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# ROUTINE INSPECTION EFFORT REQUIRED FOR VERIFICATION OF A NUCLEAR MATERIAL PRODUCTION CUTOFF CONVENTION



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November 1996

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*Executive Summary**

Estimates of the inspection effort to verify a Nuclear Material Cutoff Convention are presented based on: (1) a database of about 875 facilities in a total of eight states, i.e., the five nuclear-weapons states and three "threshold" states; (2) typical IAEA experience for specific facility types, (3) a set of three options starting with full IAEA safeguards and, (4) estimates of "challenge" inspection to investigate/detect undeclared activities.

Three routine verification options are considered. In Option 1, all peaceful nuclear activities would be declared and verified as in non-nuclear weapons states party to the Non-Proliferation Treaty. In Option 2, declarations and verifications would be restricted to enrichment and reprocessing plants and to facilities storing or processing the produced fissile material. In Option 3, declarations would cover all nuclear facilities but verifications would focus on production at enrichment and reprocessing plants and on the disposition of the fissile material produced.

To account for the likelihood that non-routine inspection procedures will be included to provide a mechanism to pursue concerns about non-compliance, estimates for "challenge" or "undeclared site" inspection effort are also included. It is expected that these estimates would be simply added to those for routine inspection since the non-routine (challenge) inspection regime is expected to be independent of that for routine inspections. Challenge inspection effort estimates were based on certain specific assumptions derived from both IAEA Special Inspection procedures and the far more detailed Challenge Inspection procedures contained in the Chemical Weapons Convention. The report does not assess the adequacy of any of these options.

The computed effort values associated with the three routine verification options are about 35,000 person days of inspection effort (PDI), 29,000 PDI, and 10,000 PDI, respectively, which can be compared with the total of 8,200 PDI expended by the IAEA Department of Safeguards in 1993. (The 1993 budget of the Department of Safeguards was about $65 million, plus about $6 million in extra budgetary resources).

Uncertainties attached to the effort estimates spring from several sources: For example, about 60 - 75% of the effort for each option is attributable to the 19 large-scale reprocessing plants assumed to be in operation in the eight states; it is likely that some of these will be shut down by the time the convention enters into force. Another important question involving about one-third of the overall effort is whether Euratom inspections in France and the U.K. could obviate the need for full-scale IAEA inspections at these facilities. Finally, the database does not yet contain many small-scale and military-related facilities. The results are, therefore, not presented as predictions but as the consequences of alternative assumptions.

Despite the preliminary nature of the estimates, it is clear that a broad application of NPT-like safeguards to the eight states would require dramatic increases in the IAEA's safeguards budget. It is also clear that the major component of the increased inspection effort would occur at large reprocessing plants (and associated plutonium facilities). Therefore, significantly bounding the increased effort requires a limitation on the inspection effort in these facility types.

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1. Introduction

On 27 September 1993, President Clinton proposed " ... a multilateral convention prohibiting the production of highly enriched uranium or plutonium for nuclear explosives purposes or outside of international safeguards." The UN General Assembly subsequently adopted a resolution recommending negotiation of a non-discriminatory, multilateral, and internationally and effectively verifiable treaty (hereinafter referred to as "the Cutoff Convention") banning the production of fissile material for nuclear weapons. The matter is now on the agenda of the Conference on Disarmament, although not yet under negotiation.

This accord would, in effect, place all fissile material (defined as highly enriched uranium and plutonium) produced after entry into force (EIF) of the accord under international safeguards. "Production" would mean separation of the material in question from radioactive fission products, as in spent fuel reprocessing, or enrichment of uranium above the 20% level, which defines highly enriched uranium (HEU). Facilities where such production could occur would be safeguarded to verify that either such production is not occurring or that all material produced at these facilities is maintained under safeguards.

Material already produced under weapons programs would be "grandfathered" and maintained as not subject to safeguards, although some nuclear weapon states may voluntarily place excess nuclear material from their weapons stockpile under safeguards. The US is already doing this.

The IAEA is expected to play a key role in the verification regime under the Cutoff Convention. It is assumed that existing comprehensive IAEA safeguards arrangements for non-nuclear-weapons states (NNWSs) would essentially meet the verification requirements of the Cutoff Convention, so that the new verification requirements would apply mainly to the nuclear-weapons states and the so-called "threshold states" which are considered to be weapons capable. Thus this paper focuses on eight states: the U.S., Russia, China, the U.K., France, India, Pakistan, and Israel (G-8). The first five states are the nuclear weapons states (P-5); the last three are the threshold states (T-3).

This new set of international safeguards would presumably be applied by the International Atomic Energy Agency (IAEA), just as safeguards are currently applied under extant international agreements, including the Nuclear Nonproliferation Treaty (NPT) and a large number of bilateral and multilateral nuclear agreements between the IAEA and many individual states.

Verification requirements for the G-8 may well be somewhat different than under the NPT and its main implementation model, IAEA document INFCIRC/153[(1)]. For example, since the Fissile Material Cutoff Treaty (FMCT) would have as its goal the capping of weapons stockpiles among states that already possess nuclear weapons it would not be necessary to be concerned with diversion of amounts as low as 1 significant quantity (SQ). Establishing a higher figure could enable the regime to meet its verification requirements, which might not be the case otherwise since many active reprocessing and any HEU enrichment facilities in at least some of the nuclear weapon states could not have their flow and inventory verified to the 1 SQ level for a number of technical reasons.

This paper provides estimates of the inspection effort that would be required under a cutoff convention for routine verification activities of declared facilities and challenge inspections for undeclared sites. For routine verification, three options are considered. Challenge inspection can be applied to any of the three options.

The estimates are based on a database of about 875 facilities in the eight states. The inspection effort estimates should be regarded as preliminary for several reasons. First, the verification options themselves are not yet clearly defined. Second, the operational status of some important facilities is uncertain at present and cannot be predicted at the time of the Convention's entry-into-force. Third, the database does not yet contain many small-scale and military-related facilities, which may affect the required inspection effort. Fourth, the facility-type inspection-effort estimates do not take into account the particular features of individual facilities, which can dramatically affect the required safeguards inspection effort.

Continuing efforts are being made to refine the database. The accuracy of the effort estimates will improve as more information is incorporated on the facilities themselves and as the verification options crystallize.

## 1.1 Previous Studies

There have been at least two studies that estimate the additional safeguards burden on the IAEA that an FMCT would entail. One was produced by Brookhaven National Laboratory(2) and the other by the IAEA itself(3). The estimates were made based on the number of facilities in the eight designated states that would be newly subject to safeguards and the amount of inspector effort required to safeguard these facilities, based on facility type and on the effort historically needed by the IAEA to maintain safeguards that could detect diversion of 1 SQ in a timely manner. Several different options for an inspection regime were assumed in these studies, ranging from the application of rigorous safeguards, under the INFCIRC/153 model to more lenient regimes, which would seek only to verify that unsafeguarded fissile material (not low enriched uranium or fertile material, for example) is not being produced at those facilities that have an inherent capability of doing so.

Even though the two studies differed in their detailed assessments of additional inspection effort required and the financial costs for the additional effort, both studies agreed that the required additional resources multiply the current total IAEA safeguards effort by roughly a factor of 2 to 5. Therefore, it would be useful to consider how to reduce this additional load upon the international inspectorate and ultimately upon the willingness of member states to finance such a large increase in IAEA inspection effort. This report also presents several options that might reduce the additional load in the long term.

## 1.2 This Study

This study updates the previous Brookhaven paper and fills in some of the gaps not covered in that study and compares the results of that study with a similar effort reported by the IAEA. To perform the various spread-sheet calculations, this study uses an updated data base of facilities in the eight states, as listed in Table 1. Table 1 includes the numbers of various facility types used for the calculations and includes, for the sake of comparison, the numbers of each facility type used in the previous study[1]. Because the updated facility data base is more complete than that used previously, we expect the current results to be more reliable. Furthermore, comparison of the data in Table 1 shows that the numbers and types of facilities has been rather dynamic. This may or may not continue in the future.

This study also assesses one additional option based on a recent (mid-1996) P-5 position. On the one hand, the U.S. and other P-5 members expect reactors (other than plutonium production reactors) and spent fuel to be excluded from safeguards under the FMCT regime. However, this new option includes an estimate of the inspector effort required for challenge inspections. Since the challenge inspection regime has not yet been defined, the basis for our estimate is, of course, open to substantial uncertainty. Nonetheless, since challenge inspections are considered necessary to provide a measure of assurance in various nations that an FMCT regime can be effective against the potential employment of clandestine production facilities some estimate seems required. The estimate included here assumes that there can be only a limited number per year, based on a quota system or on a prioritized selection process required by limited resources. Further, this option includes the requirement to safeguard MOX facilities and fresh MOX fuel, since the plutonium contained therein will not be protected by a radiation field.

There are various difficulties with challenge inspections, including the need for operators and member states to protect proprietary information from international inspectors. The need to protect proprietary information areas exists in routine inspections as well. In addition, there is the onus imposed on the inspected party for having aroused suspicion in the first place as well as the burden of allowing inspectors enough access and information to alleviate the concern that resulted in the challenge inspection. Furthermore, the economic burden placed on the inspected party may be substantial. The suggested solution[4] is, first, to apply lessons learned in developing the Chemical Weapons Convention (CWC) that make possible the maintenance of appropriate secrecy while allowing adequate inspection and, second, to "routinize" such inspections, thus removing their onus. (Note that challenge inspections in the CWC permits a substantial period between the request for a challenge inspection and the start of such an inspection.) For example, the regime might specify a quota of two challenge inspections per year per party (among the eight states). This may or may not be viewed as more equitable than, for example, having a finite number of challenge inspections available on a "first come first served" basis.

Other concerns which relate to challenge inspections is the matter of non-discrimination, frivolous challenges and the right to request a challenge inspection. It may be argued that a simple quota of two challenge inspections per state-party per year is highly discriminatory against the state parties with fewer facilities or a smaller industrial base opposed to say the United States or Russia. One approach to controlling frivolous challenges would be to require the challenge in cases where the inspection reveals no violation to pay the full cost of the inspection including that of the inspected party. Note that CWC provides that if the Elective Council finds that the state party requesting a challenge inspection has abused the intent of the CWC, it can recommend that the state partly bear some or all of the financial burden of the inspection. A further development of such an approach might require the challenger to post a bond in an amount which would approximate these costs. The right to request a challenge inspection might reasonably be limited to the group of eight. This however might be perceived as discriminatory. Another arrangement would permit challenges by all signatories of the

NPT and yet another would permit such requests by the secretariat as well. Inspection effort for challenge inspections is assessed in Section 5.

## 2. Cutoff Convention Options for Routine Verification

Three options for routine verification effort for the Cutoff Convention are considered. One option entails broad inspection activities very similar to those applied under the NPT; a second entails similar activities but restricts their scope to certain facility types; the third involves less intensive verification while the fourth is a variation of Option 2 that includes challenge inspection. Facilities to be routinely verified under these options are shown in Table 2.

In Option 1, the verification regime would include reprocessing plants, enrichment plants, all civilian reactors, and military reactors (to verify shutdown). The regime would also include spent fuel storage facilities, MOX fabrication and storage of fresh MOX fuel. Skirting the questions of whether fungibility and co-processing are to be permitted, and whether it would be necessary to verify material control and accountability to levels of 1 SQ, or not, the flow and inventory of plutonium and HEU from both reprocessing and enrichment plants would be verified and estimates of inspection effort needed would then be based on typical values for similar facilities in the past, under INFCIRC/153. The objectives of verification would be the detection of diversion and the detection of undeclared production, particularly from enrichment or reprocessing plants. All peaceful nuclear activities would be declared, including existing inventories of fissile material not for military purposes, and all would be routinely inspected. Shutdown facilities retaining nuclear material would undergo less intensive inspections than operating facilities. Facilities without nuclear material and military facilities with the exception of production reactors would not be declared or be subject to routine inspection. Production reactors would be subject to verification of their shut-down status.

Option 2 preserves the structure of IAEA safeguards but restricts the application to the facilities most relevant to the Cutoff Convention, particularly enrichment and reprocessing plants. The objectives of verification at operating facilities would be the detection of diversion or undeclared production. At shutdown facilities, the objective would be verification that production is not possible and that none has occurred since the EIF of the Cutoff Convention. All (operational or not) enrichment and reprocessing plants would be declared, as would the research and development facilities capable of the same operations. Also declared and verified would be facilities storing or processing highly enriched uranium (HEU) and plutonium produced after the Cutoff Convention's EIF. Facilities processing only low-enriched uranium (LEU), military facilities, and facilities with subject fissile material produced before the EIF of the Cutoff Convention ("grandfathered" material) would not be declared.

Option 3 has narrowly focused routine inspections but broad declarations. There would be three objectives of verification under this option. First is the verification of production and the detection of undeclared production at production facilities. Second is the verification of the disposition of subject material at storage facilities and processing facilities. Third is the detection of undeclared production at other processing facilities. All nuclear processing facilities would be declared, excluding only storage and military facilities with subject fissile material produced before the entry-into-force of the Cutoff

Convention. Table 1 summarizes the three options. Inspection efforts for these options are respectively 35,000 person-days of inspection effort (PDI), 29,000 PDI and 10,000 PDI.

The approach to estimating inspection effort outlined above, ignores the problems of detecting clandestine production facilities. For "small" facilities (say, for the sake of argument, capable of producing material for only a few weapons per year), such as hot cells or (eventually) advanced laser enrichment facilities, detection would be a severe challenge. Challenge inspections or international monitoring using environmental sampling are possible options for attempting detection of active facilities of these sorts. The resource requirements for such activities have not been accounted for in either the previous Brookhaven or the IAEA studies. On the other hand, there are strategies for savings in the IAEA effort. If EURATOM, for example, rather than IAEA, were to verify compliance by the United Kingdom and France, the cost would be borne by a subset of IAEA member states, but not by the IAEA. This is not without precedent. Recent changes in working agreements between the IAEA and EURATOM for current safeguards activities in EURATOM states may save the IAEA 50% in inspection effort of member states of EURATOM. Section 7 contains a brief discussion of this option. Similar arrangements could be worked out with other subsets of the eight states. Remote monitoring has the potential to save some fraction of inspection effort for spent fuel storage ponds and perhaps in safeguarding reactors. Remote monitoring is further discussed in Section 7.

For baseline comparative purposes using current inspection procedures, this paper employs the assumptions outlined earlier - namely, that inspection effort estimates include declared hot cells and challenge inspection, but do not include reactors, unless they use MOX fuel, or spent fuel storage. The IAEA study referred to in Section 1.2 above assesses a set of somewhat different options denoted as Alternatives A, B, C and D. Alternative A, which is the minimal option, verifies storage of separated Pu and HEU, the input and output of reprocessing and MOX facilities, enrichment plants capable of producing HEU, and MOX and HEU fueled reactors. Alternative B adds ALL enrichment facilities and calls for material balance verification at inspected facilities Alternative C adds reactors using LEU and natural uranium and irradiated fissionable material (i.e., spent fuel). Finally, Alternative D, essentially an INFCIRC/153 regime, adds LEU and fertile material.

The IAEA study provides overall assessments of inspection effort according to facility type, but not according to inspection type. The Brookhaven study provides more detailed assessments of effort required for different aspects of inspections, including physical inventory verifications (PIV), interim inventory verifications (IIV), flow verifications (FV) - and the number of each (NIV, NFV) that are required - as a function of the facility type, as listed in Table 3. Table 3 also gives the total annual inspection effort (AIE).

$$AIE = PIV + NIV * IIV + NFV * FV.$$

These quantities are stated in terms of PDI.

Table 1 referred to in Section 1, presents a breakdown for reprocessing plants, enrichment plants, power reactors, production reactors and other. The IAEA paper provides a more detailed breakdown for facilities, including hot cells, MOX facilities and some others and the IAEA estimates are used for each of these facility types. Although the Brookhaven breakdown by facility type is coarser, it is still instructive to compare the two sets of results regarding, specifically, the presence of spent fuel and LEU/natural uranium reactors on inspection effort. According to the Brookhaven study, including spent fuel and LEU/natural U reactors (roughly Option 2 versus Option 1, although there are other small differences between the two definitions of the options) adds about 20% to the estimated inspection effort. According to the IAEA, looking at Alternative C, with and without spent fuel and reactors, one arrives at a difference of about 25%. This provides some confidence in this relative estimate - i.e., with and without spent fuel and reactors.

3. Facility Information

For the current report, both classified and unclassified sources of information have been used.

The database contains information about several facility types. These encompass facilities primarily for the production of electric power for civilian needs, those primarily for the production of fissile material for military purposes, and those specializing in research and development. The facility types are listed in Table 1. Regarding military production fuel cycles, only the reactors, enrichment plants, and reprocessing plants are included in the database at present. Associated fabrication and weapons assembly-disassembly facilities are not yet included. Also absent are such small-scale but important research facilities as hot cells and many shutdown research facilities. For each facility included, the database has information about status, gross technical features, and the sources of the information. Inspection effort estimates desegregated according to facility states and country in which they are located are presented in Appendix B. Facilities currently under construction or decommissioned do not contribute to the inspection effort totals. Inspection effort estimates disaggregated according to facility status and country of facility location are presented in Appendix B.

Information about several data elements is lacking for some of the facilities in question here, particularly those in states other than France, the U.K. and the U.S. Indeed, even the exact numbers of facilities associated with the military nuclear fuel cycles are not precisely known.

There is no information in the database yet indicating that certain light-water reactors may be utilizing mixed-oxide (plutonium plus uranium) fresh fuel.

4. Facility Inspection Effort Characterization

Table 2 contains the effort values commensurate with IAEA practice under INFCIRC/153 which were used for the effort calculations. Values listed are for operating and shutdown facilities. The inspection effort estimates derive from values typical of facilities currently undergoing IAEA safeguards, for which the data are adequate and the verification systems generally good. These values characterize Option 1. Values for Options 2 and 3 are derived on the basis of judgment from the Option 1 values.

Precise predictions of actual inspection effort at nuclear facilities depend on a detailed knowledge of facility characteristics, operational status, and safeguards approach. Additionally important is the State System of Accounting for and Control of Nuclear Material (SSAC), which sets requirements for the measurement and reporting system of individual facilities. However, facility and SSAC characteristics are not known for all situations addressed here. Nor is there experience with an IAEA safeguards approach for some of the facility types. For example, there is no reliable basis for estimating the total inspection effort that would be required at large gaseous diffusion enrichment plants, so the values used are somewhat arbitrary.

Another difficult area is that of facilities in various stages of shutdown; obviously those which are completely inoperable will require less inspection effort than those on "warm standby" or "cold standby," but these distinctions are not yet captured; each plant requiring inspection effort is now designated either operating or shutdown. (Decommissioned means there is no nuclear material.)

The PDI is the most easily estimated inspection effort parameter. It is not straightforward to convert values for PDI to numbers of inspectors required because of the co-location of facilities and because one PDI can represent a very short time in a facility on a given day or it could represent an inspector present during an entire shift. A very crude conversion from PDI to dollar cost, which ignores subtleties including costs which are present and which are independent of the number of PDI and which may be significant, can be derived from the fact that the IAEA Department of Safeguards conducted 8,200 PDI in 1993 on a Department budget of $65 million; this yields a ratio of about $8,000/PDI.

- For a light water reactor (LWR), 3 PDI are required for a PIV, 4 PDI are required for all quarterly IIVs; for verification of spent fuel shipments, 2 PDI effort requirement verifications at on-load reactors (OLRs), which are refueled continuously. Monthly IIVs are required if the LWR has fresh, mixed-oxide (MOX) fuel present. The total under Option 1 is 9 PDI for LWRs and 21 PDI for OLRs.

- Plutonium production reactors with off-load refueling of natural uranium require 6 PDI for a PIV and 8 PDI for each of 8 refueling (plus spent fuel shipment) campaigns. The total effort would be 70 PDI.

- Critical facilities require increasingly large inspection efforts for the PIV and possibly monthly IIVs depending upon the nature of the facility - thermal vs. fast. (A better formulation would depend on the amount of nuclear material present). The effort ranges to 15 PDI for the PIV and 2 PDI at each of 11 monthly IIVs for a fast critical facility, for a total of 37 PDI.

- Research reactors require 1 PDI for the PIV and possibly several IIVs. For example, monthly IIVs would be needed if there is a large amount of fresh HEU fuel. Very small research reactors would require none. As used here, the total effort could range from 1 to 12 PDI and depends on the nature of the facility - thermal, fast, or training. A better formulation would depend on the amount of fresh fuel and operational mode.

- Reprocessing plants in operation require 60 PDI for the PIV, 5 PDI for each of 11 IIVs, and 600 PDI for full-time flow verification (given 200 assumed days of operation) for a total of 935 PDI. Note that this is the largest single facility-specific inspection effort total.

- Centrifuge enrichment plants in operation require 25 PDI for the PIV, 2 PDI for each of 5 IIVs, and 4 PDI for flow verification at each of 11 monthly inspections, for a total of 79 PDI.

- Gaseous diffusion enrichment plants in operation require 50 PDI for the PIV, 2 PDI for each of 5 IIVs, and 4 PDI for flow verification at each of 11 monthly inspections, for a total of 104 PDI.

- Fabrication plants making low-enriched uranium fuel require 60 PDI for the PIV and 4 PDI for each of 5 flow verifications. The total is 80 PDI.

- Conversion plants handling low-enriched uranium require 30 PDI for the PIV and 4 PDI for each of 5 flow verifications. The total is 50 PDI.

- Older fabrication plants making plutonium or mixed oxide fuel without highly automated methods require 60 PDI for the PIV, 25 PDI for each of 11 IIVs, and 400 PDI for two-shift flow verification, given 200 assumed days of operation, for a total of 735 PDI. The same effort breakdown is assumed to apply to plutonium conversion facilities.

- Very modern fabrication plants making plutonium or mixed oxide fuel by highly automated methods require 60 PDI for the PIV, 15 PDI for each of 11 IIVs, and 15 PDI for each of 11 flow verifications, for a total of 390 PDI.

- The inspection effort for other facilities, including small-scale reprocessing plants and storage facilities is given in the complete summary table included as Appendix A.

This information is summarized in Table 3. Note that bulk facilities, particularly those processing plutonium, require substantially more effort than do facilities such as reactors, which handle material in item form.

## 5. Overall Inspection Effort for Cutoff Convention Verification: BNL Estimate

### 5.1 Routine Inspection

For Option 1, the overall inspection effort required is about 35,000 PDI. To put this effort requirement in perspective, we reiterate that the effort expended by the IAEA for routine safeguards verifications, predominantly in states without nuclear weapons and not including the effort expended for verifications under UN Security Council resolutions, was 8,200 PDI in 1993. For Option 2, the overall inspection effort drops to about 29,000 PDI of inspection, because of the narrower scope of facilities subject to routine verifications. For Option 3, the inspection effort required is about 10,000 PDI of inspection. This effort is much lower than for Options 1 and 2 because of the narrower scope of facilities and the narrower focus of verifications.

The results are displayed in Table 1. Each facility group in the table lists the number of facilities in the database followed by the PDI value in the three cases. The first value includes shutdown facilities.

For all three options, the effort requirement derives predominantly from facilities handling plutonium and highly enriched uranium. Facilities such as light-water reactors require substantially less inspection effort. Reprocessing plants alone account for 60%, 74%, and 70% of the inspection effort in the three cases respectively.

Using the crude cost conversion mentioned in Section 4, the effort estimate of 35,000 PDI for Option 1 leads to a cost estimate of about $280 million. Analogously, the Option 2 effort estimate of about 29,000 PDI leads to a cost estimate of $230 million, while the Option 3 effort estimate of about 10,000 PDI leads to a cost estimate of $80 million. The range of inspection effort costs is very large, reflecting the differences in routine verifications among the three options. Note that the lowest effort scenario, Option 3, results in more than doubling the agency's inspection effort while Option 1, with the highest effort, results in multiplying the current level of inspection expenditures by more than five.

As stated earlier, it is not straightforward to convert values for PDI per year to number of inspectors required. However, one can obtain a crude estimate of the number of new inspectors that would be needed from the current staffing levels at the IAEA. The current professional staff of the three operations (inspections) divisions of the Department of Safeguards numbers about 200; these inspectors account for a yearly total of about 8,200 PDI. Given that the inspection staff size is proportional to the annual PDI, the additional inspection staff needed under the three options are 850, 710, and 240, respectively. In addition to the monetary expense for these additional inspections, bringing these additional inspectors "on line" in a timely manner would be difficult, since there will be a need for recruitment, training and field experience.

It is clear that the PDI totals are mostly driven by the large values of about 900 PDI assigned to each large reprocessing plant. It may well be that many of these facilities will be shut down by the time the convention enters into force. However, note that in Option 1 there are about 14,000 PDI assigned to facilities other than reprocessing plants, a value which by itself is 170% of current IAEA inspection effort. It is also true that small-scale facilities not included in the database may significantly increase the inspection burden.

For reasons cited throughout the report, the effort estimates are subject to large uncertainties; the results therefore are not presented as predictions but as the consequences of alternative assumptions. It is a straightforward exercise to redo estimates for other verification options and for different facility-specific effort requirements. The facility database will undergo further review and expansion based on classified information. Finally, the effectiveness of the IAEA verification procedures may not be the same for military facilities as for modern civilian facilities, for which safeguards verifications are part of the design considerations.

### 5.2 Additional Inspection Effort Due to Challenge Inspections

Challenge inspections would place an additional burden upon the IAEA, but even assuming three such inspections per party per year for the eight states, the additional burden would be relatively minor. Twenty-four inspections of 12 days each, and with 10 inspectors participating, amounts to 2880 additional PDIs or $23 million/year, or just under $1 million per challenge inspection. This is roughly a ten per cent effect. The effect of adding challenge inspections on AIE is shown in Table 4. If 20 inspectors were required, as might be needed if it were necessary to seal a facility around the clock for 7~8 days, as might be done under CWC challenge inspection, the level would be 20% of the total effort, and about 2/3 of the current total IAEA safeguards inspection effort. Additional effort to inspect hot cells only amounts to about 220 PDI's and is thus not significant. Inspecting MOX fuel fabrication facilities adds 2600 PDI's, which is a ten per cent effect as well.

Another possibility would be to use special inspections, as foreseen in INFCIRC/153. This type of challenge inspection would not be as convincing to the international community, because, under the provisions in INFCIRC/153, the host nation would have to be informed of the inspection and agree to it, allowing for lengthy delays. However, the number of inspectors would be fewer than under CWC challenge inspection rules. Perhaps five would suffice, and 8 days could be sufficient for sample taking. Then, 40 PDI's times 24 inspections would yield 960 PDI's - substantially fewer than in the other case.

An additional option for challenge inspections might be to use (with the permission of the host country) an unmanned aerial surveillance vehicle (UAV) to substitute for the large number of inspectors. The visual or infrared imaging from such a system could, in principle, be relayed in real time through satellite communications, to, for example, the Vienna HQ of the IAEA. However, the operation and maintenance of this resource is costly.

Current estimates for cost of the PREDATOR UAV, which is being used rather successfully in Bosnia[(5)], amount to about a $8.5 million purchase price (for two units with visual and infrared capability, satellite control and communications, and ground stations) and $250 per air hour operating cost. Eliminating one ground station might be possible and would reduce the cost to about $6.2 million. About 4000 hours per year could be required, amounting to $1 million in operating expenses. The cost-benefit tradeoff of a UAV of this type also depends on the period of time over which the acquisition cost can be amortized. If one assumed five years, the total cost would be well over $2 million/year, which might be enough to pay for the additional inspectors who could be replaced on challenge inspections by the UAV system. So there may be no advantage to using UAVs to reduce inspector effort.

## 6. Comparison of Inspection Effort Estimates

### 6.1 Summary

The IAEA and BNL studies referenced in Section 1.2 above concluded that a rigorous option would require on the order of 25,400 (IAEA) to 35,000 (BNL) PDI per year[(6)]. The rather large difference may be due to a more complete data set available to Brookhaven (which has access to more sources of information for nuclear sites in the P-8 than does the IAEA. Further, some additional types of military facilities are explicitly accounted for in the Brookhaven estimates.) By either estimate, the additional resources for monitoring compliance with an FMCT are enormous. For clarity, the reader is reminded that this estimate does NOT include any assignment of costs for challenge inspections or other efforts (e.g., environmental monitoring under "93+2") to detect clandestine facilities. The cost of the additional effort is considered to be between $140 million/year (IAEA) to $280 million/year (Brookhaven)[7]. Current IAEA safeguards costs are about $65 million per year, and have remained essentially constant[8] since 1985.

### 6.2 IAEA-BNL Estimate Inconsistencies

There is a puzzle in that while both BNL and IAEA agree that, for 1993, some 8,200 PDIs of inspection effort cost $65 million, the IAEA finds that this results in a cost per PDI of $7,200.

Further, using the PDI's as accounted for in the IAEA report, one arrives at an implicit assumption of only about $5600 per PDI (not $7200). This is in spite of the fact that the final costs cited include indirect costs and support costs as well (para. 36 of the IAEA report). This difference in estimates, whatever its origin, accounts for most of the difference between the more pessimistic (costly) BNL appraisal and the IAEA accounting.

Looking more closely at the PDI estimates, we can discover, according to the IAEA, how large a fraction of the total effort is due to items of interest, such as hot cells, MOX fuel fabrication facilities and storage, reactors, and spent fuel storage. The IAEA report breaks down inspection effort clearly among several different types of facilities. It estimates that, for the eight states in question, 2600 PDI's are needed for MOX facilities, 1100 PDI's for spent fuel in storage, and 4000 PDI's to inspect reactors. Reactors and spent fuel thus require 5320 PDI's out of a total of 22,100 PDI's required for the IAEA under "Alternative C." This alternative includes INFCIRC/153 safeguards for most nuclear facilities, including those that produce separated and irradiated materials. Low enriched uranium and fertile materials are excluded from the "Alternative C" inspection regime.

Removing the requirement to inspect these facilities reduces the required inspector effort by about 25%. The burden on IAEA would still be considerable, demanding a tripling of effort and resources relative to the current situation, but including these facilities would require a quadrupling of effort. Policy makers will have to consider whether the additional expense is worth the effort to safeguard these facilities and materials under an FMCT. However, there are possibilities for mitigating costs; these are presented in Section 7.

## 7. Opportunities for Economizing on Inspection Resources

### 7.1 Allow IAEA to Act as Auditor of Multilateral Inspections

Under agreements between the IAEA and EURATOM, a good part of the inspection activities of EURATOM member states are made by, and at the expense of, EURATOM itself. Since two of the eight parties envisioned as targets of the FMCT are also members of EURATOM (the United Kingdom and France), it is conceivable that the cost of inspecting those two countries could be primarily accomplished by and at the expense of EURATOM. This would reduce the burden on IAEA considerably. The IAEA could undertake a monitoring role, in this case (verifying the activities of the EURATOM inspectorate) and save about 50 % of the cost of these inspections[9]. However, the fraction of effort devoted to these two countries would constitute about 30 % of the total effort needed to verify an FMCT[10] so a 50% reduction due to substitution of inspection effort by EURATOM could, in principle, amount to a 15% reduction in total safeguards effort by the IAEA. Of course, it is not clear that the rest of the world would necessarily accept this substitution by EURATOM. It is possible that some other nations might suspect a cover-up of diversion by the allies of France and the United Kingdom.

An elaboration of this approach might include bilateral inspections by the US and Russia of each others' facilities. There are at least two considerations, as follows:

First, the US and Russia might prefer inspections by each other at their sensitive facilities compared to having inspectors from the rest of the world intruding and possibly deducing information useful for the manufacture of nuclear weapons. In fact in early analyses of a possible FMCT during the Cold War, it was considered likely that an agreement and inspections would be more achievable under a bilateral regime than under IAEA safeguards for just this reason. This, of course, depends on whether proliferation or exposing potential weapons vulnerabilities is the primary concern. Since both have advanced nuclear arsenals, the potential utility of any secrets that leaked to the other party would be problematic. This is not to imply that this would be an insignificant problem.

Second, the effort could be paid for by the U.S. and Russia instead of by the IAEA; since nearly half of the facilities in question are located in these two states (see Table 1), the reduction of IAEA effort would be considerable. Of course, the IAEA would have still have to verify the accuracy of the bilateral inspections by audits and spot checks of its own, but the resources needed for this should be considerably less than for the full-blown inspection regime. There is a precedent for the IAEA overseeing bilateral inspections by two states, i.e. the ABACC arrangement between Argentina and Brazil. Again, as for the EURATOM option, the question is whether the rest of the world would accept the US and Russia policing each other.

Taking this approach even further, suppose India and Pakistan were to inspect each other as well, with the IAEA as auditor.

We have now posited three possible bilateral arrangements among the eight countries affected, leaving out only China and Israel. For a rough estimate, if auditing by the IAEA were to cost only 50% of the total expenditure, and if only China and Israel were to remain inspected by the IAEA in a complete fashion, some 40% of the expenditure and effort by the IAEA could be saved. The question at this point is whether China and/or Israel would object to this kind of "discrimination."

The ultimate option would be to have all eight countries inspect each other, with the IAEA performing the auditing oversight function only. Then, based on the EURAT0M estimate of savings amounting to 50% of the total inspection effort, a ball park estimate would be that half of the estimated $140 million to $280 million additional cost of an FMCT could be saved by such an arrangement.

## 7.2 IAEA Authentication of U.S. Domestic Safeguards

United Stated domestic safeguards is a highly developed and effective system. Given the magnitude of the U.S. weapons stockpile clandestine activities directed toward augmenting such a stockpile are not credible. Reliance on IAEA authentication of U.S. safeguards might be acceptable as a means of substantially reducing IAEA resources required for direct FMCT inspections. Note from Table 1 the very substantial portion of IAEA resources required for inspection of U.S. facilities.

## 7.3 Remote Monitoring

Spent fuel storage ponds and reactors could be monitored in near real time, using remote monitoring systems, with the ability to transmit data (including alarms indicating illicit activity) to IAEA headquarters in Vienna or to a regional center out of country. This technique could reduce the required inspection effort considerably. One informal estimate has it that from 8% to 20% of the IAEA inspection effort could be saved by remote monitoring of this sort. If one were to accept safeguards on spent fuel and reactors, this method could greatly mitigate the 20% differential in required inspection effort for reactors and spent fuel storage.

## 7.4 Spent Fuel

Although removal of spent fuel from the category of subject material would reduce the inspection effort needed to verify an FMCT, there are serious problems with this approach. First, the fissile materials in military spent fuel cannot be "grandfathered" as non-subject material since it is not separated from fission products at EIF. So military spent fuel is apparently meant to be safeguarded under an FMCT. Why then should civilian spent fuel be exempt since the crucial related problem of finding clandestine hot cells may not be solved convincingly enough to ensure that verification of non-production is adequate?

Above what level does the radiation field of spent fuel make it self-protecting is an important question yet to be resolved. Only above this level (once determined) can spent fuel be removed from FMCT safeguards. One difficulty arises from the low irradiation levels of some fuel notably CANDU fuel, which is only irradiated to about 7500 MWD/tonne, which is far less than the irradiation levels of spent fuel from light water reactors. Another factor is that the radiation field decreases over time, diminishing its protection. The same argument may be made even more strongly for HEU-fueled research reactors, where irradiation is often even less. Military spent fuel is irradiated to only a slightly lesser degree; therefore it may be argued that the quality of the Pu in CANDU fuel is relatively good for weapons purposes. The important issue of how large the radiation field must be in order for spent fuel to be self-protecting, and thus exempt it from FMCT safeguards, is being dealt with elsewhere and will not be considered here.

# 8. Conclusions

The following general conclusions, not including the Cost Savings paragraph, appear to be supported by this study and the two previous studies (References 1 & 2).

*Total Inspection Effort*: The total inspection effort required under an FMCT would, in every case examined, substantially increase compared to the current resources expended for IAEA safeguards under the NPT.

All additional inspection efforts would take place in the eight states of current concern (i.e., the P-5, Israel, India and Pakistan). There appears to be little point in adding obligations (e.g., challenge inspection) to the NPT states at this time although this situation may change in the future. A word of caution is appropriate here. That is that the NPT regime was inadequate to the task of bringing to light the Iraqi program directed toward the development of nuclear weapons. Would NPT verification be adequate to uncover an Iranian nuclear weapons program if one existed?

Up to approximately 20% of inspection effort could be saved by not doing spent fuel and commercial and research reactors. However, substitution of remote monitoring, if implemented, for some of this inspection effort may be a mitigating factor.

*MOX Facilities*: Contribute ten per cent to the total FMCT inspection effort.

*Challenge Inspections*: Contribution to the total FMCT inspection effort is almost insignificant.

*Hot Cells*: Contribution to the total FMCT inspection effort is almost insignificant.

*Cost Savings*: Sharing inspection efforts between the IAEA and the eight nations affected by an FMCT has the potential for very large savings in inspection effort by the IAEA. (The individual states would provide the bulk of the inspection effort while the IAEA's role would be to audit their efforts for effectiveness.)

Other significant savings could come from the use of remote monitoring of spent fuel storage, other static storage areas, and possibly for reactors (not counting the capital investment for hardware and communications to implement such procedures).

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(3) "A Cutoff Treaty and Associated Costs," An IAEA Secretariat Working Paper presented at a workshop in Toronto, Canada, 17-18 January 1995.

(4) Jack Allentuck, Alan M. Bieber, Leslie G. Fishbone C. Ruth Kempf, Raymond Parsick and Jonathan Sanborn, "Options for the Negotiation of Undeclared-Site Inspections Under a Cutoff Convention." Brookhaven National Laboratory, SSN-95-17.

(5) "USAF Assumes Control of Predator in Bosnia", pg. 30, Defense News, Vol. 11, No. 36, September 9-15, 1996.

(6) This includes safeguarding MOX facilities and declared hot cells, but does not include safeguards on low enriched uranium, natural uranium, depleted uranium, and thorium, all of which are "fertile material" i.e., can be used to produce plutonium (or fissile U-233 in the case of thorium), if irradiated in a reactor. This corresponds to alternative C in the IAEA paper. Low enriched uranium can also be used as feed in a clandestine enrichment facility, which then would need be only half as large to produce the same amount of HEU per unit time (relative to a feed of natural uranium, and using the same tails assay).

(7) The Brookhaven estimate using a less-complete data base (Reference 2) was some 29,000 PDIs corresponding to $230 million.

(8) See U.S. Congress, Office of Technology Assessment, Nuclear Safeguards and the international Atomic Energy Agency, OTA-ISS-615 (U.S. Government Printing Office, Washington, D.C., June 1995), p. 18; in 1992 a modest increase was approved, but not realized, since the Soviet Union was unable to meet its payments that year.

(9) See U.S. Congress, Office of Technology Assessment, op. cit., Reference 5, pg. 51. This refers, in turn, to D. Schriefer, D. Perricos, and S. Thurstenson, "IAEA Safeguards Experience," Symposium Proceedings, International Nuclear Safeguards 1994, March 14-18, 1994, Vol. 1, p. 40.

(10) For each option, the sum of estimated efforts for inspecting the UK and France is about 30% of the total estimated effort. See Table 1.

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*Additional Reading*

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Table 1.
Inspection Effort Estimates for Each Verification Option and Numbers of Facilities*

| | Israel | India | Pak. | US | UK | France | Russia | China | Total |
|---|---|---|---|---|---|---|---|---|---|
| Reprocessing | 2 | 4 | 3 | ~~10~~ 11 | 3 | 3 | ~~6~~ 20 | ~~3~~ 6 | ~~34~~ 52 |
| (1) | 395 | 2805 | 60 | ~~2110~~ 2140 | 2805 | 2805 | ~~2835~~ 5640 | ~~1900~~ 4705 | ~~15715~~ 21355 |
| (2) | 395 | 2805 | 60 | ~~2110~~ 2140 | 2805 | 2805 | ~~2835~~ 5640 | ~~1900~~ 5640 | ~~15715~~ 21355 |
| (3) | 130 | 900 | 60 | ~~840~~ 870 | 900 | 900 | ~~930~~ 1830 | ~~630~~ 1530 | ~~5290~~ 7120 |
| Enrichment | 0 | 0 | 1 | ~~8~~ 15 | ~~3~~ 9 | ~~2~~ 3 | ~~8~~ 10 | 2 | ~~24~~ 40 |
| (1) | 0 | 0 | 79 | ~~304~~ 392 | ~~111~~ 207 | ~~208~~ 232 | ~~380~~ 404 | 208 | ~~1290~~ 1522 |
| (2) | 0 | 0 | 79 | ~~304~~ 320 | 111 | 208 | 380 | 208 | ~~1290~~ 1306 |
| (3) | 0 | 0 | 42 | ~~200~~ 216 | 74 | 104 | 232 | 104 | ~~756~~ 772 |
| Power/ Prod Reactors | 0 | 17 | 2 | ~~154~~ 159 | ~~48~~ 51 | ~~71~~ 73 | 55 | ~~8~~ 7 | ~~355~~ 364 |
| (1) | 0 | ~~186~~ 207 | 21 | ~~1102~~ 1115 | ~~759~~ 751 | ~~709~~ 704 | 863 | ~~228~~ 158 | ~~3868~~ 3819 |
| (2) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (3) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other | 3 | ~~11~~ 13 | ~~2~~ 3 | ~~117~~ 249 | ~~26~~ 48 | ~~27~~ 38 | ~~43~~ 48 | ~~13~~ 17 | ~~242~~ 419 |
| (1) | 57 | ~~240~~ 236 | ~~56~~ 60 | ~~1236~~ 1454 | ~~1133~~ 1145 | ~~2546~~ 2557 | ~~2661~~ 2685 | ~~173~~ 253 | ~~8102~~ 8447 |
| (2) | 0 | ~~28~~ 24 | 0 | ~~461~~ 741 | ~~793~~ 841 | ~~2290~~ 2322 | ~~2245~~ 2271 | ~~53~~ 81 | ~~5870~~ 6282 |
| (3) | 0 | ~~4~~ 0 | 0 | ~~80~~ 68 | 334 | 920 | 900 | 12 | ~~2250~~ 2234 |
| Total | 5 | ~~32~~ 34 | ~~8~~ 9 | ~~289~~ 434 | ~~80~~ 111 | ~~103~~ 117 | ~~112~~ 133 | ~~26~~ 32 | ~~655~~ 875 |
| (1) | 452 | ~~3231~~ 3248 | ~~216~~ 220 | ~~4752~~ 5101 | ~~4808~~ 4908 | ~~6268~~ 6298 | ~~6739~~ 9592 | ~~2509~~ 5324 | ~~28975~~ 35143 |
| (2) | 395 | ~~2833~~ 2829 | 139 | ~~2875~~ 3201 | ~~3709~~ 3757 | ~~5303~~ 5335 | ~~5460~~ 8293 | ~~2161~~ 4994 | ~~22875~~ 28943 |
| (3) | 130 | ~~904~~ 900 | ~~102~~ 130 | ~~1120~~ 1154 | 1308 | 1924 | ~~2062~~ 2962 | ~~746~~ 1646 | ~~8296~~ 10126 |

*For each facility type, the first row gives the number of facilities of a given type within the state, and the next three rows indicate the inspection effort in terms of Person-days of inspection (PDI) at those facilities for the three verification options. Values with horizontal lines are those from a previous study revised in this study.

Table 2.

Facilities to Be Routinely Verified Under Cutoff Convention Options

| *Facility Type* | *Option 1* | *Option 2* | *Option 3* |
|---|---|---|---|
| Power Reactors | X | X,s | d |
| Pu Production Reactors | X | | p,a |
| Spent Fuel Storage | X | | |
| Research Reactors and Critical Facilities | X | X,s | d |
| Reprocessing | X | X | p,a |
| Enrichment | X | X | p,a |
| Uranium Fuel Fabrication | X | | |
| Uranium Conversion | X | | |
| Plutonium Conversion | X | X | d |
| Plutonium Fuel Fabrication | X | X,s | d |
| Plutonium and HEU Storage | X | X,s | d |
| R&D Centers (including Hot Cells)* | X | X | p,a |
| Recovery, Repurification, Fabrication for Military* | | | a** |

X - Verifications according to IAEA Safeguards Criteria

s - Only if subject fissile material is present

d - Verification of disposition of subject material only

p - Verification of production only

a - Verification of absence of undeclared enrichment or reprocessing

*Very few in database at present

**Not considered in this report

Table 3.
Facility Inspection Effort Values: PID

| *Type of Facility** | *Options* | *PIV* | *IIV* | *NIV* | *FV* | *NFV* | *AIE* |
|---|---|---|---|---|---|---|---|
| Light water reactor | 1 | 3 | 1 | 4 | 1 | 2 | 9 |
| | s | - | 1 | 4 | - | | 4 |
| Light water reactor with mixed-oxide fresh fuel | 1, 2 | 6 | 1 | 11 | 1 | 2 | 19 |
| | 3 | | 1 | 4 | | | 4 |
| On-load reactor | 1 | 7 | 2 | 4 | 1 | 6 | 21 |
| | s | - | 1 | 4 | | | 4 |
| Production reactor | 1 | 6 | - | - | 8 | 8 | 70 |
| | s | 4 | 1 | 4 | | | 8 |
| Critical facility: Fast | 1, 2 | 15 | 2 | 11 | | | 37 |
| Critical facility: Thermal | 1,2 | 5 | 1 | 11 | | | 16 |
| Research reactor: Fast | 1,2 | 1 | 1 | 11 | | | 12 |
| Research reactor: Thermal | 1 | 1 | 1 | 3 | | | 4 |
| Research reactor: Training | 1 | 1 | | | | | 1 |
| Reprocessing plant | 1, 2 | 60 | 25 | 11 | 1 | 600 | 935 |
| | 3 | 23 | 7 | 11 | 1 | 200 | 300 |
| | s | 10 | 4 | 5 | | | 30 |
| Enrichment (centrifuge) | 1, 2 | 25 | 2 | 5 | 4 | 11 | 79 |
| | 3 | 10 | 2 | 5 | 2 | 11 | 42 |
| | s | 6 | 2 | 5 | | | 16 |
| Enrichment (diffusion) | 1,2 | 50 | 2 | 5 | 4 | 11 | 104 |
| | 3 | 20 | 2 | 5 | 2 | 11 | 52 |
| | s | 6 | 2 | 5 | | | 10 |
| Fabrication (LEU) | 1 | 60 | | | 4 | 5 | 80 |
| Conversion (LEU) | 1 | 30 | | | 4 | 5 | 50 |
| Fabrication (MOX, old) & Pu conversion | 1, 2 | 60 | 25 | 11 | 1 | 400 | 735 |
| | 3 | 25 | 15 | 5 | 1 | 200 | 300 |
| | s | 10 | 4 | 5 | | | 30 |
| Fabrication (MOX, new) | 1, 2 | 60 | 15 | 11 | 15 | 11 | 390 |
| | 3 | 25 | 15 | 5 | 5 | 11 | 155 |
| | s | 10 | 4 | 5 | | | 30 |

"s" denotes shutdown plant in all options, but still with nuclear material or the potential to produce it without extraordinary reconstruction.
*A few others are not listed here, including pilot-size facilities to which smaller effort numbers apply

## APPENDIX A: Effort Values

| Facility Type | Status | Option 1 | Option 2 | Option 3 |
|---|---|---|---|---|
| Light water reactor | O | 9 | 0 | 0 |
| | S | 4 | 0 | 0 |
| On-load reactor | O | 21 | 0 | 0 |
| | S | 4 | 0 | 0 |
| High temperature reactor | O | 21 | 0 | 0 |
| | S | 4 | 0 | 0 |
| Fast breeder reactor | O | 21 | 0 | 0 |
| | S | 4 | 0 | 0 |
| Reactor (other) | O | 9 | 0 | 0 |
| | S | 4 | 0 | 0 |
| Production reactor | O | 70 | 0 | 0 |
| | S | 8 | 0 | 0 |
| Thermal research reactor | O | 4 | 0 | 0 |
| | S | 1 | 0 | 0 |
| Fast research reactor | O | 12 | 12 | 0 |
| | S | 4 | 4 | 0 |
| University reactor | O | 1 | 0 | 0 |
| | S | 0 | 0 | 0 |
| Naval-type reactor | O | 12 | 12 | 0 |
| Thermal critical assembly | O | 16 | 16 | 4 |
| | S | 4 | 4 | 0 |
| Fast critical assembly | O | 37 | 37 | 8 |
| | S | 8 | 8 | 0 |
| Natural U conversion | O | 32 | 0 | 0 |
| | S | 10 | 0 | 0 |
| LEU conversion | O | 50 | 0 | 0 |
| | S | 15 | 0 | 0 |
| HEU conversion facility | O | 735 | 735 | 300 |
| | S | 30 | 30 | 30 |
| Plutonium conversion facility | O | 735 | 735 | 300 |
| | S | 30 | 30 | 30 |
| Thorium conversion facility | O | 32 | 0 | 0 |
| | S | 10 | 0 | 0 |
| Natural/depleted U fabrication | O | 52 | 0 | 0 |
| | S | 10 | 0 | 0 |
| LEU fabrication | O | 80 | 0 | 0 |
| | S | 30 | 0 | 0 |
| HEU fabrication | O | 735 | 735 | 300 |
| | S | 30 | 30 | 30 |

| Facility Type | Status | Option 1 | Option 2 | Option 3 |
|---|---|---|---|---|
| MOX fabrication (conventional) | O | 735 | 735 | 300 |
| | S | 30 | 30 | 30 |
| MOX fabrication (automated) | O | 390 | 390 | 155 |
| | S | 30 | 30 | 30 |
| Thorium fabrication | O | 735 | 735 | 300 |
| | S | 30 | 30 | 30 |
| Reprocessing (nat. U) | O | 935 | 935 | 300 |
| | S | 30 | 30 | 30 |
| Reprocessing plant (LEU) | O | 935 | 935 | 300 |
| | S | 30 | 30 | 30 |
| Reprocessing plant (HEU) | O | 935 | 935 | 300 |
| | S | 30 | 30 | 30 |
| Reprocessing plant (plutonium) | O | 935 | 935 | 300 |
| | S | 30 | 30 | 30 |
| Reprocessing (thorium) | O | 935 | 935 | 300 |
| | S | 30 | 30 | 30 |
| Reprocessing plant (pilot) | O | 365 | 365 | 100 |
| | S | 30 | 30 | 30 |
| Hot cell (lab scale) | O | 30 | 30 | 30 |
| | S | 12 | 12 | 12 |
| Diffusion plant | O | 104 | 104 | 52 |
| | S | 16 | 16 | 16 |
| Centrifuge enrichment plant | O | 79 | 79 | 42 |
| | S | 16 | 16 | 16 |
| Enrichment plant (other) | O | 79 | 79 | 42 |
| | S | 16 | 16 | 16 |
| Sealed storage (spent fuel) | O | 24 | 0 | 0 |
| | S | 4 | 0 | 0 |
| Sealed storage (nat. U) | O | 12 | 0 | 0 |
| | S | 6 | 0 | 0 |
| Sealed storage (HEU) | O | 54 | 54 | 6 |
| | S | 32 | 32 | 6 |
| Sealed storage (plutonium) | O | 70 | 70 | 10 |
| | S | 48 | 48 | 10 |
| Unsealed storage (spent fuel) | O | 48 | 0 | 0 |
| | S | 8 | 0 | 0 |
| Unsealed storage (nat. U) | O | 24 | 0 | 0 |
| | S | 12 | 0 | 0 |
| Unsealed storage (HEU) | O | 80 | 80 | 6 |
| | S | 54 | 54 | 6 |

| Facility Type | Status | Option 1 | Option 2 | Option 3 |
|---|---|---|---|---|
| Unsealed storage (plutonium) | O | 120 | 120 | 10 |
| | S | 70 | 70 | 10 |
| Weapons components fabrication | O | 735 | 735 | 300 |
| | S | 30 | 30 | 30 |
| Weapons assembly/disassembly | O | 735 | 735 | 300 |
| | S | 30 | 30 | 30 |

# Appendix B

## B. Status of Facilities

### B.1 Introduction

Data in this Appendix reports the current facility status in the P-5 and T-3. This information is important for inspection planning and assessing the current state of nuclear activities on a country-by-country basis.

### B.2 Summary Status Data

Table B-1 like Table 1, shows the total PDI for the three inspection efforts and type of facilities. Additional data are provided on facility status, i.e., operational, under construction, shutdown, decommissioned.

### B.3 Country-by-Country Facility Status

Tables B-2 to B-9 provide data of facility status for each of the P-5 and T-3 states.

### B.4 "Unknown"

In the tables referred to above, the designation "unknown" is given to facilities that are known to exist but where information on their status is lacking.

Table B-1.
Inspection Effort Estimates for Each Verification Option and Numbers of Facilities* by Operational Status

| | *Operational* | *Under Construction* | *Planned* | *Shutdown* | *Decommissioned* | *Status Unknown*** | *Total* |
|---|---|---|---|---|---|---|---|
| Reprocessing | 25 | 3 | 0 | 11 | 12 | 1 | 52 |
| (1) | 20,090 | | | 330 | | 935 | 21,355 |
| (2) | 20,090 | | | 330 | | 935 | 21,355 |
| (3) | 6,490 | | | 330 | | 300 | 7120 |
| Enrichment | 26 | 0 | 0 | 14 | 0 | 0 | 40 |
| (1) | 1,314 | | | 208 | | | 1,522 |
| (2) | 1,098 | | | 208 | | | 1,306 |
| (3) | 564 | | | 208 | | | 772 |
| Power/ Prod Reactors | 258 | 22 | 2 | 42 | 40 | 0 | 364 |
| (1) | 3,603 | | | 216 | | | 3,819 |
| (2) | 0 | | | 0 | | | 0 |
| (3) | 0 | | | 0 | | | 0 |
| Other | 203 | 11 | 2 | 200 | 3 | | 419 |
| (1) | 7,911 | | | 536 | | | 8,447 |
| (2) | 5,840 | | | 442 | | | 6,282 |
| (3) | 2,204 | | | 30 | | | 2,234 |
| Total | 512 | 36 | 4 | 267 | 55 | 1 | 875 |
| (1) | 32,918 | 0 | 0 | 1,290 | 0 | 935 | 35,143 |
| (2) | 27,028 | 0 | 0 | 980 | 0 | 935 | 28,943 |
| (3) | 9,258 | 0 | 0 | 568 | 0 | 935 | 10,126 |

*For each facility type, the first row gives the number of facilities of a given type within the status, and the next three rows indicate the inspection effort at those facilities for the three verification options.

** See Table B-5.

Table B-2.
Inspection Effort Estimates for Each Verification Option and Numbers of Facilities* by Operational Status for Israel

| Israel | *Operational* | *Shutdown* | *Total* |
|---|---|---|---|
| Reprocessing | 1 | 1 | 2 |
| (1) | 365 | 30 | 395 |
| (2) | 365 | 30 | 395 |
| (3) | 100 | 30 | 130 |
| Enrichment | 0 | | |
| (1) | | | |
| (2) | | | |
| (3) | | | |
| Power/ Prod Reactors | 0 | | |
| (1) | | | |
| (2) | | | |
| (3) | | | |
| Other | 2 | 1 | 3 |
| (1) | 56 | 1 | 57 |
| (2) | 0 | 0 | 0 |
| (3) | 0 | 0 | 0 |
| Total | 3 | 2 | 5 |
| (1) | 421 | 31 | 452 |
| (2) | 365 | 30 | 395 |
| (3) | 100 | 30 | 130 |

*For each facility type, the first row gives the number of facilities of a given type within the status, and the next three rows indicate the inspection effort at those facilities for the three verification options.

## Table B-3.
## Inspection Effort Estimates for Each Verification Option and Numbers of Facilities* by Operational Status for India

| India | *Operation* | *Construction* | *Plan* | *Shutdown* | | | *Total* |
|---|---|---|---|---|---|---|---|
| Reprocessing | 3 | 1 | | | | | 4 |
| (1) | 2,805 | | | | | | 2,805 |
| (2) | 2,805 | | | | | | 2,805 |
| (3) | 900 | | | | | | 900 |
| Enrichment | | | | | | | |
| (1) | 1,314 | | | | | | |
| (2) | 1,098 | | | | | | |
| (3) | 564 | | | | | | |
| Power/ Prod Reactors | 11 | 4 | 2 | | | | 17 |
| (1) | 207 | | | | | | 207 |
| (2) | 0 | | | | | | 0 |
| (3) | 0 | | | | | | 0 |
| Other | 203 | 11 | 2 | 200 | 3 | | 419 |
| (1) | 7,911 | | | 536 | | | 8,447 |
| (2) | 5,840 | | | 442 | | | 6,282 |
| (3) | 2,204 | | | 30 | | | 2,234 |
| Total | 512 | 36 | 4 | 267 | 55 | 1 | 875 |
| (1) | 32,918 | 0 | 0 | 1,290 | 0 | 935 | 35,143 |
| (2) | 27,028 | 0 | 0 | 980 | 0 | 935 | 28,943 |
| (3) | 9,258 | 0 | 0 | 568 | 0 | 935 | 10,126 |

*For each facility type, the first row gives the number of facilities of a given type within the status, and the next three rows indicate the inspection effort at those facilities for the three verification options.

Table B-4.
Inspection Effort Estimates for Each Verification Option and Numbers of Facilities* by Operational Status for Pakistan

| <u>Pakistan</u> | *Operational* | *Under Construction* | *Shutdown* | *Total* |
|---|---|---|---|---|
| Reprocessing | 1** | 1 | 1 | 3 |
| (1) | 30 | | 30 | 60 |
| (2) | 30 | | 30 | 60 |
| (3) | 30 | | 30 | 60 |
| Enrichment | 1 | | | 1 |
| (1) | 79 | | | 79 |
| (2) | 79 | | | 79 |
| (3) | 42 | | | 42 |
| Power/ Prod Reactors | 1 | 1 | | 2 |
| (1) | 21 | | | 21 |
| (2) | 0 | | | 0 |
| (3) | 0 | | | 0 |
| Other | 3 | | | 3 |
| (1) | 60 | | | 60 |
| (2) | 0 | | | 0 |
| (3) | 0 | | | 0 |
| Total | 6 | 2 | 1 | 9 |
| (1) | 190 | 0 | 30 | 220 |
| (2) | 109 | 0 | 30 | 139 |
| (3) | 72 | 0 | 30 | 102 |

*For each facility type, the first row gives the number of facilities of a given type within the status, and the next three rows indicate the inspection effort at those facilities for the three verification options.

** Hot cell type

## Table B-5.
## Inspection Effort Estimates for Each Verification Option and Numbers of Facilities* by Operational Status for USA

| United States | *Operational* | *Under Construction* | *Shutdown* | *Decommissioned* | *Total* |
|---|---|---|---|---|---|
| Reprocessing | 2 | | 9 | 0 | 11 |
| (1) | 1,870 | | 270 | | 2,140 |
| (2) | 1,870 | | 270 | | 2,140 |
| (3) | 600 | | 270 | | 870 |
| Enrichment | 7 | | 8 | | 15 |
| (1) | 280 | | 112 | | 392 |
| (2) | 208 | | 112 | | 320 |
| (3) | 104 | | 112 | | 216 |
| Power/ Prod Reactors | 111 | 7 | 21 | 20 | 159 |
| (1) | 1,011 | | 104 | | 1,115 |
| (2) | 0 | | 0 | | 0 |
| (3) | 0 | | 0 | | 0 |
| Other | 94 | 2 | 151 | 2 | 249 |
| (1) | 1,072 | | 382 | | 1,454 |
| (2) | 433 | | 308 | | 741 |
| (3) | 68 | | 0 | | 68 |
| Total | 214 | 9 | 189 | 22 | 434 |
| (1) | 4,233 | 0 | 868 | 0 | 5,101 |
| (2) | 2,511 | 0 | 690 | 0 | 3,201 |
| (3) | 772 | 0 | 382 | 0 | 1,154 |

*For each facility type, the first row gives the number of facilities of a given type within the status, and the next three rows indicate the inspection effort at those facilities for the three verification options.

Table B-6.
Inspection Effort Estimates for Verification Options and Numbers of Facilities* by Operational Status for United Kingdom

| UK | *Operational* | *Under Construction* | *Planned* | *Shutdown* | *Decommissioned* | *Total* |
|---|---|---|---|---|---|---|
| Reprocessing | 3 | | | | | 3 |
| (1) | 2,805 | | | | | 2,805 |
| (2) | 2,805 | | | | | 2,805 |
| (3) | 900 | | | | | 900 |
| Enrichment | 7 | | | 2 | | 9 |
| (1) | 175 | | | 32 | | 207 |
| (2) | 79 | | | 32 | | 111 |
| (3) | 42 | | | 32 | | 74 |
| Power/ Prod Reactors | 35 | | | 6 | 10 | 51 |
| (1) | 723 | | | 28 | | 751 |
| (2) | 0 | | | 0 | | 0 |
| (3) | 0 | | | 0 | | 0 |
| Other | 14 | 4 | 2 | 27 | 1 | 48 |
| (1) | 1,054 | | | 901 | | 1,145 |
| (2) | 763 | | | 78 | | 841 |
| (3) | 304 | | | 30 | | 334 |
| Total | 59 | 4 | 2 | 35 | 11 | 111 |
| (1) | 4,757 | 0 | 0 | 151 | 0 | 4,908 |
| (2) | 3,647 | 0 | 0 | 110 | 0 | 3,757 |
| (3) | 1,246 | 0 | 0 | 62 | 0 | 1,308 |

*For each facility type, the first row gives the number of facilities of a given type within the status, and the next three rows indicate the inspection effort at those facilities for the three verification options.

Table B-7.
Inspection Effort Estimates for Verification Options and Numbers of Facilities* by Operational Status for France

| France | *Operational* | *Under Construction* | *Shutdown* | *Decommissioned* | *Total* |
|---|---|---|---|---|---|
| Reprocessing | 3 | | | | 3 |
| (1) | 2,805 | | | | 2,805 |
| (2) | 2,805 | | | | 2,805 |
| (3) | 900 | | | | 900 |
| Enrichment | 3 | | | | 3 |
| (1) | 232 | | | | 232 |
| (2) | 208 | | | | 208 |
| (3) | 104 | | | | 104 |
| Power/ Prod Reactors | 58 | 4 | 8 | 3 | 73 |
| (1) | 668 | | 36 | | 704 |
| (2) | 0 | | 0 | | 0 |
| (3) | 0 | | 0 | | 0 |
| Other | 25 | 1 | 12 | | 38 |
| (1) | 2,522 | | 35 | | 2,557 |
| (2) | 2,290 | | 32 | | 2,322 |
| (3) | 920 | | 0 | | 920 |
| Total | 89 | 5 | 20 | 3 | 117 |
| (1) | 6,227 | 0 | 71 | 0 | 6,298 |
| (2) | 5,303 | 0 | 32 | 0 | 5,335 |
| (3) | 1,924 | 0 | 0 | 0 | 1,924 |

*For each facility type, the first row gives the number of facilities of a given type within the status, and the next three rows indicate the inspection effort at those facilities for the three verification options.

Table B-8.
Inspection Effort Estimates for Verification Options and Numbers of Facilities* by Operational Status for Russia

| Russia | *Operational* | *Under Construction* | *Shutdown* | *Decommissioned* | *Total* |
|---|---|---|---|---|---|
| Reprocessing | 7 | 1 | | 12 | 20 |
| (1) | 5,640 | | | | 5,640 |
| (2) | 5,640 | | | | 5,640 |
| (3) | 1,830 | | | | 1,830 |
| Enrichment | 6 | | 4 | | 10 |
| (1) | 340 | | 64 | | 404 |
| (2) | 316 | | 64 | | 380 |
| (3) | 168 | | 64 | | 232 |
| Power/ Prod Reactors | 38 | 3 | 7 | 7 | 55 |
| (1) | 815 | | 48 | | 863 |
| (2) | 0 | | 0 | | 0 |
| (3) | 0 | | 0 | | 0 |
| Other | 40 | 3 | 5 | | 48 |
| (1) | 2,674 | | 11 | | 2,685 |
| (2) | 2,265 | | 8 | | 2,273 |
| (3) | 900 | | 0 | | 900 |
| Total | 91 | 7 | 16 | 19 | 133 |
| (1) | 9,469 | 0 | 123 | 0 | 9,592 |
| (2) | 8,221 | 0 | 72 | 0 | 8,293 |
| (3) | 2,898 | 0 | 64 | 0 | 2,962 |

*For each facility type, the first row gives the number of facilities of a given type within the status, and the next three rows indicate the inspection effort at those facilities for the three verification options.

Table B-9.
Inspection Effort Estimates for Verification Options and Numbers of Facilities* by Operational Status for China (PRC)

| China (PRC) | *Operational* | *Under Construction* | *Shutdown* | *Unknown* | *Total* |
|---|---|---|---|---|---|
| Reprocessing | 4 | | 1 | 1 | 6 |
| (1) | 3,740 | | 30 | 935 | 4,705 |
| (2) | 3,740 | | 30 | 935 | 4,705 |
| (3) | 1,200 | | 30 | 300 | 1,530 |
| Enrichment | 2 | | | | 2 |
| (1) | 208 | | | | 208 |
| (2) | 208 | | | | 208 |
| (3) | 104 | | | | 104 |
| Power/ Prod Reactors | 4 | 3 | | | 7 |
| (1) | 158 | | | | 158 |
| (2) | 0 | | | | 0 |
| (3) | 0 | | | | 0 |
| Other | 16 | | 1 | | 17 |
| (1) | 249 | | 4 | | 253 |
| (2) | 77 | | 4 | | 81 |
| (3) | 12 | | 0 | | 12 |
| Total | 26 | 3 | 2 | 1 | 32 |
| (1) | 4,355 | 0 | 34 | 935 | 5,324 |
| (2) | 4,025 | 0 | 34 | 935 | 4,994 |
| (3) | 1,316 | 0 | 30 | 300 | 1,646 |

*For each facility type, the first row gives the number of facilities of a given type within the status, and the next three rows indicate the inspection effort at those facilities for the three verification options.