its parameters would be defined in the course of the negotiations rather than before the negotiations started.

Although it had been hoped that this decision could be adopted at the start of the CD's second session on May 15, it soon became evident that a handful of delegations were not in a position to agree to its adoption. China, Iran, and Pakistan have now indicated a variety of concerns with the draft decision, and all have called for any future fissban negotiation to be conducted under the Shannon mandate. Iran and Pakistan have also explicitly called for stockpiles to be covered by any such treaty. The six CD presidents sought to accommodate some of these concerns via a complementary statement without opening up the text of their proposal. Regrettably, these efforts failed to bring the reluctant states onboard, and the CD's 2007 session ended mid-September without agreement on the draft decision and without substantive work having been undertaken since the conclusion of its first session in March.

The reasons behind the opposition of China, India, and Pakistan to the proposed program of work are not altogether clear. Pakistan has been the most vocal and explicit in its rejection of the draft decision, with its National Command Authority (the country's most senior political-military body chaired by the president) meeting on August 2, 2007, and issuing a press release reaffirming Pakistan's position in favor of the Shannon mandate. Ambassador Masood Khan, Pakistan's permanent representative to the CD, elaborated on his country's position regarding fissban negotiations in an October 18 statement to the General Assembly's First Committee, saying that "[a] Fissile Material Treaty without verification would amount only to a unilateral moratorium. A[n] FMT which freezes or accentuates asymmetries, will accelerate, not arrest proliferation." Pakistan is concerned that, without ironclad verification and inclusion of stocks, a fissban could perpetuate existing imbalances with regional rival India and spur rather than subdue further increases in fissile material holdings and associated nuclear weapons. In voicing his country's objection to the "without preconditions" formula for fissban negotiations set out in the CD draft decision, Khan argued that "dropping the agreed basis for negotiations is a precondition.… The Shannon mandate was agreed and now there are moves to shelve it."

Finally, both the National Command Authority release and Khan's statement make the connection between the proposed U.S.-Indian nuclear deal and the Pakistani perspective on a fissban. As Khan stated, "We are assessing the full impact of the incipient U.S.-India nuclear deal on fissile material production in our region. This has already influenced our position on the Fissile Material Treaty." Pakistan seems to be saying that it no longer views the initiation of fissban negotiations to be in its national security interest and will oppose efforts to launch such negotiations on any basis other than the Shannon mandate.

China, the state for which strategic calculations leading to a rejection of a fissban likely loom the largest, may see the need to preserve an option for future fissile material production in light of scenarios involving a buildup of Indian nuclear forces or U.S. ballistic missile defenses. Iran, which continues to declare the exclusively peaceful nature of its nuclear program, appears to see opposition to initiation of fissban negotiations as a means of leverage vis-à-vis the international community and the United States in particular in its ongoing battle over its nuclear activities. Given the strict consensus procedures at the CD, the opposition of any one of these states (all CD members) is sufficient to deny a start to negotiations despite the support of the overwhelming majority of CD members.

A Fissban: Still Worth the Effort?

The implications of the opposition by China, Iran, and Pakistan to the presidents' proposed work program for the CD in 2008 are enormous. Having pushed matters to this point, there would appear little appetite among leading CD delegations for a retreat or falling back to some form of limited informal discussions on a fissban. At the same time, the six CD presidents for 2008 (Tunisia, Turkey, Ukraine, the United Kingdom, the United States, and Venezuela) will face a daunting challenge in devising the means to get the CD back to work on its core issues, including negotiations on a fissban, when it reconvenes in January. It would thus seem an appropriate time to assess whether a fissban remains a valid goal. I believe that it does for several reasons.

First, a fissban represents a necessary step on the road to nuclear disarmament and contributes to nonproliferation. Given that military stocks of HEU are estimated at 1,400-1,800 metric tons and that plutonium holdings approximate 500 tons roughly evenly split between military and civilian holdings, the world is awash with fissile material, and a cap on at least that part of production destined for nuclear weapons is a necessary precondition for eventual nuclear rollback.

Second, the top priority attached within the NPT context to a fissban, alongside the need for the Comprehensive Test Ban Treaty (CTBT) to enter into force, imbues it with particular diplomatic significance as an indicator of progress by the nuclear-weapon states in fulfilling their NPT Article VI disarmament commitments and as a litmus test of multilateral arms control and disarmament activity generally. Because the

commitments and as a litmus test of multilateral arms control and disarmament activity generally. Because the CTBT, although still not formally in force, is a concluded treaty with wide support, the contrast with the fissban, which remains only a gleam in a negotiator's eye, is all the more striking and underscores the deficiency of multilateral action in this regard. This deficiency in turn undermines the political basis for enhanced international cooperation on nonproliferation efforts.

Third, although the five original nuclear-weapon states are believed to be respecting a moratorium on fissile material production, this situation is vulnerable to a sudden reversal in the absence of a formalized commitment via a fissban.

Fourth, although a fissban limited to the five original nuclear-weapon states would be an accomplishment in itself, the potential for a fissban to bring in the non-NPT nuclear-weapon-possessing states (India, Israel, and Pakistan) and put a cap on their nuclear weapons ambitions remains a valuable goal for regional and global security.

Of course, the resistance of the non-NPT parties (I include North Korea in this grouping) to this last goal is probably the primary reason why fissban negotiations have not been launched. India, North Korea, and Pakistan have been actively and openly engaged in a buildup of their nuclear arsenals and hence wish to avoid any constraint on their fissile material production potential. Israel has kept a low profile on this matter at the CD and, despite its reservations about a fissban, has so far adroitly avoided being cast in a spoiler role.

Possibilities for Progress

In light of the continued reservations of at least three CD members, what are the options for making some progress? In my view, the international community should not allow issues of form or fora get in the way of coming to grips with the substance of the fissban, i.e., agreed prohibitions on fissile material production for nuclear weapons. Several feasible options exist for realizing the fissban enterprise, but these diplomatic choices will all require sufficient political will to move the fissban off square one. Some possibilities that suggest themselves are:

1. **Stay the course in the CD:** This option would envisage a renewed push to gain acceptance of the existing draft decision on a program of work when the CD reconvenes in January 2008. Such a strategy would build on the widely held preference to negotiate the fissban in the CD and the progress made in fashioning a compromise program of work that enjoyed broad support. This approach, however, remains vulnerable to being "vetoed" by one or more CD members, with Pakistan's firm public opposition making it especially unlikely that it would go along with a reversal of its stance anytime soon. An added danger is that efforts to accommodate Pakistan and others over the Shannon mandate could result in losing U.S. acceptance of the current compromise.

2. **Initiate negotiations in the NPT:** This option would entail starting fissban negotiations under the auspices of the NPT, whose members have all committed themselves to such negotiations at the 1995 and 2000 review conferences. Taking this route would utilize a forum already committed to immediate commencement of fissban negotiations and would get around the problem of Pakistan's opposition, along with India and Israel, non-states-parties of the NPT. By the same token, it would leave the three non-NPT nuclear powers outside the treaty, at least initially. It would also represent a new departure for NPT members, and any action would probably have to wait for approval from the next NPT review conference in 2010.

3. **Negotiations held under the auspices of the IAEA:** Given the close association between a fissban and the system of fissile material controls maintained by the International Atomic Energy Agency (IAEA), it may be possible to start negotiations under IAEA auspices with the director-general inviting all nine states that possess fissile material for nuclear weapons use to take part. A variant of this option would have these states

possess fissile material for nuclear weapons use to take part. A variant of this option would have these states joined by an equal number of non-nuclear-weapon states with advanced nuclear programs. This approach would provide a "neutral" but inclusive forum (all nine states with the current exception of North Korea being agency members) and could facilitate aligning responsibilities of states possessing fissile material for nuclear weapons purposes with existing restrictions on non-nuclear-weapon states pursuant to the IAEA's international safeguards system. The required consensus in the IAEA would be vulnerable however to a veto by one or more members unless its director-general acted under his own initiative. Such an initiative would also represent a departure from the IAEA's traditional technocratic role by engaging in a negotiation with an explicit international-security character.

4. **An independent initiative of the five nuclear-weapon states:** This option would aim to codify the existing declared moratoria on fissile material production by at least four of these states. Such an undertaking would get the ball rolling by having the states with the greatest holdings of fissile material for nuclear weapons and the greatest responsibility under the NPT to cease its production and eliminate the arms fashioned from it initiate action. It could serve as a means of "priming the pump" for eventual, broader negotiations including non-NPT states-parties. Such a step would require, however, a degree of leadership on the part of one or more of the nuclear-weapon states that has not recently been in evidence on this issue. China's ambiguous position concerning its own cessation of fissile material may make it unwilling to join the rest of the states in such a fissban initiative, which would detract from its appeal.

5. **Establishing an open-ended UN negotiation:** This option would build on earlier General Assembly resolutions in favor of a fissban by establishing an open-ended working group to negotiate such a treaty. Taking this path would build on existing consensual or near-consensual support in the universal body of the General Assembly for the negotiation of a fissban. As a resolution of the General Assembly, decided by majority vote, it would not be subject to the veto of an opposing state. At the same time, pursuing this option would represent a reversal of hitherto support for the CD as the forum to negotiate a fissban. It might also mean that states possessing fissile material that had opposed the resolution would not participate in any negotiation pursuant to it.

Although each has its own particular advantages and disadvantages, all of the options described above constitute diplomatically feasible means of starting negotiations on a fissban. Some would entail new departures for the organizations or groups involved, but these would not be out of keeping with similar initiatives on related subject matter in the past. One might cite in this regard the negotiations on the Convention on the Physical Protection of Nuclear Material held under IAEA auspices or the elaboration of the Hague code of conduct on ballistic missiles initiated by member states of the Missile Technology Control Regime but extended subsequently to more than 125 states. Some would carry the risk of nonparticipation of some states of the targeted group (those possessing fissile material for nuclear weapons). Yet, these risks would cut both ways, and the negative implications for a state that stood against the near-universal support for a fissban would not be negligible.

The key missing ingredient to date seems to be the political will to overcome the ever- present obstacles and achieve a significant result. Nevertheless, at a time when leading nuclear-weapon states' opposition to nuclear proliferation appears highly subjective and selective, it is difficult to conceive of these states generating the necessary political direction and determination to initiate one of the negotiating options for a fissban suggested above. As long as these powers see no major benefit to curbing the fissile material production of other nuclear-weapon states, they may be unwilling to expend the political and diplomatic capital to ensure the commencement of a negotiation, let alone persevere to ensure an outcome.

At the same time, recent or impending leadership changes in several of the states possessing fissile material for nuclear weapons provide some basis for hope that the fissban enterprise will be revalued and its potential

contribution to strengthening the international nonproliferation and disarmament regime positively reassessed. This in turn could help generate some of the diplomatic purpose and energy on behalf of a fissban that has been lacking in recent years. Such renewed engagement in favor of a fissban would be the best way to mark the 50th anniversary of the UN General Assembly resolution calling for the negotiation of this treaty and to demonstrate some solidarity with those states that forswore the acquisition of nuclear weapons long ago.

Shannon Mandate

In March 1995, the Conference on Disarmament adopted a mandate offered by Canada's Ambassador Gerald Shannon, whose text is below. Disagreement over the call for international and effective verification as well as whether to link the mandate with progress on nuclear disarmament and an outer space treaty has contributed to delay in negotiating a fissile material treaty.

1. The Conference on Disarmament decides to establish an ad hoc committee on a "ban on the production of fissile material for nuclear weapons or other nuclear explosive devices."

2. The Conference directs the Ad Hoc Committee to negotiate a non-discriminatory, multilateral and internationally and effectively verifiable treaty banning the production of fissile material for nuclear weapons or other nuclear explosive devices.

3. The Ad Hoc Committee will report to the Conference on Disarmament on the progress of its work before the conclusion of the 1995 session.

Paul Meyer served as Canada's ambassador and permanent representative to the United Nations and the Conference on Disarmament in Geneva from 2003 to 2007. The views expressed in this paper are the author's own and do not necessarily reflect those of the Department of Foreign Affairs and International Trade of Canada.

Commissioned Papers

Multinationalizing USEC

Fred McGoldrick

Introduction

The United States has long recognized that limiting the spread of enrichment facilities must be an important element of an effective global nonproliferation regime. A few large multinational enrichment facilities that would provide appropriate participation by foreign utilities and/or their governments and offer reliable nuclear fuel assurances on attractive terms could help persuade some countries that they do not need to acquire their own national enrichment plants.

Some existing enrichment plants, namely those operated by Urenco[1], Eurodif[2], and the Russian centrifuge facility at Angarsk[3] already entail some form of multinational participation. Argentina and Brazil are in the process of establishing a bi-national agency that would provide enrichment services.[4] In addition, the multinational firm Urenco is building the Louisiana Enrichment Services (LES) / National Enrichment Facility (NEF) centrifuge plant in New Mexico. The French firm AREVA is building an enrichment facility in Idaho with the AREVA and Urenco joint venture Enrichment Technology Company, LTD (ETC) supplying the centrifuge technology. The Silex plant planned for the United States will involve participation by GE-Hitachi Nuclear Energy and its subsidiary Global Laser Enrichment, (GLE) as well as the Canadian firm Cameco. The

[1] Urenco is a consortium composed of the UK Government; the Dutch government; and several German nuclear companies. Urenco operates three similar uranium enrichment plants in the UK, The Netherlands and Germany. The facilities are subject to safeguards of EURATOM and/or the International Atomic Energy Agency (IAEA).

[2] Eurodif S.A. is a private company that was formed in the 1970's to build and operate the gaseous diffusion plant located at the AREVA Tricastin site in southern France. AREVA owns approximately 60% of the Eurodif shares. Other shareholders include Spain's ENUSA, Belgium's SYNATOM, and Italy's ENEA. Eurodif does not share its technology with its investment partners. The facility is subject to EURATOM safeguards

[3] Russia is in the process of establishing the International Uranium Enrichment Center (IUEC) on the site of the Angarsk Electrolysis Chemical Complex in which other countries are invited to participate. The Russians have invited the IAEA to apply safeguards to the center. The Russian facility is oriented chiefly to providing enrichment services to states not developing uranium enrichment capabilities on their territory. Russia will not transfer its centrifuge technology to participants in the IUEC. Kazakhstan and Armenia have joined this effort.

[4] Brazil will not share its centrifuge enrichment technology with Argentina. Any enrichment facilities involved in the bilateral agency would be subject to IAEA safeguards and to the safeguards of the Brazilian–Argentine Agency for Accounting and Control of Nuclear Materials (ABAAC).

fact the U.S. is allowing new multinational enrichment plants on its territory may help others to accept this model as an international norm.

However, other plants in the United States, Russia, China and Japan have no multinational involvement. If existing technology holders, particularly those in nuclear weapon states, are not prepared to invite some form of multinational participation in their own facilities, it will be difficult to establish multinational control of sensitive nuclear facilities as a global nonproliferation norm that is acceptable to the majority of states. The United States Government should propose that new commercial uranium enrichment facilities should be multi-nationally owned and subject to safeguards agreements with the International Atomic Energy Agency (IAEA). To this end, the U.S. Government should give serious consideration to the merits and feasibility of encouraging appropriate multinational participation in the new centrifuge facility being built by the United States Enrichment Corporation (USEC).

USEC: A Candidate for Multinational Participation?

USEC runs the only currently operating enrichment facility in the United States – a gaseous diffusion facility in Paducah, Kentucky, which it is leasing from the U.S. Department of Energy (DOE). USEC plans to shut down the Paducah facility once it opens its new American Centrifuge Plant (ACP) that is under construction at Piketon Ohio. USEC secured the necessary license from the NRC in 2007 in order to build and operate the ACP, which will use a new gas centrifuge technology developed by DOE. The ACP, which is scheduled to begin operation in 2010 and to be fully built by the end of 2012, has a planned capacity of 3.8 million SWUs.

The ACP does not involve any foreign investment or participation, but USEC would clearly welcome an infusion of funds from abroad to help meet its pressing financial needs. There do not appear to be any legal barriers to foreign investment in ACP, and there are no national security reasons for barring appropriate foreign participation in this plant. What may work against foreign investment in the new USEC enrichment facility are some uncertainties about the commercial and operational reliability of the new ACP centrifuges. Attracting foreign investment may require U.S. Government subsidies that would allow USEC to service a wider body of enrichment customers (i.e., utilities in consumer countries who do not have their own enrichment capacity) at attractive prices.

<u>Legal Considerations</u>

USEC, originally a government corporation, was created as a result of the Energy Policy Act of 1992 to privatize uranium enrichment for civilian use. USEC later went public in 1998 through an initial public offering. Section 193 (f) of the Atomic Energy Act provides that "No license or certificate of compliance may be issued to the United States Enrichment Corporation or its successor under this section or section 53, 63, or 1701, if the Commission determines that–

(1) The Corporation is owned, controlled, or dominated by an alien,

> a foreign corporation, or a foreign government; or
>
> (2) The issuance of such a license or certificate of compliance would be inimical to–
>
> (A) the common defense and security of the United States; or
>
> (B) the maintenance of a reliable and economical domestic source of enrichment services.

NRC Regulations (10 CFR 70.40 and 10 CFR 76.22) implement the restrictions of Section 193 of the AEA. Under NRC regulations implementing the national industrial security program (NISP) (10 CFR Part 95), a certificate holder or licensee is required to obtain a facility clearance for any location where classified information will be used, stored or handled. The NRC review for determining whether to grant a facility clearance involves examining whether there is any foreign ownership control or influence (FOCI). NRC regulations define FOCI as follows:

> *Foreign Ownership, Control, or Influence (FOCI)* means a foreign interest that has the power, direct or indirect, whether or not exercised, and whether or not exercisable through the ownership of a U.S. company's securities, by contractual arrangements or other means, to direct or decide matters affecting the management or operations of that company in a manner which may result in unauthorized access to classified information or may affect adversely the performance of classified contracts.

According to a recent USEC press release,

> "In September 2008 we created new wholly owned subsidiaries to carry out future commercial activities related to the American Centrifuge project. These subsidiaries will own the American Centrifuge plant and equipment, provide operations and maintenance, manufacture centrifuge machines and conduct ongoing centrifuge research and development. This corporate structure will separate ownership and control of centrifuge technology from ownership of the enrichment plant and also establish a separate operations subsidiary. This structure will facilitate DOE loan guarantee financing and potential third party investment at the project level, while also facilitating any future plant expansion."

According to USEC, these wholly owned subsidiaries will allow for foreign investment as long as it remains under 50% of the total shares. The certificate of incorporation for USEC Inc. contains certain restrictions with respect to foreign ownership of common stock, and the Board of Directors of USEC, Inc. has the right to review any foreign ownership of common stock. In addition, foreign ownership of any U.S. enrichment

facility may also require review by the Committee on Foreign Investment in the United States (CFIUS).[5]

Other forms of multinational participation. Foreign investment in USEC may offer improved fuel assurances to participants and thus reduce their incentives to build national facilities. Another mechanism for enhancing confidence in fuel supply would be to offer some form of participation by foreign investors in the overall policy and management of USEC. The U.S. could also follow the Russian example at Angarsk by establishing an advisory committee which would include not only the foreign investors but also the Director General of the IAEA. Section 1304 provides that USEC, Inc.'s board of directors must be citizens of the United States. According to USEC officials, however, participation in the board of directors of its subsidiaries is permissible under the law.

Thus there appear to be no legal barriers to investment by foreign entities or their participation in the board of directors of or as advisors to USEC, Inc.'s subsidiaries.

National Security Considerations

Protection of Restricted Data and Sensitive Nuclear Technology. Any option to invite multinational participation in USEC will require arrangements that prohibit the dissemination of Restricted Date or sensitive nuclear technology to foreign participants.[6] Section 144 (a) of the Atomic Energy Act prohibits the transfer of Restricted Data except pursuant to an agreement for cooperation entered into in accordance with section 123 of the Act.

Limiting Participation to Countries that do not have their own enrichment facilities. The U.S. may also wish to consider offering foreign participation in the USEC ACP only to those countries that do not have their own parallel national enrichment activities. The Russian facility at Angarsk operates on this model.

Safeguards. It is assumed that the new USEC facility will be placed on the list of facilities eligible for IAEA safeguards in accordance with the U.S.-IAEA safeguards agreement. Under this agreement the United States has agreed to permit the Agency to apply safeguards on all source or special fissionable material in all facilities within the United States, excluding only those facilities associated with activities with direct

[5] PL 110-90 requires the Committee on Foreign Investment in the United States (CFIUS) to review all "covered" foreign investment transactions to determine whether a transaction threatens to impair the national security, or the foreign entity is controlled by a foreign government, or it would result in control of any "critical infrastructure that could impair the national security."

[6] ETC, the 50/50 joint venture between Urenco and AREVA, does not share its technology with its shareholder/customers. In fact, strong "firewalls" must exist at all times between ETC employees and Urenco and AREVA employees. ETC supplies only "black boxed" technology to Urenco's and AREVA's enrichment facilities in Europe and the U.S. France does not permit access to its gaseous diffusion barrier technology by its investment partners in its Eurodif enrichment enterprise. Russia will not transfer to participants in its centrifuge facility at Angarsk uranium enrichment technology or information that constitutes a state secret.

national security significance to the United States. This means in practice that, while the IAEA would have the right to apply safeguards, it would not actually do so since the IAEA has limited funding for safeguards and has placed priority on safeguarding nuclear materials in non-nuclear weapon states. If the United States wished the IAEA to apply safeguards to the new USEC facility, it would have to finance such safeguards through a voluntary contribution to the IAEA.

Production of naval fuel and tritium. In order to attract foreign participation in USEC, it will be important to maintain a separation of the USEC facility from any nuclear weapons or military activities. As noted, the ACP should be placed on the eligible list of the U.S.-IAEA safeguards agreement. Under that agreement, the United States has the right to withdraw materials or facilities from the eligible list upon notification to the Agency. USEC has argued in its petition on a recent anti-dumping case that USEC is the only domestic company that employs uranium enrichment technologies available to meet defense needs.[7] However, there should be no need to call upon the USEC facility for the production of either tritium for nuclear weapons or for naval reactor fuel. The United States has a supply of tritium sufficient to meet future needs for well over a decade. Moreover, as of mid-2007 the United States has set aside some 128 tons of highly enriched uranium for navel fuel. In addition, the United States has large numbers of warheads awaiting dismantlement. Once these warheads are dismantled, further HEU would become available for naval uses. Furthermore, under the 2002 Strategic Offensive Reductions Treaty (SORT or Moscow Treaty), the United States and Russia have committed to reduce their arsenals to 1700–2200 deployed strategic warheads each by 2012, and proposals have been made for further reductions down to 1000 total warheads for each country. Such reductions would provide additional quantities of HEU which should be ample for any navel propulsion or for blending down to LEU for any needed tritium production.[8] The U.S. Nuclear Regulatory Commission's license for the ACP authorizes USEC to enrich uranium only up to 10 percent of the fissile isotope uranium-235—an enrichment well below what is currently used in U.S. naval fuel.

Peaceful Use Assurance. Under the U.S.-IAEA safeguards agreement, the United States has the right to withdraw any nuclear facility that is on the eligible list from the safeguards agreement. In order to enhance confidence among potential foreign participants in the peaceful uses of the ACP, the U.S. should give serious consideration to making a political commitment to the IAEA that it will not withdraw ACP from the U.S.-IAEA safeguards agreement.

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[7] In USEC, Inc v. Eurodif SA et al, brief number 55, USEC has argued that it is the only entity that employs U.S. enrichment technology free of restrictions that encumber all other available sources of enriched uranium for the military needs of the United States, that it is the sole supplier of LEU used to fuel the government-owned nuclear reactors that produce tritium, a radioactive isotope necessary to maintain the U.S. nuclear arsenal in the future as stocks for the current stocks of HEU needed for the U.S. Navy's nuclear powered submarines and aircraft carriers are depleted.

[8] The U.S. DOE presently uses TVA's civilian light-water reactors (the Watts Bar and Sequoyah facilities) to produce tritium to help maintain the existing nuclear weapons stockpile. There is no legal bar to enriching uranium outside of USEC's facilities for supply at the TVA reactors.

Commercial Considerations

Some observers have serious doubts about whether USEC can be competitive against other enrichment suppliers. To date, the high cost of operating the outmoded and energy intensive gaseous diffusion technology has made it difficult for USEC to remain competitive in the U.S. and international market. This cost problem has been exacerbated by recent significant increases in power charges by TVA which supplies electricity to the Paducah facility.

On the other hand, USEC's competitiveness has benefited from a) obtaining relief under U.S. trade law and b) acquiring 50% of their LEU needs from the Russian Federation under the 1992 High Enriched Uranium (HEU) Agreement based on prices at or "below their cost of producing the LEU." These prices were negotiated with the Russian Federation, via their executive agent TENEX, under the HEU Agreement.

The U.S. Department of Commerce had made a preliminary affirmative dumping determination against Russian uranium imports in 1992. Before that determination became final, the U.S. Government entered into a "Suspension Agreement" with Russia under which Russia and the other former Soviet countries "voluntarily" limited their exports to the United States. The resulting import restrictions allowed Russia only a minimal share of the U.S. market. In 2008, the U.S. and Russia reached an agreement that allowed an increase in Russian exports of uranium to the United States beginning in 2011 over a ten-year period. This would, in effect, allow Russia to compete for 20% of the U.S. market from 2014 to 2020 and to compete without any restraints after that date. Legislation passed by Congress in September 2008 (the "Domenici Amendment") confirms the 20% allowance for Russian SWU imports but places all LEU purchased under SWU or enriched uranium product contracts under the 20% quota, regardless of U.S. court interpretations of SWU as a service or a product. Moreover, the U.S.-Russia HEU purchase agreement terminates in 2013, and the Russians have given every indication that they do not intend to extend the deal on its current terms. Russia's reasons for entering the original deal, namely the need for hard currency to pay for Russian nuclear assets, no longer apply. Finally, USEC will no longer be the only U.S. enrichment provider, since three new enrichment plants are being contemplated in the United States, LES/NEF, AREVA and GE-Hitachi, which will compete with USEC's new centrifuge plant.

ACP's competitiveness

There are also a number of concerns about the commercial competitiveness of the ACP, including the untried nature of the new centrifuge technology, the project's creditworthiness, rising construction costs and delays in scheduling, as well as questions about USEC's ability to produce SWU at prices that generate returns above its cost of capital. Significant price pressure on labor, commodities and construction materials has increased the company's anticipated cost for completing the ACP.

Technical uncertainties. Although USEC has confidence in the reliability of its new centrifuges (the AC100 series centrifuge machine), some experts believe that USEC's

failure to test the new design adequately could adversely and seriously affect the reliability of the machines in commercial operation. To these skeptics, it is particularly worrisome that USEC plans to start operations of its second Lead Cascade using 40 – 50 centrifuge machines manufactured for the first time by its supplier group in March 2009 but has yet to settle on its final value-engineered design. Other concerns from technical experts relate to the fact that USEC's centrifuge machine design calls for 350 SWU/machine while the top-of-the-line ETC machine runs at 80-90 SWU/machine and ETC has been manufacturing and operating centrifuge machines for over 35 years. ETC has chosen a "no maintenance" machine philosophy but this leads one to think that the USEC machine may be difficult to maintain in commercial operation.

Costs. Originally, USEC had anticipated the project to cost $1.7 billion. In May 2008 USEC estimated the project cost to be about $3.5 billion. This amount includes project spending to date but does not include financing costs or financial assurance, which USEC hopes to cover through a loan guarantee which it is seeking from DOE. USEC is trying to reduce its ACP machine manufacturing costs through value-engineering the centrifuge design but this could come at a price of reducing the reliability of its new centrifuges.

Need for additional ACP funding. USEC may also run into cash flow difficulties or have to slow the ACP construction in the future if it does not receive additional financing funds for the ACP. USEC received some $775 million in the form of equity shares and bonds in September 2007, but these funds are rapidly being consumed for the ACP construction. USEC's stock price, which was $14.25 per share at the IPO opening in 1998, is now below $4.00, and its corporate debt has a high yield or "junk bond" rating.

USEC is thus in need of funding to continue the ACP project. The omnibus fiscal year 2008 appropriations act authorized DOE to issue $2 billion worth of loan guarantees through the end of fiscal year 2009 for advanced "front-end" nuclear fuel cycle facilities. USEC has submitted the required phase I and phase II applications for the loan guarantee to DOE.[9] USEC is likely to obtain this loan guarantee from the DOE and will also acquire the funding itself from the U.S. Government through the Federal Financing Bank. (USEC's deteriorating credit rating has made obtaining loans from private banks for the ACP highly problematic.) Even if DOE approves the loan guarantee for USEC, the credit subsidy cost will need to be scored by the Office of Management and Budget, and USEC may have to pledge significant funds to pay this cost even before the construction of the ACP.

USEC would likely welcome foreign investment in the ACP, which could help provide crucial help in funding for USEC. However, investing in USEC's ACP could be a high-risk venture, and under present conditions the U.S. Government may be the only entity prepared to take that risk.

Market uncertainties. USEC currently delivers around 12 – 13 million SWUs per year to the market. If it sticks by its decision to close its Paducah gaseous diffusion plant once ACP begins operations, USEC SWU capacity will significantly drop to 3.8 million

[9] AREVA has also applied for a loan guarantee under this program for its proposed plant in Idaho.

SWUs. These SWUs are planned to be committed to domestic customers. (Japan is already moving to other sources of supply as USEC will be unable to supply any of the enrichment needs of the Japanese utilities after the HEU Agreement ends in 2013 if the GDP is also shut down leaving USEC with only the 3.8 million SWU of ACP capacity). Unless USEC decides to continue operation of its high-cost gaseous diffusion plant, it will not be in position to offer new enrichment contracts to foreign customers. Hence, it is not certain that USEC will be in a position to attract investment from foreign utilities or governments based on assurance of supply at competitive prices, unless it keeps the gaseous diffusion plant operating or expands the ACP well beyond its current planned initial capacity of 3.8 million SWU. (The ACP facility is licensed for up to 7.0 million SWU so USEC could continue to add centrifuge capacity to the ACP after it reaches the 3.8 million SWU level).

In addition, AREVA, Russia and Urenco are increasing their SWU capacity, and some estimates project that by the year 2018, this increased supply will be sufficient to meet global demand. Thus USEC is in a race to secure a market position before this capacity comes on line. Another question that could affect the future of the enrichment market is the laser enrichment process being developed by GE-Hitachi (GEH) using the Silex laser isotope separation process. If the GEH Silex process realizes its potential within the next decade, it will be far more competitive than the centrifuge.

In sum, USEC faces considerable market uncertainties, and it is open to question whether it will be able to offer enrichment services to foreign utilities at competitive prices.

Conclusions

Encouraging foreign participation in the ACP would enable the U.S. to take a leadership role in establishing a global norm that all new enrichment plants should be multinational in nature and subject to IAEA safeguards agreements. It would also further U.S. national interests by helping to maintain a reliable and competitive source of domestic enrichment services. An appropriate international financing scheme to operate a U.S.-based enrichment facility could service nuclear consumer countries that do not have their own enrichment capability. Finally, the economic competitiveness of USEC could be enhanced with a more robust financial structure that includes “credit-quality” international financial players. USEC could reduce its financial risks by expanding the financing structure with foreign entities and by offering firm contracts at attractive prices.

However, offering foreign utilities or governments an opportunity to participate in USEC’s ACP facility will present some challenges. USEC is facing a highly competitive market with a commercially unproven technology, a cost basis that may not prove to be competitive with other enrichment providers and substantial uncertainties in the future of the enrichment market. There is some doubt that USEC will be able to survive without the DOE loan guarantee of $2.0 billion. There is greater than 50 % probability that USEC will receive such a loan guarantee in the near future, but there is only a 50/50 chance that USEC will be able to absorb the front-end costs of such a loan guarantee, depending on the credit subsidy cost requirements.

It is open to question whether foreign utilities or governments would be willing to make what appears to be a high-risk investment in USEC unless USEC has strong political and financial support from the U.S. Government. If the U.S. Government decides that such support is in the national interest for economic, nonproliferation or other reasons, then multinational participation in USEC may be feasible. Offering participation in the ACP to foreign utilities or states, however, will require strong leadership from the Executive Branch and close consultations with the key Congressional leaders and the relevant Committees of Congress.

The Nuclear Suppliers Group and Multinational Enrichment Plants

Fred McGoldrick

The Untied States has long sought to limit the spread of enrichment and reprocessing facilities. Most recently, pursuant to the United States-India Nuclear Cooperation Approval and Nonproliferation Enhancement Act, President Bush certified that, "It is the policy of the United States to work with members of the Nuclear Suppliers Group, individually and collectively, to agree to further restrict the transfers of equipment and technology related to the enrichment of uranium and reprocessing of spent nuclear fuel."

The 45 members of Nuclear Suppliers Group (NSG) seek to prevent the spread of nuclear weapons through the implementation of guidelines for the nuclear and nuclear related exports. Each participating government applies the guidelines in accordance with its national laws, regulations and policies.

The NSG Guidelines were originally published in 1978 as International Atomic Energy Agency (IAEA) Document INFCIRC/254. The guidelines include a number of conditions for the export of nuclear materials and equipment that were identified on a "trigger list," so-called because the export of these items "triggered" a requirement that the recipient state provide certain nonproliferation assurances as a condition of supply. These included the acceptance of IAEA safeguards in perpetuity and a pledge that the transferred items would be used only for peaceful, non-explosive purposes as well as agreement to apply physical protection measures and to accept controls on retransfers of such items.

The NSG has evolved over time in order to keep pace with technical innovations and political developments and in response to various challenges to the nonproliferation regime. Among other things, the NSG now controls dual-use items and technology, i.e., articles that have both nuclear and non-nuclear applications and that could make a significant contribution to a nuclear explosive activity or an unsafeguarded nuclear facility. It also requires that a recipient of items on the NSG nuclear trigger list must accept IAEA safeguards on all its peaceful nuclear activities as a condition of new supply—so-called comprehensive or full-scope safeguards.

The original NSG guidelines included provisions for the transfer of sensitive nuclear technology (SNT), which included enrichment, reprocessing and heavy water production technology. These included the following provisions:

> Nonproliferation conditions. Safeguards, peaceful use assurances, physical protection and controls over retransfer should apply to facilities for reprocessing, enrichment, or heavy-water production, utilizing technology directly transferred

by the supplier or derived from transferred facilities, or major critical components thereof.

Restraint in the transfer of sensitive nuclear technology. Suppliers should exercise restraint in the transfer of sensitive facilities, technology as well as weapons-usable materials.

Multinational or supplier involvement. "If enrichment or reprocessing facilities, equipment or technology are to be transferred, suppliers should encourage recipients to accept, as an alternative to national plants, supplier involvement and/or other appropriate multinational participation in resulting facilities, Suppliers should also promote international (including IAEA) activities concerned with multinational regional fuel cycle centres."

No Production of HEU. The guidelines required an assurance by the recipient nation that any transferred enrichment or reprocessing technology or a facility based on such technology will be designed or operated for the production of uranium enriched no higher than 20 % without the consent of the supplier.

Replication of SNT. The NSG members agreed that the transfer of sensitive nuclear facilities, or major critical components thereof, or related technology, should require an undertaking (1) that IAEA safeguards apply to any facilities of the same type (i.e. if the design, construction or operating processes are based on the same or similar physical or chemical processes, as defined in the trigger list) constructed during an agreed period in the recipient country and (2) that there should at all times be in effect a safeguards agreement permitting the IAEA to apply Agency safeguards with respect to such facilities identified by the recipient, or by the supplier in consultation with the recipient, as using transferred technology. This provision was designed to prevent a recipient state that did not have full-scope safeguards from importing SNT under safeguards and then replicating another plant free of international safeguards. This requirement was subsequently deleted from the guidelines when the NSG adopted the requirement of full-scope safeguards as a condition of supply in 1992. Now that the NSG has exempted India from it full-scope safeguards requirement, the absence of a replication provision leaves a potential loophole, if members ever supply enrichment or reprocessing technology to India.

Facilitation of the Application of Safeguards. Finally, the guidelines called upon suppliers to encourage the designers and makers of sensitive equipment to construct it in such a way as to facilitate the application of safeguards.

While the NSG has made a number of amendments and additions to its guidelines over the years, the provisions for transfer of SNT have not changed except for the deletion of the replication provision.

In the wake of the revelations about the clandestine transfers of enrichment technology from Pakistan (the A.Q. Khan network) to the DRPK, Iran and Libya, President Bush called for two new initiatives designed to prevent the spread of enrichment and reprocessing capabilities. In a speech on February 11, 2004, President Bush proposed that a) the members of the NSG should refuse to sell enrichment and reprocessing equipment and technologies to any state that does not already possess full-scale, functioning enrichment and reprocessing plants and b) the world's leading nuclear exporters should ensure that states have reliable access at reasonable cost to fuel for civilian reactors, so long as those states renounce enrichment and reprocessing.

These proposals were not well received by many non-nuclear weapon states who saw them as a demand to forego or compromise their sovereign rights as independent states or their right under Article IV of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) to pursue their own peaceful nuclear program, including enrichment technology. Although the Bush Administration backpedaled from the language of renunciation and denial, suspicions remain about U.S. intentions.

Thus far the members of NSG have been unable to reach agreement on President Bush's proposals for enrichment and reprocessing transfers. Although the U.S. sought a new guideline that would ban the transfer of SNT except to countries already possessing such capabilities, most NSG members favored an approach suggested by France that would allow NSG members to export SNT to countries that meet specific criteria. The criteria approach would require that recipients meet at least all of the following criteria:

> Is a party to the NPT and is in full compliance with its obligations under that Treaty;
>
> Is implementing a comprehensive safeguards agreement and has an Additional Protocol in force or is acting in accordance with the AP while actively working with the IAEA to conclude and implement an Additional Protocol;
>
> Has not been identified by the IAEA as being in serious breach of its safeguards agreement, is not the subject of Board of Governors decisions calling upon it to take additional steps to comply with its safeguards obligations or to build confidence in the peaceful nature of its nuclear program, nor has been reported by the IAEA Secretariat as a state where the IAEA is currently unable to implement its safeguards agreement.
>
> Is adhering to the NSG Guidelines and has reported to the Security Council of the United Nations that it is implementing effective export controls as identified by Security Council Resolution 1540;
>
> Has concluded an intergovernmental agreement with the supplier including assurances regarding non-explosive use, effective safeguards in perpetuity, and retransfer;
>
> Has made a commitment to the supplier to apply mutually agreed standards of physical protection based on current international guidelines;

> Has committed to IAEA safety standards and adheres to accepted international safety conventions.

In addition the criteria-based proposal calls upon suppliers to consider:

> Whether the transfer would have a negative impact on the stability and security of the recipient state;
>
> Whether the recipient has a credible and coherent rationale for pursuing an enrichment or reprocessing capability in support of civil nuclear power generation programs.
>
> If enrichment or reprocessing facilities, equipment or technology are to be transferred, suppliers should encourage recipients to accept, as an alternative to national plants, supplier involvement and/or other appropriate multinational participation in resulting facilities. (This language is already in the present NSG guidelines and would remain unchanged in the new criteria-based approach.)

U.S. eventually came to accept the criteria-based approach but proposed three additional criteria:

> The transfer must take place under conditions that will not permit or enable the replication of the technology (the so-called “black-box” approach).
>
> Suppliers have to take into account whether a transfer would stimulate other countries in a region to seek their own SNT or whether it might lead to instability in the area.
>
> Suppliers will not transfer SNT to countries that have agreed to refrain from acquiring such technology. This is aimed at the South Korea and North Korea and their 1992 agreement under which both states agreed to refrain from possessing enrichment or reprocessing plants.

The additional criteria proposed by the United States were not accepted by some members of the NSG. The most significant difference concerned the criteria of black-boxing transfers of technology. Canada suggested that, instead of requiring black-boxing as a criterion for transferring SNT, suppliers would only have to consider the option of black-boxing the technology, or operating a turn-key operation when deciding whether to transfer enrichment or reprocessing to states in good nonproliferation standing. The U.S. and Canada are now trying to reach a compromise on this issue. Canada has recently proposed to accept the U.S. position but only for enrichment technologies that are already commercially deployed. The U.S. is insisting that the criteria apply to all enrichment technologies identified on the NSG trigger list, including those that are not yet commercially proven. In addition, some other members of the NSG have taken the position that no state that is in good nonproliferation standing should be denied access to

enrichment and reprocessing technology. Thus at this time, NSG members have been unable to agree on a new guideline for enrichment and reprocessing transfers.

If the NSG can agree on a new set of criteria on transfers of enrichment technology, it would strengthen, or at least give some specificity to, the existing guideline on encouraging "supplier involvement or appropriate multinational participation" as an alternative to national enrichment plants by providing that transfers should not permit or enable the revelation of sensitive information to the recipient.

The U.S. should also consider other steps that the NSG could take to promote a global norm that enrichment facilities should involve some appropriate form of multinational participation. First, the U.S. could propose reviving the debate that took place in the initial meetings of the NSG the mid-1970s when some states argued for a guideline that suppliers should "require" rather than encourage "supplier involvement" or "appropriate multinational participation" as an alternative to national enrichment plants. Some non-nuclear weapon states members may see this as a form of discrimination and a violation of their rights under Article IV of the NPT. However, objections to this criterion might be mitigated if NSG members who are also technology holders were to agree to invite multinational participation in their own enrichment facilities. The U.S. should explore with other technology holders whether they would be willing to make such an undertaking.

Second, the U.S. could attempt to persuade NSG members to assume a more positive and cooperative role in international nuclear cooperation. The NSG has an image problem. Some non-nuclear-weapon states, particularly developing countries, have viewed the NSG as a cartel aimed at denying them the benefits of the peaceful uses of nuclear energy and at relegating them to a position of technical and commercial inferiority. The language employed initially by the Bush Administration requiring renunciation of enrichment and reprocessing as a condition for receiving improved fuel assurances has only heightened this suspicion. The NSG could seek to assume a more positive and cooperative role in promoting international peaceful nuclear commerce rather than one that is devoted exclusively to imposing nonproliferation conditions on nuclear exports. For example, the NSG could adopt a common statement of principles that NSG members will strengthen the security of supply to importing countries and will not interfere with their supply arrangements as long as such states are in full compliance with their nonproliferation obligations. (See attachment for a suggested statement of such principles.) One of these principles could contain an offer to countries that do not possess enrichment facilities and that are in good nonproliferation standing the opportunity to participate in the enrichment plants of NSG member states. Such participation would include guaranteed supplies of nuclear fuel but would not include access to enrichment technology.

As an informal multilateral arrangement whose primary purpose is to control nuclear exports, the NSG can play only a limited role in promoting the idea of multinationalizing enrichment plants. Support for making multinational rather than national enrichment facilities an international norm will require a wider consensus that includes consumers and non-nuclear-weapon states. One possible way to accomplish this is by trying to

persuade the 2010 Review Conference on the Treaty on the Non-Proliferation of Nuclear Weapons to endorse this norm. However, this will require considerable effort, given the sensitivity of many states to maintain their rights under Article IV of the Treaty.
Attachment:

Suggested NSG Nuclear Supply Principles

The members of the NSG:

> Reaffirm the inalienable right of all parties to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) to the use of nuclear energy for peaceful purposes in conformity with their obligations under the NPT.
>
> Agree to promote international cooperation in the peaceful uses of nuclear energy.

In this spirit, NSG members agree to:

> Implement all nuclear supply agreements and contracts in good faith and with due regard to the legitimate commercial interests of importing states.
>
> Avoid hampering or delaying the peaceful nuclear activities in the territories of importing states.
>
> Avoid hindering, or interfering in, the peaceful nuclear activities in the territories of importing states.
>
> Take full account of the long-term requirements of the nuclear energy programs in the territories of importing states.
>
> Will not use their supply agreements or contracts to secure unfair commercial or industrial advantage to the disadvantage of the importing state, or to restrict trade or to hamper the international or domestic commercial or industrial interests of the importing states.
>
> Will not use authorizations, including export licenses and authorizations or consents to third parties relating to trade or industrial operations, in order to restrict peaceful nuclear trade.
>
> Will cease cooperation or suspend nuclear supplies only if an importing state materially violates its nonproliferation obligations.
>
> Will urge other nuclear suppliers to cease cooperation or suspend nuclear supplies to a state only if that state materially violates its nonproliferation obligations.

In addition, members of the NSG who operate uranium enrichment plants are prepared to provide states that do not have such facilities and are in full compliance with their nonproliferation obligations the opportunity to participate in their enrichment plants. Such participation would include guaranteed access to nuclear fuel supplies.