THE PENNSYLVANIA STATE UNIVERSITY SCHREYER HONORS COLLEGE

DEPARTMENT OF MECHANICAL AND NUCLEAR ENGINEERING

AN ANALYSIS OF COSTS INVOLVED IN APPLYING ADVANCED SAFEGUARDS SYSTEMS AND APPROACHES TO GAS CENTRIFUGE ENRICHMENT PLANTS

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ABSTRACT

IAEA safeguards at gas centrifuge enrichment plants (GCEPs) need improvement to verify declared LEU production, detect undeclared LEU production and detect HEU production. Due to increases in facility size and volume of throughput, the current safeguards regime for large capacity GCEPs must be enhanced to meet detection probability targets. Current safeguards efforts employ attended systems operated by inspectors on-site to determine uranium enrichment levels and total uranium mass of UF₆ cylinders to verify operator declarations. Verification of enrichment levels and uranium mass could be improved by a combination of process monitoring and unattended advanced safeguards systems currently under development at several U.S. national laboratories. The effectiveness of these efforts could be augmented by implementing information-driven inspections and relaxing probability of detection standards given a broader state-level conclusion of an absence of proliferation activities. The hardware costs of these options for new GCEPs safeguards were analyzed for different detection probabilities. The savings of an advanced safeguards system were quantified and the benefits for operators and the Inspectorate were discussed.

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LIST OF ACRONYMS

AEM: Advanced Enrichment Monitor

AP: Additional Protocol

C/S: Containment and Surveillance

CEMO: Continuous Enrichment Monitor

CTS: Cylinder Tracking System

D: Operator-Inspector Difference Statistic.

DA: Destructive Analysis

DIV: Design Information Verification

DNLEU: Depleted, Natural, and Low Enriched Uranium

DOE: Department of Energy (US)

ETS: Enrichment Technology Services

GCEP: Gas Centrifuge Enrichment Plant

HEU: Highly Enriched Uranium

HSP: Hexapartite Safeguards Project

IAEA: International Atomic Energy Agency

IIV: Intermediate Inventory Verifications

ITV: International Target Values

LANL: Los Alamos National Laboratory

LCBWS: Load Cell Balance Weight System

LEU: Low Enriched Uranium

LFUA: Low Frequency Unannounced Access

MBA: Material Balance Area

MBP: Material Balance Period

MSSP: Member State Support Program

MtSWU/yr: Metric Ton of Separative Work Units per year (measure of plant capacity)

MUF: Material Unaccounted For

NDA: Non-Destructive Analysis

NNWS: Non-Nuclear Weapons State

NWS: Nuclear Weapons State

ORNL: Oak Ridge National Laboratory

PD: Probability of Detection

PIV: Physical Inventory Verifications,

RFID: Radio-Frequency Identification

SNRI: Short Notice Random Inspection

SQ: Significant Quantity

SSAC: State System of Accounting and Control

UCAS: Uranium Cylinder Assay System

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INTRODUCTION

Uranium enrichment is an essential step in the nuclear fuel cycle, since most of the world's nuclear reactors cannot sustain a chain reaction using fuel made from uranium with natural isotopic abundances. Natural uranium, comprised of the ²³⁴U, ²³⁵U, and ²³⁸U isotopes, contains 99.3% ²³⁸U by weight [1]. Before use in a fission process, the concentration of the fissile ²³⁵U isotope must be increased from its natural abundance of 0.711% through a process known as uranium enrichment. Most nuclear reactors operating around the world today are light water reactors and require fuel enriched to 2-5% ²³⁵U. Research reactors can require fuel enrichments up to 90%. Uranium-based atomic weapons require even higher enrichments, approaching 100% ²³⁵U.

All uranium enrichment technologies operate on the same basic principle. A feed stream is introduced into a separation element which creates an enriched stream and a depleted stream. Separation elements are often connected into cascades, where the enriched and depleted streams are fed into additional separation elements optimized for maximum efficiency.

Several diverse processes exist for the enrichment of uranium, each manipulating the different nuclear properties of the ²³⁸U and ²³⁵U isotopes. Electromagnetic, diffusion, phase equilibrium, and photo excitation properties have all been utilized to separate the two isotopes. Most widely used are the gas centrifuge and gaseous diffusion processes.

Gaseous diffusion plants utilize the slight difference in diffusion speed between the uranium isotopes. The uranium is converted into a gas through fluorination and then repeatedly forced through thin membranes. Since the ²³⁸U atoms are larger than the ²³⁵U atoms, they take slightly longer to diffuse through the membrane, eventually creating enriched and depleted streams of uranium gas.

Gas centrifuge plants utilize centrifugal force to separate the isotopes in the uranium gas in a high-velocity centrifuge. The centrifugal force causes the heavier ²³⁸U –containing molecules to move closer to the outside of the rotor, where it is collected and sent to a depleted stream. The lighter ²³⁵U-

containing molecules are also captured and sent to an enriched stream. In a gas centrifuge enrichment plant, many individual centrifuge separation elements are connected to optimize the end product and tails enrichments.

Since the end of the Cold War, world enrichment capacity has increased through the commercialization of the gas centrifuge. The most successful of these commercial ventures is URENCO, a consortium formed in 1971 by enrichment companies from the UK (BNFL), the Netherlands (Ultra-Centrifuge Nederland NV), and Germany (Uranit GmbH). This collaboration grew out of the Treaty of Almelo in 1970, which established legal precedent for the cooperative development of centrifuge technology for commercial operation [2]. URENCO has since partitioned its operations and centrifuge technology into separate divisions, with an URENCO corporation called Enrichment Technology Services (ETS) providing and maintaining all centrifuge technology at the URENCO plants. The use of ETS allows greater security of the sensitive centrifuge technology.

URENCO has steadily expanded its facilities at Capenhurst (UK), Almelo (Netherlands), and Gronau (Germany), as well as beginning operations at the URENCO USA plant in Eunice, New Mexico. URENCO's ETS is also supplying centrifuges for AREVA's Georges Besse II centrifuge plant in Pierrelatte, France. These expansions, along with General Electric's proposed Laser Isotope Separation plant in Wilmington, NC, are listed in Table 1.

Table 1: Selection of Commercial Enrichment Plants (Operational, Under Construction, Planned) [3], [4].

ENDICHMENT DI ANT	CADA CUTY IMACYULL
ENRICHMENT PLANT	CAPACITY [MtSWU/yr]
URENCO (Centrifuge)	
Capenhurst, UK (operation)	5000
URENCO (Centrifuge)	
Almelo, NL (operation)	4400 (planned expansion to 6200)
URENCO (Centrifuge)	
Gronau, Germany (operation)	2750 (planned expansion to 4500)
URENCO USA (Centrifuge)	
Eunice, NM, USA – base (construction)	1000
URENCO USA (Centrifuge)	
Eunice, NM, USA – revised final (planned)	5700
AREVA – Georges Besse II (Centrifuge)	
Pierrelatte, France (construction)	8200 (planned expansion to 11 000)
GEH GLE (Laser Isotope Separation)	
Wilmington, NC USA (planned)	3500–6000

Table 1 shows a selection of commercial enrichment plants currently operational, under construction, or planned. According to press releases [5], URENCO desires to expand to a total of 18,000 MtSQU/yr by 2015. These projections communicate a growing trend in the nuclear industry—fuel cycle facilities are becoming larger and more multinational in nature. This poses unique safeguards challenges for the IAEA, especially since these enrichment plants are located in both Nuclear Weapons States (NWS) and Non-Nuclear Weapons States (NNWS). Safeguards must be roughly equal in similar facilities regardless of location to ensure a level field of competition. Increases in plant size mandate more frequent and invasive inspections in order to maintain current levels of assurance. At the same time, however, the safeguards budget of the IAEA is projected to remain virtually unchanged, according to a study done by Kollar [6]. In fact, due to the growth of the nuclear industry around the world, the amount the IAEA spends safeguarding each significant quantity (SQ) of nuclear material will decrease from approximately \$1800 USD per SQ in 1990 to under \$300 USD per SQ (projected) in 2030 [6].

The increased demands on the IAEA for safeguards identified by Kollar and others require new approaches to safeguarding large commercial facilities across the nuclear fuel cycle. These approaches include encouraging Member States to accept Additional Protocol (AP) Comprehensive Safeguards agreements, delegating safeguards responsibilities to regional inspectorate authorities (e.g. EURATOM), and implementing advanced safeguards technologies and methods which require less inspector labor while maintaining assurances. For GCEPs, these advanced systems and approaches must reliably cover the main diversion scenarios while maintaining continuity of knowledge and also reducing inspection costs over the long term.

BACKGROUND

GCEPs Diversion Scenarios

From 1980 to 1983, representatives from Australia, EURATOM, the IAEA, Japan, the USA, Germany, the Netherlands, and the UK met to discuss how best to implement safeguards inspections in gas centrifuge enrichment plants. These meetings, known as the Hexapartite Safeguards Project (HSP), produced a standard safeguards regime addressing undeclared highly-enriched uranium (HEU) and low enriched uranium (LEU) production in GCEPs. This standard safeguards regime has been applied around the world, largely to URENCO facilities, with little modification since its inception.

In general, when considering safeguards at GCEPs, there are three basic concerns with plant misuse:

- The production and diversion of an SQ of product enriched above declaration (especially HEU),
- 2. The diversion of a declared SQ of LEU,
- 3. The production and diversion of LEU from an undeclared feed.

The HSP addressed the issues of HEU production and LEU diversion, but did not address the concern of the production of excess LEU from an undeclared feed. The greatest concern is the production of HEU since HEU can be used for nuclear weapons without further enrichment. In the undeclared feed scenario, the LEU produced in the facility would be "off the books," allowing it to be shipped to a clandestine enrichment plant or made into targets for plutonium production in a power reactor. The undeclared feed scenario is especially problematic, as it can be concealed so as not to affect the material accountancy records. The HSP did not address the undeclared feed scenario, and it is currently seen as a significant lapse in the safeguards regime for GCEPs [7].

In order to analyze the activities of facilities under safeguards, the IAEA has developed definitions of two main diversion tactics. The first, *diversion into MUF*, focuses on the concept of material unaccounted for (MUF), which is the sum of the uncertainties associated with each component of

the material flow through the plant over the course of the material balance period (MBP). In this scenario, the operator diverts just enough material so that that it falls within the statistical uncertainty (σ_{MUF}) of the MUF.

The second diversion scenario is known as *diversion into D*, where D is the operator-inspector difference statistic. The operator-inspection difference measures the difference between the operator declaration and the inspector's verification of the same group of items. When the D statistic is for a particular item is above a predetermined limit, the inspector investigates the anomaly. The IAEA also estimates the maximum amount of MUF possible, known as the MUF-D statistic. This is the amount of MUF which cannot be attributed to the differences in measurement systems used by the operator and inspector [8].

MUF is determined from the material balance equation [1]:

MUF=PB+X-Y-PE

where:

PB is the physical inventory at the beginning of the MBP;

X is the receipts of material during the MBP;

Y is the shipments of material during the MBP;

PE is the physical inventory at the end of the MBP.

MUF is calculated for total uranium mass and also for mass of ²³⁵U. Because the MUF is comprised of feed, product and tails, samples must be taken from all three strata. Large facilities such as George Besse II in France and the URENCO USA plant in New Mexico will have throughputs of hundreds of SQs of LEU every year, and the MUF of these high throughput plants has been shown to be greater than one SQ [3]. This means that an operator could divert more than an SQ of material in a year and not be caught by the IAEA because the MUF is so high. To ensure that material has not been diverted, it is necessary to develop advanced safeguards systems and approaches which bring these

uncertainties to acceptable levels. Systems which achieve this goal will not just verify declarations but also provide process monitoring capability to ensure that diversion has not occurred.

Option A: Existing HSP Safeguards Regime

The existing safeguards regime as established for INFCIRC/153 Comprehensive Safeguards Agreements under the Hexapartite Safeguards Project was used in this study as a control with which to compare the proposed advanced systems. This regime consists of Intermediate Inventory Verifications (IIV), Physical Inventory Verifications (PIV), Low Frequency Unannounced Access (LFUA) inspections, and Short Notice Random Inspections (SNRI).

While the timeliness of DNLEU is one year, the sheer amount of throughput of uranium through a GCEP demands an inspection regime where inspections occur with enough frequency to verify material in a representative population of cylinders of uranium to be statistically valid. This timely verification of material flow through the facility is achieved through the IIV [9]. These interim inspections occur every month to fulfill the statistical nature of the verification process and take two inspectors three to four days to perform.

In the IIV, the inspector must prepare extensively beforehand to develop a sampling plan which satisfies the statistical requirements dictated by the performance of the techniques and instruments used by the Agency. The Agency generally uses historical data from previous inspections at representative facilities to calculate this performance. However, since this information is Safeguards Confidential, this study used the International Target Values (ITV) [10] as reasonable approximations of the behavior of the instruments in a GCEP for our study. These values should be a reasonable assumption to evaluate the safeguard regime, as they represent optimal values for the verification methods used in GCEPs safeguards.

During the IIV, the books must be carefully audited and recorded so the operator declarations of uranium mass and enrichment may be compared with the values obtained through the NDA and DA sampling analysis. Then random DA and NDA samples and weight measurements of cylinders in the

storage MBA are taken according to the sampling plan conceived upon receiving the operator's declaration after arrival on-site. The operator's declarations of cylinders in the heating and cooling units in the process MBA are verified by visual inspection. If a LFUA is triggered, the inspector can take environmental swipe samples in the cascade halls to verify if undeclared production of HEU has occurred [11]. After the inspection, the inspectors return to headquarters to analyze the data and draw a conclusion about the completeness and correctness of the operator's declaration and presence or absence of undeclared nuclear activities.

The purpose of the PIV is to verify all inventories in accordance with the timeliness goals for nuclear material, and occurs approximately every 12 months, with the window extending no longer than a 14 month interval. The inventory is examined for gross defects at 50% detection probability. A typical PIV takes two to four inspectors 10-15 days to conduct [11].

In the PIV, all the verification activities of the IIV are performed, as well as verification of all material previously verified but remaining on site. At a GCEP this would be recently received and verified natural uranium feed and LEU product not yet shipped to the fuel fabrication plant, as well as depleted uranium tails which are generally stored for years on site. The operator's measurement procedures are verified through calibrating balances, scales and cold traps, as well as observing sampling procedures. The facility undergoes a Design Information Verification, where the current configuration of the plant is compared with the configuration recorded at the time of construction and any declared modifications by the operator. The switchover in the process MBA from the previous material balance period (MBP) to the new MBA is verified [11].

The absence of HEU is verified through the use of LFUA inspections which are randomly triggered throughout the MBP either during planned inspections or by separate short notice inspections. The number of LFUAs per MBP is determined by the throughput of the facility, inspection schedule, and detection probability requirements for HEU production. In an LFUA, the inspectors are granted access to the cascade halls to compare what they see with a picture taken during the DIV. Environmental swipe

samples can also be taken. NDA measurements are taken and DA samples are taken from the process gas in the cascades [11]. The LFUA inspection is confined to the centrifuge halls—random access to the feed and withdrawal areas is not allowed.

Since the HSP was established, centrifuge technology has advanced and use of facilities has become more flexible, with a variety of plant configurations and enrichment levels possible. Safeguards technologies have also improved, with the addition of the Continuous Enrichment Monitor (CEMO). This unattended, continuously operating system relies on measurement of the 186 keV gamma ray peak from ²³⁵U to determine enrichment levels. Short notice Random Inspections (SNRI) have been implemented in Japan to verify transfers of safeguarded material to and from facilities using a concept known as the "mailbox." A simple yet powerful tool, the mailbox consists of a desktop computer [12] in which the operator enters flow information, reports shipment and receipts, and other components of the material flow through the facility. Since the operator is required to enter this information as shipments go out and receipts come in, near-real time material accountancy is possible, and the selection of the date for the SNRI can be influenced by this flow information [13]. This selection is an example of information-driven safeguards—using unattended systems not to draw safeguard conclusions about a facility but rather to trigger inspections at opportune times from a material flow perspective.

Unattended Monitoring and Information-Driven Safeguards

With the growth of uranium enrichment capacity around the world, IAEA resources will be spread thin. This necessitates the implementation of advanced unattended monitoring systems and information-driven safeguards. Unattended monitoring systems can help better utilize IAEA resources by reducing the inspector labor necessary for safeguarding a given facility by analyzing raw data from continuous operation automatically. The data from these systems will be used to reduce the number of DA and NDA samples needed during the inspectors' visit. The power of unattended monitoring systems is truly utilized however, when they are paired with information-driven safeguards.

In information-driven safeguards, unattended monitoring systems can be used not for just for drawing safeguards conclusions but also to "trigger" inspections at opportune times based on plant operations schedules. This allows fewer random inspections to be scheduled in each material balance period, while remaining within the statistical window of certainty for the facility and acting as a deterrent on the operator by the threat of a random inspection [14].

Advanced Safeguards Concepts

The HSP as set forth in the Treaties of Almelo and Cardiff [15] established the precedent for protection of sensitive plant information. This information ranges from classified state secrets with proliferation implications to industry proprietary information which if leaked could eliminate competitive advantages. However, as the size of the throughput of GCEPs around the world increases, significant quantities of nuclear material can be lost in the MUF itself given the current detection methods. This situation dictates an updated approach to safeguards in GCEPs. Specifically there is a need to couple the operator's declaration with an understanding of plant processes to pinpoint inspection measures. One way to get this fuller sense of plant behavior is through process monitoring systems acting as complementary measures to supplement accountancy; operators however, cite the HSP's restriction of inspector access to plant data and are generally opposed to sharing plant data. They consider this information a trade secret, since it is closely related to the optimization of the plant.

These concerns must be taken into account as the next generation of safeguards technologies are developed. One proposed solutions include a "go/no-go" declaration system [14] which would provide the inspector with a relevant conclusion about plant activities while shielding the actual proprietary operations data. From the inspector's perspective, the current HSP regime is resource and labor intensive, especially at the high-throughput facilities being built and planned around the world. Development of enrichment technology by non-HSP states such as China, Russia, France, Brazil and Iran has also prompted the addition of the SNRI and mailbox concepts to the model GCEPs safeguard regime.

Coupling these declarations with integrated safeguards allows the IAEA to reduce detection probability targets if a state-level conclusion of non-proliferation has been reached. This allows the Agency to more efficiently utilize its limited human and financial resources in areas where proliferation is a higher concern. This is especially relevant for large throughput facilities located in NWS—Agency resources would be better used safeguarding facilities located in NNWS. These identified needs have driven the development of a series of advanced unattended monitoring concepts. The following advanced safeguards concepts, labeled Options B-E, are being researched for use in GCEPs by DOE national laboratory teams. Each option proposes a combination of less labor-intensive methods to obtain enrichment and mass data from the plant. The prospect of a resident inspector dedicated to a particular facility has also been identified, but this concept is outside of the scale of this analysis.

Option B: Member State Support Program (MSSP) Specifications

Option B is not a developed system but rather specifications established by the IAEA in a proposal to investigate the instruments needed to advance GCEPs safeguards. By setting performance targets, the Agency encouraged member states to develop next-generation unattended systems [9]. Specifically, these uncertainty specifications were developed to replicate current NDA capabilities with unattended enrichment and flow monitoring devices to measure the enrichment and flow rate of the process gas. This poses considerable challenges due to the low pressure and flow rate of the UF₆ process gas, and therefore the weight uncertainties for the MSSP specifications are significantly higher than the traditional method of using load cell balance scales.

Option C: Passive Neutron Detection

Option C utilizes passive neutron counting using 3 He detectors to measure both mass of uranium and 235 U enrichment of the UF₆ gas while it is in the cylinders. Passive neutron counting relies on the detection of neutrons emitted from the natural decay and interactions within the material. In the case of

enriched UF₆, the primary source of neutrons comes from the (α, n) reaction of ¹⁹F in the cylinder. The alpha particle comes from the spontaneous decay of ²³⁴U. The concentration of ²³⁴U is generally proportional to that of ²³⁵U, so measurement of ²³⁵U enrichment is possible through this technique, assuming a known ratio of ²³⁴U to ²³⁵U (thus if reprocessed uranium was being used, this technique would no longer be applicable without more research and understanding of the ratio of ²³⁴U to ²³⁵U in UF₆ process gas). Spontaneous decay of ²³⁸U is also an important source of neutrons in UF₆. By counting the total neutrons from both the ²³⁴U and the ²³⁸U, the mass of uranium in the cylinder can be determined. This allows the load cell mass data to be independently verified.

A system employing this technique, the Uranium Cylinder Assay System (UCAS) was developed by Los Alamos National Laboratory for Japan Nuclear Fuels Limited (JNFL)'s Rokkasho Enrichment Plant and has been implemented with favorable results [16]. In the Rokkasho facility, the UCAS has been used both as a mobile unit capable of measuring a variety of items and a fixed-geometry system mounted on the cylinder transfer cart for cylinder verification, as shown in Figure 1.

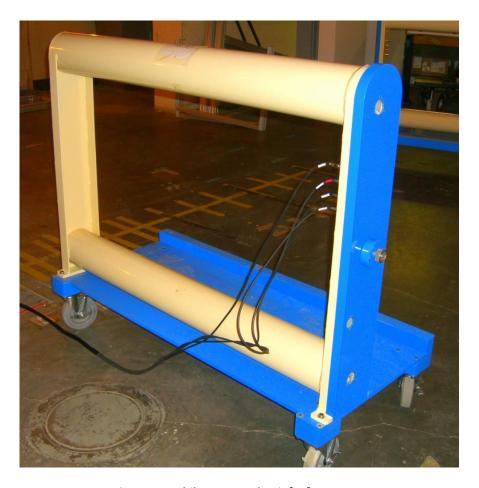


Figure 1: Mobile UCAS pod unit [16].

The fixed-geometry design shows promise for use in other enrichment facilities as it would be unobtrusive to everyday plant operations.

Option D: Advanced Enrichment Monitor and Accountancy Scales

Option D combines the use of the operator's own accountancy scales and an advanced enrichment monitor (AEM) placed on the process header pipes to verify the operator's weight and enrichment declarations. The traditional approach to measuring process UF₆ gas in header pipes is based on NaI (Tl) detector measurement of the 186-keV gamma ray from ²³⁵U and measurement of the UF₆ gas density through the attenuation of low energy radiation from a ¹⁰⁹Cd source. This methodology is currently used in the CEMO system. This proves difficult, however, since the ¹⁰⁹Cd source decays and must be

frequently replaced, significantly disrupting plant operations. Researchers at LANL have proposed that the accuracy and reliability of this continuous monitoring system can be improved through the substitution of the ¹⁰⁹Cd source with an X-ray tube which would not require frequent replacement [17]. In addition, the CEMO counting statistics are poor in the low-density UF₆ process gas. The placement of the AEM on the header pipe after process pumps increase the gas pressure should decrease uncertainties in enrichment measurements.

The enrichment information from the header-mounted AEM is coupled with cylinder weight data from the operator's own accountancy scales. These data would be authenticated to ensure that the operator was not tampering with the declaration. One method of authentication, shown in Figure 2, would be to correlate the data from the accountancy scales with data from load cells in the process MBA feed and withdrawal stations.

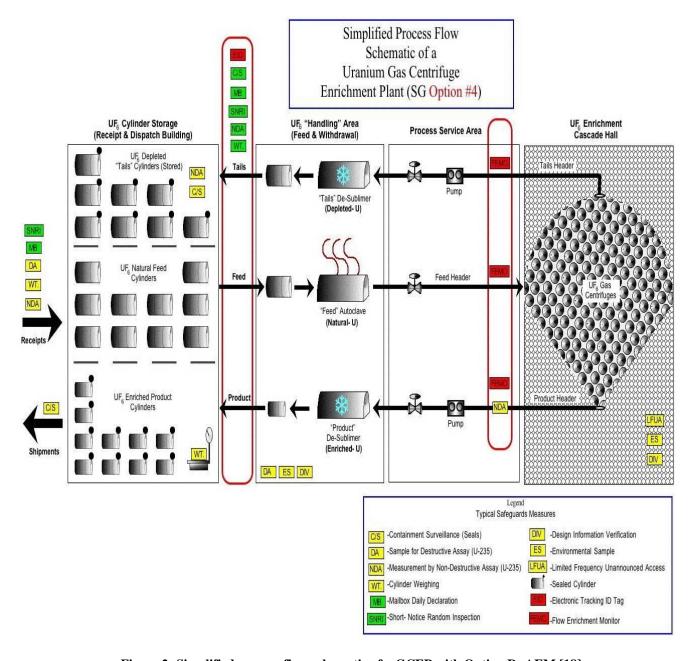


Figure 2: Simplified process flow schematic of a GCEP with Option D: AEM [18].

These two independently measured weight values could "cross authenticate" each other—the mass of UF_6 could be compared using both methods by the use of an algorithm which would report an anomaly if the two did not agree within a predetermined statistical window.

Option E: Neutron Detection and Advanced Enrichment Monitor Hybrid

Option E is a combination of Options C and D. A combination of UCAS with the AEM would provide two independent non-destructive measurements of uranium mass and ²³⁵U enrichment which would in turn be compared with the mass data from the accountancy scales and process load cell balances. In order to organize these data, each measurement must be connected to the cylinder from which it came. This requires a cylinder tracking system of some kind to correlate the various instruments' enrichment and weight measurements of individual cylinders and prevent operator misuse. One such system uses cylinder-mounted radio-frequency identification (RFID) tags to trace the path each cylinder throughout the facility. As each measurement point, the RFID tag would allow the mass and enrichment data to be matched to a particular cylinder.

ANALYSIS

This study analyzed the five options explained above and compared them for a variety of common plant sizes and proposed detection probabilities. Varying the plant size shows the economies of scale which begin to influence costs as the plants grow larger. The four advanced unattended systems were compared against the current HSP safeguards regime, which uses attended NDA and DA measurements taken while the inspector is physically at the site.

Probability of Detection Reduction

If these attended systems were replaced by unattended continuous monitoring systems, the case could be made to relax the probability of detection (PD) target for the inspection of the facility. If this were the case, the number of samples taken during a PIV, IIV, or LFUA would be less since the inspector would have greater confidence from the data being reported by the unattended systems. Under INFCIRC/153 safeguards, the probability of detection for DA could be reduced from 50% to 10% with the addition of these data from unattended monitoring systems. Under INFCIRC/540 safeguards, the PD for DA could be reduced from the original 20% to 10%. These reductions are summarized in Table 2:

Table 2: Reductions in DA probability of detection possible with unattended monitoring systems.

Safeguards Regime:	NDA PD:	DA PD:
INFCIRC/153	50%	50%
INFCIRC/153	50%	10%
INFCIRC/540	20%	20%
INFCIRC/540	20%	10%

These reductions are possible because the comprehensive data collected on the feed, product, and tails strata prevent the operator from introducing undeclared feed or removing undeclared product without being noticed. In light of this additional information, Boyer and Erpenbeck, [3] argue that the bias defect

sampling requirement under INFCIRC/153 Comprehensive Safeguards Agreements could be relaxed from P_D =50% to P_D =10% for the advanced safeguards options B, C, D, and E. In their analysis, they found the range of DA samples to be 119-356 for plants in the 3000-9000 MtSWU/yr range. This means that approximately 10-30 samples would need to be taken per month at each inspection (assuming an average of 12 inspections/year).

If INFCIRC/540, also known as the Additional Protocol (AP), is in place at a nation, then the probability of detection for the bias defect sampling can be reduced further from that required by INFCIRC/153, provided the state-wide conclusion of non-proliferation has been reached. Under the AP, the P_D for DA bias defect sampling is 20%, but if unattended monitoring systems were providing continuous data, this could be reduced to P_D=10%. The cost analysis of advanced safeguards concepts begun by Boyer and Durst [18] has been expanded for five different plant sizes: 500, 1000, 3000, 6000, and 9000 MtSWU/yr with four different DA sampling detection probabilities: INFCIRC/153 safeguards with 50% DA PD, INFCIRC/153 safeguards with 10% DA PD, INFCIRC/540 safeguards with 20% DA PD, and INFCIRC/540 safeguards with 10% DA PD. A sample breakdown of the analysis for INFCIRC/153 safeguards with 50% DA PD is found in the body of this text; the other cases can be found in Appendix A-E.

In this analysis, the costs of initial equipment purchase, the equipment maintenance and repair in the field, as well as inspector labor on site and back at headquarters were considered. The costs associated with analyzing DA and environmental samples were also estimated. The costs displayed are for one year, with hardware costs spread out over an estimated 10 year lifespan. Table 3 displays an example itemized equipment cost calculation:

Table 3: Cost of Safeguards Options at 3000 MtSWU/yr GCEP for INFCIRC/153 Safeguards with NDA PD= 50%, DA PD=50%

EXAMPLE GCEP of 3000	Assay Unit																	
	•				0			0-4			Ontinu (O-4:	_		04:	-
	Totals 115	TOT	690		Option	I A		Option E	5		Option (,		Option	עו		Option	I E
Nom. Feed cylinders/yr /assay unit	58		350															
Nom. Product cylinders/year	104		626															
Nom. Tails cylinders/year Cascade Halls	8		48															
Load cell monitors/assay unit	23		138															
Assay units	6		100	Trad/Int S	ads		١,	MSSP SPEC	:s		NEUT DET			AEM AC	c.c	NEUT DET	+ AFM AC	:c
rioda, amo	-			Trud/IIIC C	gus			NOON OF EC			NEOT DET			ALII AC		NEOT DET	T ALIII A	
Item SG system capital costs per an	num basis (10	A	nnual															
year life span for equipment)	,	Cos	st/ item	Items	Total ite	m Cost	Items	Total iten	n Cost	Items	Total item	Cost	Items	Total	item Cost	Items	Total ite	m Cost
DA Sample Bottles		\$	16	119	\$	1,845	248	\$	3,844	122	\$	1,891	30	\$	465	30	\$	465
Portable LCBWS		\$	680	1	\$	680	1	\$	680	1	\$	680	1	\$	680	1	\$	680
Reference weights		\$	-	1	\$		1	\$	-	1	\$	-	1	\$	-	1	\$	-
HPGe gamma spec (IMCG)		\$	3,700	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Nal Detector		\$	3,700	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Upgraded CHEM system		\$	15,000	0	\$		0	\$		0	\$		0	\$		0	\$	
Load cell monitors		\$	500	0	\$	-	0	\$	-	0	\$	-	138	\$	69,000	138	\$	69,000
PNUH		\$	40,000	0	\$	-	0	\$	_	0	\$	-	0	\$	-	0	\$	
AEM- Installed detection system		\$	10,000	0	\$		0	\$	-	0	\$	-	18	\$	180,000	18	\$	180.000
AEM - Data collect cabinet		\$	10,000	0	\$	-	0	\$	_	0	\$	-	6	\$	60.000	6	\$	60,000
Neutron Detection System		\$	6,500	0	\$		0	\$	-	1	\$	6.500	0	\$	-	1	\$	6,500
Neut Det - Data collect cabinet		\$	7,800	0	\$	-	0	\$	-	1	\$	7,800	0	\$	-	1	\$	7,800
Data acquisition system		\$	10,000	0	\$	-	1	\$	10,000	2	\$	20,000	6	\$	60,000	6	\$	60,000
Digital surv camera - F/W		s	2,000	0	\$	-	0	\$	-	24	ŝ	48,000	24	\$	48,000	24	\$	48,000
Accountability scale monitor + camera		\$	1,500	0	\$	-	0	\$		2	\$	3,000	2	\$	3,000	2	\$	3,000
ID tag interrogation antennas		\$	20	0	\$	-	0	\$	-	0	\$	-	162	\$	3,240	162	\$	3,240
ID tag interrogation readers		\$	200	0	\$	-	0	\$	-	0	\$	-	150	\$	30,000	150	\$	30,000
ID tags		\$	10	0	\$	-	0	\$	-	0	\$	-	1666	\$	16,660	1666	\$	16,660
Seals (IAEA costs/seal)		\$	33	100	\$	3.300	100	\$	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300
Total equipment cost per annum basi	is				\$	20,625		\$	32,624		\$	105,971		\$	489,145		\$	503,445
Equip. spares&installation =% of ann	ual cost		10%			\$2,062			\$3,262			\$10,597			\$48,915			\$50,345
	uarcost		10 /0			\$2,687			\$35,886			\$116,568			\$538,060			\$553,790
Total Annual Equipment Costs	4	0/ -6	Feede			\$22,007			\$35,666			\$110,000			\$338,060			\$553,790
Annual equipment cost - repairs, trip factor of equip. cost	os, costsas		Equip. t Factor															
Est. Annual Equipment Upkeep Costs	i		10.0%			\$2,268.7			\$3,588.6			\$11,656.8			\$53,806.0			\$55,379.0
Total Annual Equipment Costs					\$	24,956		\$	39,475		\$	128,225		\$	591,865		\$	609,168
Inspections Needed per Option Regin	ne				# of Insp	oections		# of Inspe	ections		# of Inspe	ections		# of Ir	nspections		# of Ins	pections
No. routine inspections/yr						11			11			11			3			3
No. supplemental inspections/yr						2			2			2			2	2		2
No. Addl LFUA inspections/yr						8			0			0		1	0)	1	0
No. PIV/yr						1			1			1			1			1
·		C	Cost/											Samp	le			
Annual Sample Procedure Costs per	Option Regime	Sa	am ple	Sample	Sam ple	Costs/Year	Sample	Sample C	osts/Year	Sam ple	Sample C	osts/Year	Sam ple	Costs		Sample	Sam ple	Costs/Year
DA Sample - procedures /yr		\$	700	79	\$	55,300	165	\$	115,500	81	\$	56,700	20	\$	14,000	20	\$	14,000
ES Samples/yr		\$	500	6	\$	3,000	6	\$	3,000	6	\$	3,000	6	\$	3,000	6	\$	3,000
TOTAL Sample Costs/yr					\$	58,300		\$	118,500		\$	59,700		\$	17,000		\$	17,000

Cost of Advanced Unattended Systems

The costs of the UCAS and AEM systems were determined through personal communication with researchers associated with their development at Los Alamos. For Option C's UCAS, the estimate at the date of publication was \$65,000 USD for the entire system, mainly due to its use of ³He tubes for neutron detection [19]. This translates to a yearly cost for the system of \$6,500 USD. For Option D, the cost of the AEM unit was estimated at time of publication as \$100,000 USD, for a yearly cost of \$10,000 USD. It is estimated that this figure could be reduced through economies of scale if enough units were produced [20].

The specific implementation of these safeguards technologies also affects the costs for each option. In the case of Option C, passive neutron detection, the UCAS system would be mounted on the transfer cart which carries the cylinders from the storage MBA to the process MBA and back again. It was assumed that the plants of capacity 500 and 1000 MtSWU/yr would have one transfer cart, and the larger plants of capacity 3000-9000 MtSWU/yr would have two carts—the calculations reflect these assumptions. As the feed, product, and tails cylinders rest on the cart, measurements would be taken and recorded by a data collection and storage system located in a nearby cabinet. This data collection system is estimated to cost \$78,000 USD, or \$7,800 USD annually.

In Option D, the AEM would be mounted on the headers of the centrifuge halls. Assuming a cascade hall has an individual capacity of 500 MtSWU/yr, the number of "assay units" (cascades) can be calculated for a facility of a particular throughput. Within each assay unit, each stratum has its own header and therefore its own AEM. Therefore, each assay unit requires three AEM units, one each for feed, product, and tails. The AEM also requires a data collection cabinet, but it is assumed that the data from all three strata can be collected by a single system, so therefore costs have been calculated for a single cabinet per assay unit, estimated at \$100,000 USD per cabinet, or \$10,000 USD annually. A tenvear lifespan is assumed for all detection systems.

For each safeguards option, attended inspections will still be performed. In order to verify operator declarations, a portable Load Cell Balance Weight System (LCBWS), portable HPGe gamma spectroscopy system (IMCG) and NaI detector are kept on site for use by Agency inspectors during their inspections. Due to inspector experience, it is assumed that one LCBWS will be sufficient, but having two duplicate HPGe and NaI systems is standard practice. During the course of inspections, IAEA seals will be applied on various items and instruments for later verification—it is assumed a maximum of 100 seals per year would be used for all safeguards options and plant sizes, at a cost of \$33 USD per seal. The number of DA sample bottles (\$16 per item) is also dictated by the number of DA samples which must be taken over the course of a year.

Inspector Labor Estimate

Inspector labor has also been estimated and example results for a 3000 MtSWU/yr plant with INFCIRC/153 Safeguards with a DA PD of 50% are shown in Table 4 below. The itemized list from Durst and Boyer has been expanded and updated, incorporating data from former IAEA inspectors working at DoE laboratories and current IAEA staff.

Table 4: Cost of Safeguards Labor at 3000 MtSWU/yr GCEP for INFCIRC/153 Safeguards with NDA PD=50%, DA PD=50%

EXAMPLE GCEP of 3000 MTSWU/yr Capacity	Assay Unit Totals	TOTAL		Option	A		Option B			Optio	on C	Option D		ı D		Option E	
Nom. Feed cylinders/yr /assay unit	115	690															
Nom. Product cylinders/year	59	354															
Nom Tails cylinders/year	104	626															
Cascade Halls	8	48															
Load cell monitors/assay unit	23	138															
Assay units	6		Trad/Int S	gds			ISSP SPECS	S		NEUT	DET	A	EM AC	CC	NEUT DET 4	AEM ACC	
la constitue Otalian and Income discontinue	\			# of Inon	a a tara		# of Inone	04070		# 06 1	noncetoro		# of la	noncotoro		# of Inconce	loro
Inspection Staffing per Inspection C	Jost			# of Insp	ectors		# of Inspe			# Of II	nspectors		# OT II	nspectors		# of Inspect	ors
Inspectors / routine inspection					2			2		-	2			2			2
Inspectors / suppl inspection					1			1			1			1			1
Inspectors / LFUA inspection					2			0			0			0			0
Inspectors / PIV inspection					3			3			3			3			3
Inspection Time Cost				Length (I	Days)		Length (Da	ays)		Leng	th (Days)		Leng	th (Days)		Length (Day	/s)
Duration of routine inspection					3			3			3			3			3
Duration of suppl inspection					1			1			1			1			1
Duration of LFUA inspection					1			0			0			0			0
Duration of PIV inspection					10			10			10			7			7
Rest days during routine inspection					0			0			0			0			0
Rest days during suppl inspection					0			0			0			0			0
Rest days during LFUA inspection					0			0			0			0			0
Rest days during PIV inspection					2			2			2			2			2
Travel days/inspector/trip					2			2			2			2			2
Office Time Cost (Prep/Aanalysis)				Length (I	_		Length (Da			Leng	th (Days)		Leng	th (Days)		Length (Day	/e\
Office days/IIV inspection day				Length (i	0.4		Length (D	0.6		Leng	0.8		Leng	ııı (Days)		Length (Day	1
					0.25			0.25			0.25			0.25			0.25
Office days/suppl inspection day																	
Office days/LFUA inspection day					0.125			0.125			0.125			0.125			0.125
Office days/PIV inspection day					0.25			0.25		_	0.5			1			1
Labor Cost of Inspector - burdened				Cost (US			Cost (USD			Cost	(USD)		Cost	(USD)		Cost (USD)	
Staff cost/day - trip PDI					\$2,000			\$2,000			\$2,000			\$2,000			\$2,000
Staff cost/day - trip Rest Day					\$1,000			\$1,000			\$1,000			\$1,000			\$1,000
Travel cost /trip					\$4,650			\$4,650			\$4,650			\$4,650			\$4,650
Staff cost/day - office					\$1,054			\$1,054			\$1,054			\$1,054			\$1,054
Inspector Labor Costs by Insp. Type	е		PDI	Cost (US	SD)	PDI	Cost (USD))	PDI	Cost	(USD)	PDI	Cost	(USD)	PDI	Cost (USD)	
Staff costs for routine inspection			66	\$	220,000	66	\$	220,000	66	\$	220,000	18	\$	60,000	18	\$	60,000
Staff costs for suppl inspection			2	\$	8,000	2	\$	8,000	2	\$	8,000	2	\$	8,000	2	\$	8,000
Staff costs for LFUA inspection			16	\$	64,000	0	\$	-	0	\$	-	0	\$		0	\$	-
Staff costs for PIV inspection			30	\$	84,000	30	\$	84,000	30	\$	84,000	21	\$	66,000	21	\$	66,000
Total Inspector Labor Cost			114	\$	376,000	98	\$	312,000	98	\$	312,000	41	\$	134,000	41	\$	134,000
Inspector Travel Costs by Insp. Typ	ie				·			,			,			,			
Travel costs for routine inspection				\$	102,300		\$	102,300		\$	102,300		\$	27,900		\$	27,900
Travel costs for suppl inspection				\$	9,300		\$	9,300		\$	9,300		\$	9,300		\$	9,300
Travel costs for LFUA inspection				\$	74,400		\$	-		\$	-		\$	-		\$	-
Travel costs for PIV inspection				\$	13,950		\$	13,950		\$	13,950		\$	13,950		\$	13,950
Total travel cost				\$	199,950		\$	125,550		\$	125,550		\$	51,150		\$	51,150
Inspector Office Costs by Insp. Typ	e			S	07.000		•	44.700		•	55.054		•	40.070		\$	40.070
Staff office costs for routine inspection				\$	27,826 527		\$	41,738 527		\$	55,651 527		\$	18,972 527		\$	18,972 527
Staff office costs for suppl inspection Staff office costs for LFUA inspection				\$	2,108		\$	521		\$	521		\$	521		\$	541
Staff office costs for PIV inspection				\$	7,905		\$	7,905		\$	15,810		\$	22,134		\$	22,134
Total staff office costs				\$	38,366		\$	50,170		\$	71,988		\$	41,633		\$	41,633
Total annual labor/staff/sampling c	osts			\$	614,316		\$	487,720		\$	509,538		\$	226,783		\$	226,783
Total Annual costs				\$	697,571		\$	645,695		\$	697,463		\$	835,648		\$	852,951
Total Annual costs in 1M\$ reflection	ng accuracy		\$M	0.7		\$M	0.6		\$M	0.7		\$М	8.0		\$M	0.9	

These estimates are not intended to provide a definitive budget; rather, they communicate the variances in each option's dependence on labor, technology and sampling. A key estimate in this section of the analysis was the number of inspections needed per year to maintain the assurances established in [23] for clear statistically significant data collection. If the probability of detection is reduced due to safeguards "bona fides," it is proposed that the number of interim inspections can be reduced as long as the unattended systems are functioning. Interim inspections would still be required to ensure that the operator has not tampered with the devices and that all systems are recording meaningful data. It is envisioned that these systems could send an automated daily "check-up" message to safeguards headquarters, informing inspectors immediately of any system failures. These messages could be integrated into a go/no-go system as proposed by Laughter to notify the Agency of all anomalies.

Cylinder Tracking System

As mentioned above, the advanced unattended monitoring systems in Options C-E require synchronization with a cylinder tracking system (CTS) in order to correlate their weight and enrichment measurements with specific cylinders. This could be achieved through the use of RFID tags (\$10 USD/year) located on the cylinders. The signals from these RFID tags would be captured using interrogation antennas (\$20/year).

The application of RFIDs to GCEPs is not a trivial one. The physical robustness of a RFID tag is largely dictated by the temperature range it can withstand, due to the harsh operating conditions found at GCEPs. In addition, cylinders are moved around the facility on carts and slings, often undergoing rough treatment and vibrations. Cylinders are inserted into autoclave stations which heat the contents to introduce the UF₆ into the centrifuge cascades(maximum temperature 140°C) and cold boxes which deposit (desublime) the UF₆ gas back into a solid (minimum temperature -40°C). Active tags, with their wide operating range and flexibility, are most susceptible to high temperature failure. In fact, in an

ORNL study on RFID tags [21], the temperature sensitivity in the autoclaves of GCEPS was identified as a major obstacle to the implementation of an RFID-based CTS.

Many authors in the safeguards community have touted the security benefits of an RFID-based CTS. Kovacic, et al. state that a CTS "be integrated with other systems and programmatic elements for the purpose of building defense-in-depth into facility safeguards [21]." They recommend researching ways to interface the CTS with other safeguards systems such as detectors, monitors, tamper-indicating devices, and surveillance cameras. They see this integration as a means to achieve a more thorough safeguards approach to GCEPs. The possibility of integration introduces the question: would RFIDs strengthen security or introduce weaknesses to the existing system?

Not all in the safeguards community are sold on the idea of RFIDs. Jon Warner and Roger Johnston, both with ANL's Vulnerability Assessment Team, claim that while RFIDs "are useful for inventory purposes," they are not reliable when used to monitor theft, tampering, or material diversion for safeguards or security systems [22]. They base this conclusion on a wealth of information from the internet on homegrown methods to hack even the most secure of commercial devices. RFIDs are easily mirrored, moved and replaced on different objects, and susceptible to electronic "eavesdropping." These concerns must be heeded—the security of the entire system could be compromised by its weakest link. However, if the goal is to reduce effort for IAEA inspectors and aid in the identification of cylinders, it is possible that a simple RFID-based CTS could be applied to GCEPs. Coupled with other containment and surveillance (C/S) measures such as cameras, the security weaknesses of RFIDs can be overcome.

DA Sampling Costs

During the course of inspections, DA samples will be taken according to the sampling plans described in [23]. DA costs also grow with plant throughput, due to the increased uncertainties in feed and tails measurements. Collecting these DA samples becomes extremely labor-intensive for both inspectors and operators, as each sample requires about 35 minutes to weigh the cylinder, draw a sample,

and store and seal the vial [24]. For smaller GCEPs in the current HSP regime, this procedure is reasonable. As plant throughput approaches 9000 MtSWU/year, however, the number of DA samples necessary to provide statistical assurance becomes prohibitive.

In *Defining the Needs for GCEPs Advanced Safeguards* [3], Boyer and Erpenbeck determine the number of NDA and DA measurements necessary to safeguard a facility at the level of HSP safeguards. As stated above, this analysis concludes that in the case of a 9000 MtSWU/yr facility under traditional HSP safeguards, a total of 356 DA samples would need to be taken throughout the course of the year, or almost 30 per month. In Option B: MSSP Specifications, the number of DA samples increases over 38% to 493 samples/year. This is because the increased uncertainties associated with the flow monitor specifications must be compensated for by increased DA sampling. Due to the capabilities of the other options, especially the AEM, the number of DA samples required to achieve the same P_D is much less. The DA sampling plans for the plants in this study are displayed in Table 5-Table 8:

Table 5: DA Sampling plan for INFCIRC/153 Safeguards with NDA=50%, DA=50%

DA Samı	oling 153 SGS	50-50			
Plant Size					
[MtSWU/yr]:	Option A	Option B	Option C	Option D	Option E
500	20	28	15	3	3
1000	40	55	27	7	7
3000	79	165	81	20	20
6000	238	329	162	39	39
9000	356	493	242	58	58

Table 6: DA Sampling plan for INFCIRC/153 Safeguards with NDA=50%, DA=10%

DA Samı	oling 153 SGS	50-10			
Plant Size [MtSWU/yr]:	Option A	Option B	Option C	Option D	Option E
500	20	5	3	3	3
1000	40	10	6	3	3
3000	79	27	13	5	5
6000	238	51	25	8	8
9000	356	77	38	11	11

Table 7: DA Sampling plan for INFCIRC/540 Safeguards with NDA=20%, DA=20%

DA Samı	oling 540 SGS	20-20			
Plant Size [MtSWU/yr]:	Option A	Option B	Option C	Option D	Option E
500	7	10	6	3	3
1000	14	19	10	3	3
3000	40	53	27	8	8
6000	77	106	52	13	13
9000	115	159	79	20	20

Table 8: DA Sampling plan for INFCIRC/540 Safeguards with NDA=20%, DA=10%

DA Samı	oling 540 SGS	20-10			
Plant Size [MtSWU/yr]:	Option A	Option B	Option C	Option D	Option E
500	7	5	3	3	3
1000	14	10	6	3	3
3000	40	27	13	5	5
6000	6	13	25	8	8
9000	115	77	38	11	11

DA sampling is expensive—the analysis associated with one sample bottle is estimated at \$700 USD [25]. This is due to the costs of the isotopic analysis, as well as shipping the sample bottles from the

facility to laboratories around Europe. The annual sampling costs as a normalized fraction of the HSP Safeguards option for the different plant sizes and advanced options are summarized in Table 9-Table 11.

Table 9: Comparison of annual DA costs with total Inspection Costs for 3000 MtSWU/yr capacity GCEP

3000 MtSWU/yr Plant	Op	tion A	Opt	tion B	Op	tion C	Op	tion D	Op	tion E
Total Annual Equipment Costs	\$	24,956	\$	39,475	\$	128,225	\$	591,865	\$	609,168
Weighted fraction of Option A		1.0000		1.5818		5.1381		23.7167		24.4100
Total annual labor/staff/sampling costs	\$	614,316	\$	487,720	\$	509,538	\$	226,783	\$	226,783
Weighted fraction of Option A		1.0000		0.7939		0.8294		0.3692		0.3692
Total Annual costs	\$	697,571	\$	645,695	\$	697,463	\$	835,648	\$	852,951
Weighted fraction of Option A		1.0000		0.9256		0.9998		1.1979		1.2227

Table 10: Comparison of annual DA costs with total Inspection Costs for 6000 MtSWU/yr capacity GCEP

6000 MtSWU/yr Plant	Opti	on A	Opt	tion B	Op	tion C	Opt	tion D	Opt	ion E
Total Annual Equipment Costs	\$	29,419	\$	44,089	\$	130,494	\$	1,059,058	\$	1,076,361
Weighted fraction of Option A		1.0000		1.4986		4.4357		35.9987		36.5869
Total annual labor/staff/sampling costs	\$	729,137	\$	576,855	\$	277,937	\$	235,697	\$	226,783
Weighted fraction of Option A		1.0000		0.7911		0.3812		0.3233		0.3110
Total Annual costs	\$	928,156	\$	854,244	\$	524,832	\$	1,325,054	\$	1,333,444
Weighted fraction of Option A		1.0000		0.9204		0.5655		1.4276		1.4367

Table 11: Comparison of annual DA costs with total Inspection Costs for 9000 MtSWU/yr capacity GCEP

9000 MtSWU/yr	Option	n A	Opti	on B	Opt	tion C	Opt	ion D	Opt	ion E
Total Annual Equipment Costs	\$	32,739	\$	48,703	\$	132,745	\$	1,526,232	\$	1,543,535
Weighted fraction of Option A		1.0000		1.4876		4.0546		46.6182		47.1467
Total annual labor/staff/sampling costs	\$	786,202	\$	487,720	\$	312,297	\$	235,697	\$	235,697
Weighted fraction of Option A		1.0000		0.6204		0.3972		0.2998		0.2998
Total Annual costs	\$	1,071,140	\$	884,523	\$	617,441	\$	1,805,528	\$	1,822,831
Weighted fraction of Option A		1.0000		0.8258		0.5764		1.6856		1.7018

As can be seen in Table 9-Table 11, the equipment costs are substantially higher for the advanced safeguards options, even as high as 47 times more expensive than the HSP in the case of Option E at the 9000 MtSWU/yr GCEP. These increases are largely offset in the sampling and labor costs, with that same Option E reducing sampling and labor costs by over 70% at the 9000 MtSWU/yr GCEP.

The cost of Options D and E is greater than the current HSP safeguards regime, as seen in Table 9-Table 11. The cost of these approaches largely hinges on the cost of the AEM and range from 1.2-1.7 times more expensive than the base HSP case. However, the difference in cost between the options could be offset by increased safeguards assurances and better safeguards at these facilities. This becomes increasingly apparent as the plants grow in size. The throughput at the largest facilities becomes too big

for the HSP safeguards to handle, and the increase of DA sampling and supplemental inspections needed to maintain assurances causes the costs to rise substantially.

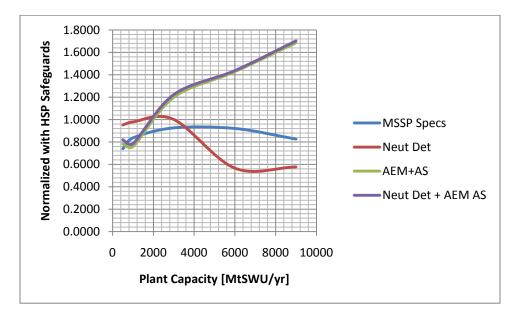


Figure 3: 153 Safeguards with NDA PD=50%, DA PD =50%

Figure 3 shows that the costs of HSP safeguards are largely influenced by labor costs as the plant size increases. If the probability of detection is reduced, as in Figure 4, then the number of DA samples is reduced and the difference between the HSP safeguards and the AEM options decreases by almost 4% in the case of the 9000 MtSWU/yr plant.

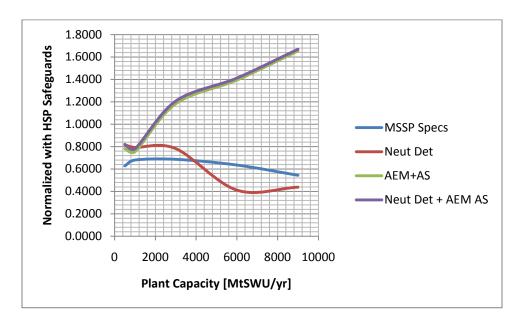


Figure 4: 153 Safeguards with NDA PD=50%, DA PD =10%

If the IAEA can be assured that the unattended systems provide increased ability to detect undeclared LEU and HEU production, then the case can be made to reduce the probability of detection to 10%. This reduces the number of necessary DA samples significantly, and the few remaining samples could be collected at four to seven unannounced inspections when the inspector comes to check up on the monitoring devices.

This study analyzed the five advanced safeguards options and compared them for a variety of common plant sizes and proposed detection probabilities. The full analysis can be found in Appendix A-E, but the trends highlighted here show the considerable costs associated with implementing an unattended system at GCEPs of various sizes. These costs are acceptable, however, when they are balanced against the increased safeguards knowledge and lowered inspector intrusion into everyday plant operations. DA sampling for the larger facilities has been shown to be prohibitive, and could be replaced by unattended monitoring systems while maintaining statistical assurances for the larger plants. Since DA sampling requires an on-site inspection, the labor costs associated with the higher-capacity plants are also a greater proportion of the total safeguards expenditures for the facility.

CONCLUSIONS

In this analysis, the costs of advanced safeguards options for five model GCEPS of capacity 500-9000 MtSWU/yr were compared with current methods based on the HSP for normal and reduced P_D under both INFCIRC/153 and INFCIRC/540 safeguards. Hardware and labor costs were estimated through personal communication with experts. This analysis shows that a main cost of safeguarding GCEPS is not in safeguards systems hardware but inspector labor. A large component of the inspector labor costs is DA sampling, which increases prohibitively with facility throughput. The larger facilities will require a new approach utilizing unattended monitoring systems because taking the number of DA samples necessary in such facilities is unrealistic. Despite the increases in overall safeguards cost with these unattended systems, the benefits of increased assurance and reduced inspector effort are worth the additional expenditure. Costs are also reduced if a reduction of the probability of detection can be justified given the state's overall safeguards conclusion. Overall, unattended systems are needed to improve safeguards in GCEPs and have been shown to be cost-effective.

Recommendations for Future Work

Since hardware is developed, installed, and maintained through the use of member states' support programs and not Agency funds, the main recommendation of this report is to conduct an in-depth stakeholder analysis to determine how the implementation of advanced safeguards systems affects the IAEA, operators, SSACs, and member support programs. Such an analysis could be useful for communicating incentives for operators to allow process monitoring systems instead of further intrusions into plant operations under the current system. More dialogue with operators is also necessary to ensure that the next generation of safeguards systems for GCEPs is well-integrated into plant operations with minimal effort required on the part of the operator.

Considering the advanced safeguards options analyzed in this paper, several areas have been identified for further work. RFID-based cylinder tracking systems require more research to develop robust tags which can withstand the rough treatment of cylinders in GCEPs, especially the heat of the autoclaves. Since the implementation of any new system is filled with complications, more field trials and optimization research for these advanced safeguards systems are necessary to ensure a smooth transition to the next generation of GCEPs safeguards. These trials will confirm if these advanced systems will actually reduce inspector effort and Agency costs in the long run.

As the uranium enrichment industry becomes more multinational and the separative capacity of enrichment plants around the world grows, the monetary and labor demands on the IAEA will only increase. In order to ensure the fulfillment of the IAEA's mission to promote the peaceful use of nuclear technology, the safeguards approach for GCEPs established by the HSP must be updated. Unattended monitoring systems and other advanced safeguards concepts will provide the enhanced safeguards needed at tomorrow's enrichment facilities.

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Appendix A:

Costs of Safeguards at a 500 MtSWU/yr GCEP
Table 12-Table 19 display the itemized cost analysis for safeguards at a GCEP of capacity 500 MtSWU/yr compared with current methods based on the HSP for normal and reduced P_{D} under both INFCIRC/153 and INFCIRC/540 safeguards regimes.

Table 12: Hardware Cost of Safeguards Options at 500 MtSWU/yr GCEP for INFCIRC/153 Safeguards with NDA PD= 50%, DA PD=50%

EXAMPLE GCEP of	Assay																	
	Unit																	
		тот			a			O4' I	_		a	- 0	١,				O41	-
	Totals	TOT		,	Option A	١		Option I	В	1	Optio	n C	,	Option	טו	'	Option	E
Nom. Feed cylinders/yr /ass:	115		115															
Nom. Product cylinders/year	58		58															
Nom. Tails cylinders/year	104		104															
Cascade Halls	8		8															
Load cell monitors/assay uni	23		23															
Assay units	1			Trad/Int Sg	ıds		M	SSP SPE	CS		NEUT [DET		AEM AC	CC	NEUT DET +	AEM A	CC
Item SG system capital c			ual Cost/															
annum basis (10 year life	span for	_	item	Items		em Cost	Items	_	em Cost	Items	_	l item Cost	Items		item Cost	Items		em Cost
DA Sample Bottles		\$	16	30	\$	465	42	\$	651	23	\$	357	5	\$	78	5	\$	78
Portable LCBWS		\$	680	1	\$	680	1	\$	680	1	\$	680	1	\$	680	1	\$	680
Reference w eights		\$	-	1	\$	-	1	\$	-	1	\$	-	1	\$	-	1	\$	-
HPGe gamma spec (IMCG)		\$	3,700	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Nal Detector		\$	3,700	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Upgraded CHEM system		\$	15,000	0	\$	-	0	\$	-	0	\$	-	0	\$	-	0	\$	-
Load cell monitors		\$	500	0	\$	-	0	\$	-	0	\$	-	23	\$	11,500	23	\$	11,500
PNUH		\$	40,000	0	\$	-	0	\$	-	0	\$	-	0	\$	-	0	\$	-
AEM- Installed detection systematics	em	\$	10,000	0	\$		0	\$		0	\$	_	3	\$	30,000	3	\$	30,000
ALIVE ITSTAILED DETECTION SYST	.CIII	Ψ	10,000	0	Ψ		0	Ψ		- 0	Ψ			Ψ	30,000		Ψ	30,000
AEM - Data collect cabinet		\$	10,000	0	\$	-	0	\$	-	0	\$	-	1	\$	10,000	1	\$	10,000
Neutron Detection System		\$	6,500	0	\$	-	0	\$	-	1	\$	6,500	0	\$	_	1	\$	6,500
Neut Det - Data collect cabine	et	\$	7,800	0	\$	-	0	\$		1	\$	7,800	0	\$	_	1	\$	7,800
Data acquisition system		\$	10,000	0	\$	_	1	\$	10,000	2	\$	20,000	1	\$	10,000	1	\$	10,000
Digital surv camera - F/W		\$	2,000	0	\$		0	\$	10,000	24	\$	48,000	24	\$	48,000	24	\$	48,000
Digital Sulv Camera - 1/vv		Ψ	2,000	0	Ψ		0	Ψ		24	Ψ	40,000	24	Ψ	40,000	24	Ψ	40,000
Accountability scale monitor -	+ camera	\$	1,500	0	\$	-	0	\$	-	2	\$	3,000	2	\$	3,000	2	\$	3,000
ID tag interrogation antennas		\$	20	0	\$	-	0	\$	-	0	\$	-	162	\$	3,240	162	\$	3,240
ID tag interrogation readers		\$	200	0	\$	-	0	\$	-	0	\$	-	150	\$	30,000	150	\$	30,000
ID tags		\$	10	0	\$	-	0	\$	-	0	\$	-	277.6667	\$	2,777	277.6667	\$	2,777
Seals (IAEA costs/seal)		\$	33	100	\$	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300
basis					\$	19,245		\$	29,431		\$	104,437		\$	167,374		\$	181,674
annual cost			10%			\$1,925			\$2,943			\$10,444			\$16,737			\$18,167
Total Annual Equipment	Costs		- 10.0			\$21,170			\$32,374			\$114,880			\$184,112			\$199,842
Annual equipment cost - I		% of	Equip.						***			*************************************			4 . 4 . 4 . 1			+ 100,01
trips, costsas factor of			Factor					L									<u></u>	
Costs			10.0%			\$2,117.0			\$3,237.4			\$11,488.0			\$18,411.2			\$19,984.2
Total Annual Equipment	Costs				\$	23,286		\$	35,612		\$	126,368		\$	202,523		\$	219,826
Regime					# of Inc	pections		# of Inc	pections		# of	Inspections		# of le	spections		# of In	spections
No. routine inspections/yr		1			., 01 1113	11		01 1113	11		<i>,,,</i> 01	11		., 0. 11	3	<u> </u>	01 111	2 SPSOUGHS
No. supplemental inspections	her	1			1	2		 	2		+	2		1	2		l	າ
No. Addl LFUA inspections/yi		1		-	+	8		 	0		1	0		+	2			0
No. PIV/yr		1			1	1		 	1		+	1		1	1		l	1
Annual Sample Procedure	Costs	-	Cost/		Sample			Sample			Sam			Samp			Sample	<u>1</u>
per Option Regime			am ple	Sample	Costs/\		Sample	Costs/		Sam ple		ts/Year	Sample	Costs		Sam ple	Costs	
DA Sample - procedures /yr		\$	700	20	\$	14,000	28	\$	19,600	15	\$	10,500	3	\$	2,100	3	\$	2,100
pio procoduros/yi		Ψ									_		_ <u> </u>	_			_	
ES Samples/yr		\$	500	6	\$	3,000	6	\$	3,000	6	\$	3,000	6	\$	3,000	6	\$	3,000

Table~13:~Labor~Cost~of~Safeguards~Options~at~500~MtSWU/yr~GCEP~for~INFCIRC/153~Safeguards~with~NDA~PD=50%, DA~PD=50%, DA~PD=50%,

EXAMPLE GCEP of	Assay																
500 MTSWU/yr Capacity	Unit Totals	TOTAL	_	ption A		,	ption B		_	ption C		_	ption	n		Option	_
Nom. Feed cylinders/yr /assa	115	115		puon A			puon b		U	puon c	'		puon	U	'	option	_
Nom. Product cylinders/year	59	59															
Nom. Tails cylinders/year	104	104															
Cascade Halls	8	8															
Load cell monitors/assay uni	23	23															
Assay units	1		Trad/Int Sg	ds		MS	SSP SPECS		N	EUT DET		A	EM AC	C	NEUT DET +	AEM AC	С
Inspection Staffing per In	spection Co			# of Inspec	ctors		# of Inspecto	rs		# of Ins	pectors		# of Ins	spectors		# of Ins	pectors
Inspectors / routine inspection	on				1			1			1			1			1
Inspectors / suppl inspection	1				1			1			1			1			1
Inspectors / LFUA inspection	า				2			0			0			0			0
Inspectors / PIV inspection					2			2			2			2			2
Inspection Time Cost				Length (Da	ıys)		Length (Days)		Length	(Days)		Length	(Days)		Length	(Days)
Duration of routine inspection	n				3			3			3			3			3
Duration of suppl inspection					1			1			1			1			1
Duration of LFUA inspection					1			0			0			0			0
Duration of PIV inspection					10			10			10			7			7
Rest days during routine ins	pection				0			0			0			0			0
Rest days during suppl inspe	ection				0			0			0			0			0
Rest days during LFUA inspe	ection				0			0			0			0			0
Rest days during PIV inspec					2			2			2			2			2
Travel days/inspector/trip					2			2			2			2			2
Office Time Cost (Prep/A	analvsis)			Length (Da	ıvs)		Length (Days			Length			Length			Length	(Davs)
Office days/IIV inspection da					0.4		<u> </u>	0.6			0.8			1			1
Office days/suppl inspection					0.25			0.25			0.25			0.25			0.25
Office days/LFUA inspection	•				0.125			0.125			0.125			0.125			0.125
Office days/PIV inspection d	•				0.25			0.25			0.5			1			1
Labor Cost of Inspector -				Cost (USD)			Cost (USD)			Cost (U			Cost (L	ISD)		Cost (U	SD)
Staff cost/day - trip PDI	Dai dollod			,	\$2,000			2,000		0001(0	\$2,000		,,,,,,,	\$2,000		0001 (0	\$2,000
Staff cost/day - trip Rest Day	.,				\$1,000			1,000			\$1,000			\$1,000			\$1,000
Travel cost /trip	у				\$4,650			4,650			\$4,650			\$4,650			\$4,650
Staff cost/day - office					\$1,054			1,054			\$1,054			\$1,054			\$1,054
Inspector Labor Costs by	v Insn. Tyne		PDI	Cost (USD)		PDI	Cost (USD)	.,00.	PDI	Cost (U		PDI	Cost (L		PDI	Cost (U	
Staff costs for routine inspe			33		0,000	33		,000	33		110,000		\$	30,000	9	\$	30,000
Staff costs for suppl inspect			2	,	8,000	2	,	3,000		\$	8,000		\$	8,000	2	\$	8,000
			16	,	34,000		\$,000		\$	0,000		\$	0,000	0	\$	0,000
Staff costs for LFUA inspec			†	,				-	20		FC 000		_	44.000			44.000
Staff costs for PIV inspectio			20		6,000	20		5,000			56,000	14		44,000	14	\$	44,000
Total Inspector Labor Co			71	\$ 23	88,000	55	\$ 174	,000	55	\$	174,000	25	\$	82,000	25	\$	82,000
Inspector Travel Costs b Travel costs for routine insp				\$ 5	51,150		\$ 51	,150		\$	51,150		\$	13,950		\$	13,950
Travel costs for suppl inspe					9,300		•	,130		\$	9,300		\$	9,300		\$	9,300
Travel costs for LFUA inspe					4,400		\$	-		\$	-		\$	-		\$	- 0,000
Travel costs for PIV inspecti				\$	9,300			,300		\$	9,300		\$	9,300		\$	9,300
Total travel cost				\$ 14	4,150		\$ 69	,750		\$	69,750		\$	32,550		\$	32,550
Inspector Office Costs by	, ,																
Staff office costs for routine			ļ		3,913			,869		\$	27,826		\$	9,486		\$	9,486
Staff office costs for suppli	•		1	\$	527		\$	527		\$	527		\$	527		\$	527
Staff office costs for LFUA	_		-		2,108 5,270		\$ \$ 5	- 5,270		\$	10,540		\$	14750		\$	14.750
Staff office costs for PIV ins Total staff office costs	pection		-		5,270 21,818			,666		\$	38,893		\$	14,756 24,769		\$	14,756 24,769
Total annual labor/staff/s	sampling co				3,968			,416		\$	282,643		\$	139,319		\$	139,319
	, ,													,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,			
Total Annual costs					4,254			,628		\$	422,511		\$	346,942		\$	364,245
reflecting accuracy			\$M	0.4		\$M	0.3		\$M	0.4		\$M	0.3		\$M	0.4	

Table 14: Hardware Cost of Safeguards Options at 500 MtSWU/yr GCEP for INFCIRC/153 Safeguards with NDA PD= 50%, DA PD=10%:

EXAMPLE GCEP of	Assay																	
500 MTSWU/yr	Unit																	
Capacity	Totals	тот	Δ1		Option A			Option	R		Option	1 C	,	otion	D		Option E	
Nom. Feed cylinders/yr /ass	115		115		P.1.0 7 t			орио	_		puo.	. •	`	puo.	_		оршон .	
Nom. Product cylinders/year	58		58															
Nom. Tails cylinders/year	104		104															
Cascade Halls	8		8															
Load cell monitors/assay un	23		23															
Assay units	1		_,	Trad/Int Sg	ds		М	SSP SPE	cs	l .	NEUT D	DET	,	EM AC	с	NEUT DET +	AEM AC	
Item SG system capital o	osts per	Annı	ual Cost/															
annum basis (10 year life	e span for	_	item	Items	Total iter		Items		em Cost	Items	_	item Cost	Items		item Cost	Items	Total ite	
DA Sample Bottles		\$	16	30	\$	465	8	\$	124	5	\$	78	5	\$	78	5	\$	78
Portable LCBWS		\$	680	1	\$	680	1	\$	680	1	\$	680	1	\$	680	1	\$	680
Reference w eights		\$	-	1	\$	-	1	\$	-	1	\$	-	1	\$	-	1	\$	-
HPGe gamma spec (IMCG)		\$	3,700	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Nal Detector		\$	3,700	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Upgraded CHEM system		\$	15,000	0	\$		0	\$	-	0	\$	-	0	\$		0	\$	
Load cell monitors		\$	500	0	\$	-	0	\$	-	0	\$		23	\$	11,500	23	\$	11,500
PNUH		\$	40,000	0	\$	-	0	\$	-	0	\$		0	\$	-	0	\$	
AEM- Installed detection sys	tem	\$	10,000	0	\$		0	\$		0	\$		3	\$	30,000	3 1	\$	30,000
AEM - Data collect cabinet		\$	10,000	0	\$		0	\$	<u> </u>	1	\$	6.500	0	\$	10,000	1	\$	10,000
Neutron Detection System Neut Det - Data collect cabin	-4	\$	6,500 7.800	0	\$		0	\$		1	\$	7,800	0	\$		1	\$	6,500 7.800
Data acquisition system	et	\$	10.000	0	\$		1	\$	10,000	2	\$	20.000	1	\$	10.000	1	\$	10.000
Digital surv camera - F/W		\$	2.000	0	\$		0	\$	10,000	24	\$	48,000	24	\$	48.000	24	\$	48.000
Accountability scale monitor	+ camora	\$	1,500	0	\$		0	\$		2	\$	3,000	2	\$	3.000	2	\$	3.000
ID tag interrogation antennas		\$	20	0	\$		0	\$		0	\$	3,000	162	\$	3,240	162	\$	3,240
ID tag interrogation readers	<u> </u>	\$	200	0	\$		0	\$	-	0	\$		150	\$	30,000	150	\$	30,000
ID tags		\$	10	0	\$		0	\$		0	\$	-	277.6667	\$	2,777	277.6667	\$	2,777
Seals (IAEA costs/seal)		\$	33	100	\$	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300
basis		Ť			\$	19,245		\$	28,904		\$	104,158		\$	167,374		\$	181,674
annual cost			10%			\$1,925			\$2,890			\$10,416			\$16,737			\$18,167
Total Annual Equipment	Costs					\$21,170			\$31,794			\$114,573			\$184,112			\$199,842
Annual equipment cost -			Equip.															
trips, costsas factor of	f equip.	Cost	Factor															
Costs		-	10.0%			\$2,117.0			\$3,179.4			\$11,457.3			\$18,411.2			\$19,984.2
Total Annual Equipment	Costs				\$	23,286		\$	34,974		\$	126,031		\$	202,523		\$	219,826
Regime					# of Insp	ections		# of Ins	pections		# of I	Inspections		# of Ir	spections		# of Ins	pections
No. routine inspections/yr						9			9			8			3			3
No. supplemental inspections	s/yr					2			2			2			2			2
No. Addl LFUA inspections/y	r					6			0			0			0			0
No. PIV/yr		<u> </u>				1			1			1			1			1
Annual Sample Procedure	e Costs		Cost/		Sample		L .	Sample		L .	Samp			Samp		L .	Sample	
per Option Regime		_	ample	Sample	Costs/Ye		Sample	Costs/		Sam ple	_		Sample	Costs		Sample	Costs/Y	
DA Sample - procedures /yr		\$	700	20	\$	14,000	5	\$	3,500	3	\$	2,100	3	\$	2,100	3	\$	2,100
ES Samples/yr		ι \$	500	6	\$	3,000	6	\$	3,000	6	\$	3,000	6	_	3,000	6		3,000
TOTAL Sample Costs/yr		<u> </u>			Þ	17,000	l	\$	6,500	l	\$	5,100		\$	5,100		\$	5,100

Table 15: Labor Cost of Safeguards Options at 500 MtSWU/yr GCEP for INFCIRC/153 Safeguards with NDA PD= 50%, DA PD=10%

EXAMPLE GCEP of	Accov																
500 MTSWU/yr	Assay Unit																
Capacity	Totals	TOTAL	0	ption A		,	Option	n B	0	ntio	on C	_	ption E	,		Option E	
Nom. Feed cylinders/yr /assa	115	115		puon A	•	,	puoi			puo) ii O		puon E		,	opaon t	
Nom. Product cylinders/year	59	59															
Nom. Tails cylinders/year	104	104.3333333															
Cascade Halls	8	8															
Load cell monitors/assay uni	23	23															
Assay units	1		Trad/Int Sg	ds		M:	SSP SI	PECS	N	EUT I	DET	Α	EM ACC		NEUT DET +	AEM AC	C
Inspection Staffing per In	spection Co			# of Ins	pectors		# of I	nspectors		# of	Inspectors		# of Ins			# of Ins	pectors
Inspectors / routine inspection	n				1			1			1			1			1
Inspectors / suppl inspection					1			1			1			1			1
Inspectors / LFUA inspection	١				2			0			0			0			0
Inspectors / PIV inspection					2			2			2			2			2
Inspection Time Cost				Length	(Days)		Leng	th (Days)		Len	gth (Days)		Length	(Days)		Length	(Days)
Duration of routine inspection	า				3			3			3			3			3
Duration of suppl inspection					1			1			1			1			1
Duration of LFUA inspection					1			0			0			0			0
Duration of PIV inspection					10			10			10			7			7
Rest days during routine insp	pection				0			0			0			0			0
Rest days during suppl inspe	ection				0			0			0			0			0
Rest days during LFUA inspe	ection				0			0			0			0			0
Rest days during PIV inspec	tion				2			2			2			2			2
Travel days/inspector/trip					2			2			2			2			2
Office Time Cost (Prep/A	analysis)			Length	(Days)		Leng	th (Days)		Len	gth (Days)		Length	(Days)		Length	(Days)
Office days/IIV inspection da	ıy				0.4			0.6			0.8			1			1
Office days/suppl inspection	day				0.25			0.25			0.25			0.25			0.25
Office days/LFUA inspection	day				0.125			0.125			0.125			0.125			0.125
Office days/PIV inspection d	ay				0.25			0.25			0.5			1			1
Labor Cost of Inspector -	burdened			Cost (U	ISD)		Cost	(USD)		Cos	st (USD)		Cost (U	SD)		Cost (U	SD)
Staff cost/day - trip PDI					\$2,000			\$2,000			\$2,000			\$2,000			\$2,000
Staff cost/day - trip Rest Day	/				\$1,000			\$1,000			\$1,000			\$1,000			\$1,000
Travel cost /trip					\$4,650			\$4,650			\$4,650			\$4,650			\$4,650
Staff cost/day - office					\$1,054			\$1,054			\$1,054			\$1,054			\$1,054
Inspector Labor Costs by	Insp. Type		PDI	Cost (U	ISD)	PDI	Cost	(USD)	PDI	Cos	st (USD)	PDI	Cost (U	SD)	PDI	Cost (U	SD)
Staff costs for routine inspe-	ction		27	\$	90,000	27	\$	90,000	24	\$	80,000	9	\$	30,000	9	\$	30,000
Staff costs for suppl inspect	ion		2	\$	8,000	2	\$	8,000	2	\$	8,000	2	\$	8,000	2	\$	8,000
Staff costs for LFUA inspec	tion		12	\$	48,000	0	\$	-	0	\$	-	0	\$	-	0	\$	-
Staff costs for PIV inspection	n		20	\$	56,000	20	\$	56,000	20	\$	56,000	14	\$	44,000	14	\$	44,000
Total Inspector Labor Co.	st		61	\$	202,000	49	\$	154,000	46	\$	144,000	25	\$	82,000	25	\$	82,000
Inspector Travel Costs by	y Insp. Type																
Travel costs for routine inspe	ection			\$	41,850		\$	41,850		\$	37,200		\$	13,950		\$	13,950
Travel costs for suppl inspec	ction			\$	9,300		\$	9,300		\$	9,300		\$	9,300		\$	9,300
Travel costs for LFUA inspe-				\$	55,800		\$	-		\$	-		\$	-		\$	-
Travel costs for PIV inspection	on			\$	9,300		\$	9,300		\$	9,300		\$	9,300		\$	9,300
Total travel cost	Inon Tuno			\$	116,250		\$	60,450		\$	55,800		\$	32,550		\$	32,550
Inspector Office Costs by Staff office costs for routine	to a section			\$	11,383		\$	17,075		\$	20,237		\$	9,486		\$	9,486
Staff office costs for routine				\$	527		\$	527		\$	527		\$	527		\$	527
Staff office costs for LFUA i				\$	1,581		\$	-		\$	-		\$	-		\$	-
Staff office costs for PIV ins				\$	5,270		\$	5,270		\$	10,540		\$	14,756		\$	14,756
Total staff office costs				\$	18,761		\$	22,872		\$	31,304		\$	24,769		\$	24,769
Total annual labor/staff/s	sampling co			\$	337,011		\$	237,322		\$	231,104		\$	139,319		\$	139,319
Total Annual sects				¢	277 000		¢	270 700		¢	260.027		¢	246.040		¢	264 245
Total Annual costs reflecting accuracy			\$M	\$ 0.4	377,298	\$M	\$ 0.3	278,796	\$M	\$ 0.4	362,234	\$M	\$ 03	346,942	\$M	\$ 0.4	364,245
renecting accuracy			φIVI	J.4		φIVI	0.3		ΨVI	0.4		ΨIVI	0.3		φIVI	J.4	

Table 16: Hardware Cost of Safeguards Options at 500 MtSWU/yr GCEP for INFCIRC/540 Safeguards with NDA PD=20%, DA PD=20%

EXAMPLE GCEP of	Assay										•							
500 MTSWU/vr	Unit																	
Capacity	Totals	TOTAL		,	Option A			Option	B		Option		,	Optio	. D		Option	_
	115	115		•	opuon A			Орион	В		Optioi	10	,	Jpuoi	טו		Option	_
Nom. Feed cylinders/yr /ass																		
Nom. Product cylinders/year	58	58																
Nom. Tails cylinders/year	104	104	1															
Cascade Halls	8	8																
Load cell monitors/assay uni	23	23																
Assay units	1			Trad/Int Sg	ds		N	ISSP SP	ECS		NEUT D)ET	,	AEM A	cc	NEUT DET +	AEM A	cc
Item SG system capital o	•	Annual			T - 4 - 1 /4 -	0		T-1-11									T-1-11	01
annum basis (10 year life	e span for	iter		Items	Total ite		Items	_	tem Cost	Items	_	item Cost	Items	_	item Cost	Items		em Cost
DA Sample Bottles		\$	16	11	\$	171	15	\$	233	9	\$	140	5	\$	78	5	\$	78
Portable LCBWS		\$	680	1	\$	680	1	\$	680	1	\$	680	1	\$	680	1	\$	680
Reference w eights		\$		1	\$		1	\$		1	\$		1	\$		1	\$	
HPGe gamma spec (IMCG)			3,700	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Nal Detector			3,700	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Upgraded CHEM system			5,000	0	\$	-	0	\$	-	0	\$		0	\$		0	\$	
Load cell monitors		\$	500	0	\$	-	0	\$		0	\$		23	\$	11,500	23	\$	11,500
PNUH			0,000	0	\$	-	0	\$	-	0	\$	-	0	\$	-	0	\$	-
AEM- Installed detection sys	tem		0,000	0	\$	-	0	\$	-	0	\$	-	3	\$	30,000	3	\$	30,000
AEM - Data collect cabinet		\$ 10	0,000	0	\$	-	0	\$	-	0	\$	-	1	\$	10,000	1	\$	10,000
Neutron Detection System		\$	6,500	0	\$	-	0	\$	-	1	\$	6,500	0	\$	-	1	\$	6,500
Neut Det - Data collect cabin	et	\$	7,800	0	\$	-	0	\$	-	1	\$	7,800	0	\$	-	1	\$	7,800
Data acquisition system		\$ 1	0,000	0	\$	-	1	\$	10,000	2	\$	20,000	1	\$	10,000	1	\$	10,000
Digital surv camera - F/W		\$	2,000	0	\$	-	0	\$	-	24	\$	48,000	24	\$	48,000	24	\$	48,000
Accountability scale monitor	+ camera	\$	1,500	0	\$	-	0	\$	-	2	\$	3,000	2	\$	3,000	2	\$	3,000
ID tag interrogation antennas	1	\$	20	0	\$	-	0	\$	-	0	\$	-	162	\$	3,240	162	\$	3,240
ID tag interrogation readers		\$	200	0	\$	-	0	\$	-	0	\$	-	150	\$	30,000	150	\$	30,000
ID tags		\$	10	0	\$	-	0	\$	-	0	\$	-	277.6667	\$	2,777	277.6667	\$	2,777
Seals (IAEA costs/seal)		\$	33	100	\$	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300
basis					\$	18,951		\$	29,013		\$	104,220		\$	167,374		\$	181,674
annual cost			10%			\$1,895			\$2,901			\$10,422			\$16,737	·		\$18,167
Total Annual Equipment	Costs					\$20,846			\$31,914			\$114,641			\$184,112			\$199,842
Annual equipment cost -	repairs,	% of Equ	ıip.															
trips, costsas factor of	f equip.	Cost Fa	ctor															
Costs		1	0.0%			\$2,084.6			\$3,191.4			\$11,464.1			\$18,411.2			\$19,984.2
Total Annual Equipment	Costs				\$	22,930		\$	35,105		\$	126,106		\$	202,523		\$	219,826
Regime					# of Insp	ections		# of In	spections		# of I	nspections		# of I	nspections		# of In	spections
No. routine inspections/yr						8			8			7		<u> </u>	2	1		2
No. supplemental inspections	s/yr					2			2			2		<u> </u>	2	1		2
No. Addl LFUA inspections/y	r					6			0			0			0			0
No. PIV/yr						1			1			1			1			1
Annual Sample Procedur	e Costs	Cos			Sample			Samp			Samp			Samp			Sampl	
per Option Regime		Sam		Sam ple	Costs/Y		Sam ple	Costs		Sam ple		s/Year	Sam ple		s/Year	Sample	Costs	
DA Sample - procedures /yr		\$	700	7	\$	4,900	10	\$	7,000	6	\$	4,200	3	\$	2,100	3	\$	2,100
ES Samples/yr		\$	500	6	\$	3,000	6	\$	3,000	6	\$	3,000	6	\$	3,000	6	\$	3,000
TOTAL Sample Costs/yr				l	\$	7,900		\$	10,000		\$	7,200		\$	5,100		\$	5,100

Table 17: Labor Cost of Safeguards Options at 500 MtSWU/yr GCEP for INFCIRC/540 Safeguards with NDA PD= 20%, DA PD=20%

								-				-
	Assay											
	Unit	TOTAL			,	Santiana D	_		١,	antina B		0-4 5
Capacity Nom. Feed cylinders/yr /assa	Totals 115	TOTAL 115	U	ption A	,	Option B	,	ption C	,	Option D		Option E
Nom. Product cylinders/year	59	59										
Nom. Tails cylinders/year	104	104.3333333										
Cascade Halls	8	8										
Load cell monitors/assay uni	23	23										
Assay units	1		Trad/Int Sgo	ds	MS	SSP SPECS	N	EUT DET	,	AEM ACC	NEUT DET +	AEM ACC
Inspection Staffing per In	spection Co			# of Inspectors		# of Inspectors		# of Inspectors		# of Inspectors		# of Inspectors
Inspectors / routine inspectio	n			1		1		1		1		1
Inspectors / suppl inspection				1		1		1		1		1
Inspectors / LFUA inspection				2		0		C)	0)	0
Inspectors / PIV inspection				2		2		2	!	2		2
Inspection Time Cost				Length (Days)		Length (Days)		Length (Days)		Length (Days)		Length (Days)
Duration of routine inspection	١			3		3		3	1	3		3
Duration of suppl inspection				1		1		1		1		1
Duration of LFUA inspection				1		0		C)	0)	0
Duration of PIV inspection				10		10		10		7		7
Rest days during routine insp	ection			0		0		C)	0		0
Rest days during suppl inspe	ection			0		0		C		0		0
Rest days during LFUA inspe				0		0		C		0		0
Rest days during PIV inspect				2		2		2		2		2
Travel days/inspector/trip				2		2		2		2	_	2
Office Time Cost (Prep/Aa	analysis)			Length (Days)		Length (Days)		Length (Days)		Length (Days)		Length (Days)
Office days/IIV inspection da				0.4		0.6		0.8		1		1
Office days/suppl inspection				0.25		0.25		0.25		0.25		0.25
Office days/LFUA inspection	•			0.125		0.125		0.125		0.125	+	0.125
Office days/PIV inspection days				0.25		0.25		0.5		1		1
Labor Cost of Inspector -	•			Cost (USD)		Cost (USD)		Cost (USD)		Cost (USD)		Cost (USD)
Staff cost/day - trip PDI				\$2,000		\$2,000		\$2,000		\$2,000		\$2,000
Staff cost/day - trip Rest Day	,			\$1,000		\$1,000		\$1,000		\$1,000	1	\$1,000
Travel cost /trip				\$4,650		\$4,650		\$4,650		\$4,650		\$4,650
Staff cost/day - office				\$1,054		\$1,054		\$1,054		\$1,054		\$1,054
Inspector Labor Costs by	Insp. Type		PDI	Cost (USD)	PDI	Cost (USD)	PDI	Cost (USD)	PDI	Cost (USD)	PDI	Cost (USD)
Staff costs for routine inspec			24	\$ 80,000	24	' '	21	\$ 70,000	6	' '	6	· · · · ·
Staff costs for suppl inspect			2	\$ 8,000		\$ 8,000	2		2		2	
Staff costs for LFUA inspect			12	\$ 48,000		\$ -	0		0		0	
Staff costs for PIV inspection			20	\$ 56,000	20		20		14		14	
·			58	\$ 192,000	46	\$ 144,000	43	\$ 134,000	22	\$ 72,000	22	
Inspector Travel Costs by			36	Ψ 192,000	40	Ψ 144,000	43	Ψ 134,000	- 22	Ψ 12,000	22	Ψ 12,000
Travel costs for routine inspe				\$ 37,200		\$ 37,200		\$ 32,550		\$ 9,300		\$ 9,300
Travel costs for suppl inspec				\$ 9,300		\$ 9,300		\$ 9,300		\$ 9,300		\$ 9,300
Travel costs for LFUA inspec				\$ 55,800		\$ -		\$ -		\$ -		\$ -
Travel costs for PIV inspection	on			\$ 9,300		\$ 9,300		\$ 9,300		\$ 9,300		\$ 9,300
Total travel cost				\$ 111,600		\$ 55,800		\$ 51,150		\$ 27,900		\$ 27,900
Inspector Office Costs by				. 40.112							ļ	
Staff office costs for routine				\$ 10,118 \$ 527		\$ 15,178 \$ 527		\$ 17,707 \$ 527	-	\$ 6,324 \$ 527	}	\$ 6,324 \$ 527
Staff office costs for suppl in Staff office costs for LFUA in				\$ 1,581		\$ 527		\$ 527	1	\$ 527	1	\$ 521
Staff office costs for PIV ins				\$ 5,270		\$ 5,270		\$ 10,540		\$ 14,756		\$ 14,756
Total staff office costs				\$ 17,496		\$ 20,975		\$ 28,774		\$ 21,607		\$ 21,607
Total annual labor/staff/s	ampling co			\$ 321,096		\$ 220,775		\$ 213,924		\$ 121,507		\$ 121,507
Total Annual costs			4.	\$ 351,927	*:-	\$ 265,880		\$ 347,230		\$ 329,130		\$ 346,433
reflecting accuracy			\$M	0.4	\$M	0.3	\$M	0.3	\$M	0.3	\$M	0.3

Table 18: Hardware Cost of Safeguards Options at 500 MtSWU/yr GCEP for INFCIRC/540 Safeguards with NDA PD= 20%, DA PD=10%

EXAMPLE GCEP of	A 0001				1								
	Assay												
500 MTSWU/yr	Unit												
Capacity	Totals	TOTAL	C	Option A	'	Option B		Option C	(Option D		Option E	
Nom. Feed cylinders/yr /ass	115	115											
Nom. Product cylinders/year	58	58.33333333											
Nom. Tails cylinders/year	104	104.3333333											
Cascade Halls	8	8											
Load cell monitors/assay un	23	23											
Assay units	1		Trad/Int Sg	ds	M	SSP SPECS		NEUT DET	,	AEM ACC	NEUT DET +	- AEM ACC	:
Item SG system capital of		Annual Cost/											
annum basis (10 year lif	e span for	item	Items	Total item Cost	Items	Total item Cost	Items	Total item Cost	Items	Total item Cost	Items	Total iter	
DA Sample Bottles		\$ 16	11	\$ 171	8	\$ 124	5	\$ 78	5	\$ 78	5	\$	78
Portable LCBWS		\$ 680	1	\$ 680	1	\$ 680	1	\$ 680	1	\$ 680	1	\$	680
Reference w eights		\$ -	1	\$ -	1	\$ -	1	\$ -	1	\$ -	1	\$	-
HPGe gamma spec (IMCG)		\$ 3,700	2	\$ 7,400	2	\$ 7,400	2	\$ 7,400	2	\$ 7,400	2	\$	7,400
Nal Detector		\$ 3,700	2	\$ 7,400	2	\$ 7,400		\$ 7,400	2	\$ 7,400	2	\$	7,400
Upgraded CHEM system		\$ 15,000	0	\$ -	0	\$ -	0	\$ -	0	\$ -	0	\$	-
Load cell monitors		\$ 500	0	\$ -	0	\$ -	0	\$ -	23	\$ 11,500	23	\$	11,500
PNUH		\$ 40,000	0	\$ -	0	\$ -	0	\$ -	0	\$ -	0	\$	-
AEM- Installed detection sys	tem	\$ 10,000	0	\$ -	0	\$ -	0	\$ -	3	\$ 30,000	3	\$	30,000
AEM - Data collect cabinet		\$ 10,000	0	\$ -	0	\$ -	0	\$ -	1	\$ 10,000	1	\$	10,000
Neutron Detection System		\$ 6,500	0	\$ -	0	\$ -	1	\$ 6,500	0	\$ -	1	\$	6,500
Neut Det - Data collect cabin	et	\$ 7,800	0	\$ -	0	\$ -	1	\$ 7,800	0	\$ -	1	\$	7,800
Data acquisition system		\$ 10,000	0	\$ -	1	\$ 10,000	2	\$ 20,000	1	\$ 10,000	1	\$	10,000
Digital surv camera - F/W		\$ 2,000	0	\$ -	0	\$ -	24	\$ 48,000	24	\$ 48,000	24	\$	48,000
Accountability scale monitor	+ camera	\$ 1,500	0	\$ -	0	\$ -	2	\$ 3,000	2	\$ 3,000	2	\$	3,000
ID tag interrogation antennas	3	\$ 20	0	\$ -	0	\$ -	0	\$ -	162	\$ 3,240	162	\$	3,240
ID tag interrogation readers		\$ 200	0	\$ -	0	\$ -	0	\$ -	150	\$ 30,000	150	\$	30,000
ID tags		\$ 10	0	\$ -	0	\$ -	0	\$ -	277.6667	\$ 2,777	277.6667	\$	2,777
Seals (IAEA costs/seal)		\$ 33	100	\$ 3,300	100	\$ 3,300	100	\$ 3,300	100	\$ 3,300	100	\$	3,300
basis				\$ 18,951		\$ 28,904		\$ 104,158		\$ 167,374		\$	181,674
annual cost		10%		\$1,895		\$2,890)	\$10,416		\$16,737			\$18,167
Total Annual Equipment	Costs			\$20,846		\$31,794	ļ	\$114,573		\$184,112			\$199,842
Annual equipment cost -		% of Equip.											
trips, costsas factor of	f equip.	Cost Factor											
Costs		10.0%		\$2,084.6		\$3,179.4		\$11,457.3		\$18,411.2			\$19,984.2
Total Annual Equipment	Costs			\$ 22,930		\$ 34,974		\$ 126,031		\$ 202,523		\$	219,826
Regime				# of Inspections		# of Inspections		# of Inspections		# of Inspections		# of Insp	
No. routine inspections/yr				/				6		3			3
No. supplemental inspections		1		2		2		2		2		1	2
No. Addl LFUA inspections/y	r	.		6		(C	1	0		1	0
No. PIV/yr	- 0	0		1			-	1		1		0	1
Annual Sample Procedur	e Costs	Cost/ Sample	Sample	Sample Costs/Year	Sam ple	Sample Costs/Year	Sample	Sample Costs/Year	Sample	Sam ple Costs/Year	Sample	Sample Costs/Ye	aar
per Option Regime DA Sample - procedures /yr		\$ 700	Sample 7	\$ 4,900	Sample 5	\$ 3,500		\$ 2.100	Sample 3	\$ 2,100	Sample 3	\$	2.100
ES Samples/yr		\$ 700	6	\$ 4,900	6	\$ 3,500		\$ 2,100	6	\$ 2,100	6	\$	3,000
TOTAL Sample Costs/yr		φ 500	O	\$ 3,000 \$ 7,900	b	\$ 3,000 \$ 6.500	0	\$ 3,000 \$ 5,100	· · ·	\$ 3,000 \$ 5.100	· · ·	\$	5,100
TOTAL Sample Costs/yr				a 7,900		\$ 6,500		\$ 5,100		\$ 5,100		\$	5,100

Table 19: Labor Cost of Safeguards Options at 500 MtSWU/yr GCEP for INFCIRC/540 Safeguards with NDA PD= 20%, DA PD=10%

EVAMBLE COED (
EXAMPLE GCEP of	Assay											
500 MTSWU/yr	Unit		_				_					
Capacity	Totals	TOTAL	C	option A	,	Option B	C	ption C	C	Option D	,	Option E
Nom. Feed cylinders/yr /ass	115	115										
Nom. Product cylinders/year	59	59										
Nom. Tails cylinders/year Cascade Halls	104 8	104.3333333										
Load cell monitors/assay un	23	23										
Assay units	1	20	Trad/Int Sg	de	м	SSP SPECS		IEUT DET		NEM ACC	NEUT DET +	AFM ACC
			Tradjin og			0. 0. 200			,		INEG! DE! !	7.00
Inspection Staffing per In	spection Co			# of Inspectors		# of Inspectors		# of Inspectors		# of Inspectors		# of Inspectors
Inspectors / routine inspection				1		1		1		1		1
Inspectors / suppl inspection				1		1		1		1		1
Inspectors / LFUA inspection				2		0		0		0		0
Inspectors / PIV inspection	•			2		2		2		2		2
				_		_		_		-		Langth (Days)
Inspection Time Cost				Length (Days)		Length (Days)		Length (Days)		Length (Days)		Length (Days)
Duration of routine inspection	n			3		3		3		3		3
Duration of suppl inspection				1		0		0		0		1
Duration of LFUA inspection												0
Duration of PIV inspection				10		10		10		7		7
Rest days during routine ins	pection			0		0		0	1	0		0
Rest days during suppl inspe	ection			0		0		0		0	!	0
Rest days during LFUA insp	ection			0		0		0		0		0
Rest days during PIV inspec	tion			2		2		2		2		2
Travel days/inspector/trip				2		2		2		2		2
Office Time Cost (Prep/A	analysis)			Length (Days)		Length (Days)		Length (Days)		Length (Days)		Length (Days)
Office days/IIV inspection da	ay			0.4		0.6		0.8		1		1
Office days/suppl inspection	n day			0.25		0.25		0.25		0.25		0.25
Office days/LFUA inspection	n day			0.125		0.125		0.125		0.125		0.125
Office days/PIV inspection d	lay			0.25		0.25		0.5		1		1
Labor Cost of Inspector				Cost (USD)		Cost (USD)		Cost (USD)		Cost (USD)		Cost (USD)
Staff cost/day - trip PDI				\$2,000		\$2,000		\$2,000		\$2,000		\$2,000
Staff cost/day - trip Rest Day	v			\$1,000		\$1,000		\$1,000		\$1,000	1	\$1,000
Travel cost /trip	у			\$4,650		\$4,650		\$4,650		\$4,650		\$4,650
Staff cost/day - office				\$1,054		\$1,054		\$1,054		\$1,054		\$1,054
Inspector Labor Costs by	/ Insn Tyne		PDI	Cost (USD)	PDI	Cost (USD)	PDI	Cost (USD)	PDI	Cost (USD)	PDI	Cost (USD)
Staff costs for routine inspe			21	\$ 70,000	21	\$ 70,000	18			\$ 30,000	9	\$ 30,000
Staff costs for suppl inspec			2	\$ 8,000	2			\$ 8,000	2	\$ 8,000	2	\$ 8,000
Staff costs for LFUA inspec			12	\$ 48,000	0			\$ -	0	\$ -	0	\$ -
Staff costs for PIV inspectio			20		20		20	,	14	\$ 44,000	14	\$ 44,000
			55		43	\$ 134,000	40	\$ 124,000	25	\$ 82,000	25	\$ 82,000
Total Inspector Labor Co Inspector Travel Costs b			55	\$ 182,000	43	\$ 134,000	40	\$ 124,000	25	\$ 62,000	25	\$ 62,000
Travel costs for routine insp				\$ 32,550		\$ 32,550		\$ 27,900		\$ 13,950		\$ 13,950
Travel costs for suppl inspe				\$ 9,300		\$ 9,300		\$ 9,300		\$ 9,300		\$ 9,300
Travel costs for LFUA inspe				\$ 55,800		\$ -		\$ -		\$ -		\$ -
Travel costs for PIV inspecti				\$ 9,300		\$ 9,300		\$ 9,300		\$ 9,300		\$ 9,300
Total travel cost				\$ 106,950		\$ 51,150		\$ 46,500		\$ 32,550		\$ 32,550
Inspector Office Costs by	y Insp. Type											
Staff office costs for routine				\$ 8,854		\$ 13,280		\$ 15,178		\$ 9,486		\$ 9,486
Staff office costs for suppl i				\$ 527		\$ 527		\$ 527		\$ 527		\$ 527
Staff office costs for LFUA	-			\$ 1,581		\$ -		\$ -		\$ -	-	\$ -
Staff office costs for PIV ins	pection			\$ 5,270		\$ 5,270 \$ 19,077		\$ 10,540		\$ 14,756 \$ 24,769		\$ 14,756
Total staff office costs Total annual labor/staff/s	eampling on			\$ 16,232 \$ 305,182		\$ 19,077 \$ 204,227		\$ 26,245 \$ 196,745		\$ 24,769 \$ 139,319		\$ 24,769 \$ 139,319
Total allitual labor/Stall/s	samping co			ψ 303,162		Ψ 204,22 <i>1</i>		¥ 130,745		Ψ 135,319		Ψ 135,319
Total Annual costs				\$ 336,012		\$ 245,701		\$ 327,875		\$ 346,942		\$ 364,245
reflecting accuracy			\$M		\$M		\$M		\$M		\$M	0.4
							,					

Appendix B:

Costs of Safeguards at a 1000 MtSWU/yr GCEP

Table 20-Table 27 display the itemized cost analysis for safeguards at a GCEP of capacity 1000 MtSWU/yr compared with current methods based on the HSP for normal and reduced $P_{\rm D}$ under both INFCIRC/153 and INFCIRC/540 safeguards regimes.

Table 20: Hardware Cost of Safeguards Options at 1000 MtSWU/yr GCEP for INFCIRC/153 Safeguards with NDA PD= 50%, DA PD=50%

EXAMPLE GCEP of 1000	Assay Unit			Option A													
MTSWU/yr Capacity	Totals	TOTAL		Ontion A			ption	В		Option	ı C	0	ption	D		Option	F
Nom. Feed cylinders/yr /assay unit	115	230										-		_			_
Nom. Product cylinders/year	58	116.66667	1														
Nom. Tails cylinders/year	104	208.66667	1														
Cascade Halls	8	16	i														
Load cell monitors/assay unit	23	46	1														
Assay units	2		Trad/Int Sg	de		м	SP SP	ECS	١,	NEUT D	ET		EM AC	``	NEUT DET +	AEM ACC	
Item SG system capital costs per		Annual	rrau/iiit og	us		INIC	301 31		'	VLOT D		^	LIVI AC	,,,	NEOI DEI T	ALM ACC	
basis (10 year life span for equip		Cost/ item	Items	Total item (Cost	Items	Total	item Cost	Items	Total	litem Cost	Items	Total	item Cost	Items	Total ite	m Cost
DA Sample Bottles	<u>'</u>	\$ 16	60	\$	930	83	\$	1,287	41	\$	636	11	\$	171	11	\$	171
Portable LCBWS		\$ 680	1	\$	680	1	\$	680	1	\$	680	1	\$	680	1	\$	680
Reference weights		\$ -	1	\$	-	1	\$	-	1	\$	-	1	\$	-	1	\$	-
HPGe gamma spec (IMCG)		\$ 3,700	2		7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Nal Detector		\$ 3,700	2		7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Upgraded CHEM system		\$ 15,000	0	\$	-,	0	\$		0	\$		0	\$		0	\$	
Load cell monitors		\$ 500	0	\$		0	\$		0	\$	_	46	\$	23,000	46	\$	23,000
PNUH		\$ 40,000	0	\$		0	\$		0	\$		0	\$	23,000	0	\$	23,000
AEM- Installed detection system		\$ 10,000	0	\$		0	\$		0	\$		6	\$	60,000	6	\$	60,000
AEM - Data collect cabinet		\$ 10,000	0	\$		0	\$		0	\$		2	\$	20,000	2	\$	20,000
Neutron Detection System		\$ 6,500	0	\$		0	\$		1	\$	6,500	0	\$	20,000	1	\$	6,500
•			0	\$	-	0	\$		1	\$		0	\$		1	\$	
Neut Det - Data collect cabinet		\$ 7,800		-	-		\$	40.000	2		7,800	2	\$		2	•	7,800
Data acquisition system		\$ 10,000	0	\$	-	1	\$	10,000		\$	20,000			20,000		\$	20,000
Digital surv camera - F/W		\$ 2,000	0	\$	-	0	_	-	24	\$	48,000	24	\$	48,000	24	\$	48,000
Accountability scale monitor + camera		\$ 1,500	0	\$	-	0	\$	-	2	\$	3,000	2	\$	3,000	2	\$	3,000
ID tag interrogation antennas		\$ 20	0	\$	-	0	\$	-	0	\$	-	162	\$	3,240	162	\$	3,240
ID tag interrogation readers		\$ 200	0	\$	-	0	\$	-	0	\$	-	150	\$	30,000	150	\$	30,000
ID tags		\$ 10	0	\$	-	0	\$	-	0	\$		555.3333	\$	5,553	555.3333	\$	5,553
Seals (IAEA costs/seal)		\$ 33	100		3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300
Total equipment cost per annum b					19,710		\$	30,067		\$	104,716		\$	231,744		\$	246,044
Equip. spares&installation =% of a	nnual cost	10%			\$1,971			\$3,007			\$10,472			\$23,174			\$24,604
Total Annual Equipment Costs				\$:	21,681			\$33,073			\$115,187			\$254,918			\$270,648
Annual equipment cost - repairs, costsas factor of equip. cost	trips,	% of Equip. Cost Factor															
Est. Annual Equipment Upkeep Co	sts	10.0%			2,168.1			\$3,307.3			\$11,518.7			\$25,491.8			\$27,064.8
Total Annual Equipment Costs				\$ 2	23,849		\$	36,380		\$	126,706		\$	280,410		\$	297,713
Inspections Needed per Option Re	egime			# of Inspec	ctions		# of I	nspections		# of	Inspections		# of I	nspections		# of Insp	ections
No. routine inspections/yr					11			11			11			3			3
No. supplemental inspections/yr					2			2			2			2			2
No. Addl LFUA inspections/yr					8			0			0			0			0
No. PIV/yr					1			1			1			1			1
Annual Sample Procedure Costs	per Option	Cost/		Sam ple			Samp	ole		Sam	ple		Samp	ole			
Regime		Sam ple	Sam ple	Costs/Year	r	Sam ple		s/Year	Sam ple	_	s/Year	Sam ple		s/Year	Sam ple		Costs/Year
DA Sample - procedures /yr		\$ 700	40		28,000	55	\$	38,500	27	\$	18,900	7	\$	4,900	7	\$	4,900
ES Samples/yr		\$ 500	6	\$	3,000	6	\$	3,000	6	\$	3,000	6	\$	3,000	6	\$	3,000
TOTAL Sample Costs/yr				\$ 3	31,000		\$	41,500		\$	21,900		\$	7,900		\$	7,900

Table 21: Labor Cost of Safeguards Options at 1000 MtSWU/yr GCEP for INFCIRC/153 Safeguards with NDA PD=50%, DA PD=50%

EXAMPLE GCEP of 1000	Assay Unit																
MTSWU/yr Capacity	Totals	TOTAL	o	ption	A	o	ption	В	o	ptic	on C	0	otion	D		Option E	_
Nom. Feed cylinders/yr /assay unit	115	230												_		-	
Nom. Product cylinders/year	59	118															
Nom. Tails cylinders/year	104	208.66667	1														
Cascade Halls	8	16															
Load cell monitors/assay unit	23	46															
Assay units	2		Trad/Int Sgo	ls		MS	SP SP	ECS	N	IEUT	DET	Α	EM AC	:c	NEUT DET +	AEM ACC	
	_																
Inspection Staffing per Inspection	n Cost			# of Ins	pectors		# of I	nspectors		# 0	of Inspectors		# of II	nspectors		# of Inspe	ectors
Inspectors / routine inspection					2			2		_	2			2			2
Inspectors / suppl inspection					1			1		_	1			1			1
Inspectors / LFUA inspection					2			0			0			0			0
Inspectors / PIV inspection					2			2			2			2			2
Inspection Time Cost				Length	(Days)		Leng	th (Days)		Lei	ngth (Days)		Leng	th (Days)		Length (E	Jays)
Duration of routine inspection					3			3			3			3			3
Duration of suppl inspection					1			1			1			1			1
Duration of LFUA inspection					1			0			0			0			
Duration of PIV inspection					10			10			10			7			7
Rest days during routine inspection					0			0			0			0			
Rest days during suppl inspection					0			0			0			0			C
Rest days during LFUA inspection					0			0			0			0			
					2			2			2			2			
Rest days during PIV inspection										-	2						
Travel days/inspector/trip				1	(Dave)			2			2 math (Davis)		1	4h (Dava)		Lameth (F	2
Office Time Cost (Prep/Aanalysis)			Length	(Days)		Leng	th (Days)		Lei	ngth (Days)		Leng	th (Days)		Length (E	ays)
Office days/IIV inspection day					0.4			0.6		-	0.8			1			1
Office days/suppl inspection day					0.25			0.25			0.25			0.25			0.25
Office days/LFUA inspection day					0.125			0.125			0.125			0.125			0.125
Office days/PIV inspection day					0.25			0.25			0.5			1			1
Labor Cost of Inspector - burden	ed			Cost (L	JSD)		Cost	(USD)		Co	st (USD)		Cost	(USD)		Cost (US	D)
Staff cost/day - trip PDI					\$2,000			\$2,000			\$2,000			\$2,000			\$2,000
Staff cost/day - trip Rest Day					\$1,000			\$1,000			\$1,000			\$1,000			\$1,000
Travel cost /trip					\$4,650			\$4,650			\$4,650			\$4,650			\$4,650
Staff cost/day - office					\$1,054			\$1,054			\$1,054			\$1,054			\$1,054
Inspector Labor Costs by Insp. T	ype		PDI	Cost (L	JSD)	PDI	Cost	(USD)	PDI	Co	st (USD)	PDI	Cost	(USD)	PDI	Cost (US	D)
Staff costs for routine inspection			66	\$	220,000	66	\$	220,000	66	\$	220,000	18	\$	60,000	18	\$	60,000
Staff costs for suppl inspection			2	\$	8,000	2	\$	8,000	2	\$	8,000	2	\$	8,000	2	\$	8,000
Staff costs for LFUA inspection			16	\$	64,000	0	\$	_	0	\$	-	0	\$	-	0	\$	-
Staff costs for PIV inspection			20	\$	56,000	20	\$	56,000	20	\$	56,000	14	\$	44,000	14	\$	44,000
Total Inspector Labor Cost			104	\$	348,000	88	\$	284,000	88	_	284,000		\$	112,000	34	\$	112,000
Inspector Travel Costs by Insp. T	vpe				0.0,000		*	20.,000		Ť	20 1,000		•	,	-	*	
Travel costs for routine inspection	<i>,</i> ,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,			\$	102,300		\$	102,300		\$	102,300		\$	27,900		\$	27,900
Travel costs for suppl inspection				\$	9,300		\$	9,300		\$	9,300		\$	9,300		\$	9,300
Travel costs for LFUA inspection				\$	74,400		\$	-		\$	-		\$	-		\$	-
Travel costs for PIV inspection				\$	9,300		\$	9,300		\$	9,300		\$	9,300		\$	9,300
Total travel cost				\$	195,300		\$	120,900		\$	120,900		\$	46,500		\$	46,500
Inspector Office Costs by Insp. T	уре	ļ								_							
Staff office costs for routine inspection		ļ	 	\$	27,826		\$	41,738		\$	55,651		\$	18,972		\$	18,972
Staff office costs for suppl inspection		ļ		\$	527		\$	527		\$	527		\$	527		\$	527
Staff office costs for LFUA inspection	1	-	 	\$	2,108		\$			\$	40.540		\$	44750		\$	44750
Staff office costs for PIV inspection Total staff office costs		1	 	\$	5,270 35,731		\$	5,270 47,535		\$ \$	10,540 66,718		\$ \$	14,756 34,255		\$ \$	14,756 34,255
Total staff office costs Total annual labor/staff/sampling	a costs	 		\$	579,031		\$	452,435		\$	471,618		\$	192,755		\$	192,755
	, ,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,				0.0,001			.02,700			1,010		į	.02,100			.02,100
Total Annual costs				\$	633,880		\$	530,316		\$	620,224		\$	481,065		\$	498,368
accuracy			\$M	0.6		\$M	0.5		\$M	0.6		\$M	0.5		\$M	0.5	

Table 22: Hardware Cost of Safeguards Options at 1000 MtSWU/yr GCEP for INFCIRC/153 Safeguards with NDA PD=50%, DA PD=10%

	A 0001/																
EXAMPLE GCEP of 1000	Assay Unit																
MTSWU/yr Capacity	Totals	TOTAL					S4!	_		Option		_		_		Ontion I	
	115	230	,	Option	А	,	Option	Ь	,	optioi	16		ption	עו		Option E	
Nom. Feed cylinders/yr /assay unit	58		-														
Nom. Product cylinders/year		117	4														
Nom. Tails cylinders/year	104	209	-														
Cascade Halls	8	16															
Load cell monitors/assay unit	23	46															
Assay units	2		Trad/Int Sg	ds		M	SSP SPE	CS	l	NEUT D	ET	А	EM A	cc	NEUT DET +	AEM ACC	
Item SG system capital costs per		Annual		T-4-1		14	T-4-13	04		T -4-			T-4-			T-4-1 14	. 04
basis (10 year life span for equip	ment)	\$ 16	Items 60	\$	item Cost 930	Items 15	_	tem Cost 233	Items 9	\$	litem Cost 140	Items	\$	litem Cost	Items 5	Total item	
DA Sample Bottles		7		\$			\$			_		5				\$	78
Portable LCBWS		\$ 680 \$ -	1 1	\$	680	1	\$	680	1	\$	680	1	\$	680	1	\$	680
Reference weights		-		•	7 100	2	\$	7.400	1	\$	7 400		\$	7 400		\$	7 400
HPGe gamma spec (IMCG)		\$ 3,700 \$ 3,700	2	\$	7,400 7,400	2	\$		2	\$	7,400 7,400	2	\$	7,400 7,400	2	\$	7,400 7,400
Nal Detector		7		\$	7,400	0	\$	7,400			7,400		-	7,400			7,400
Upgraded CHEM system		\$ 15,000	0	\$		0	\$		0	\$		0 46	\$	23,000	0 46	\$	22.000
Load cell monitors		\$ 500		\$		0							\$	23,000		\$	23,000
PNUH		\$ 40,000	0			0	\$		0	\$		0	\$		0	\$	
AEM- Installed detection system		\$ 10,000	0	\$		0	\$		0	\$		6	\$	60,000	6 2	\$	60,000
AEM - Data collect cabinet		\$ 10,000 \$ 6,500		\$		0				_			_	20,000	1		20,000
Neutron Detection System		,	0	_		0	\$		1	\$	6,500	0	\$		1	\$	6,500
Neut Det - Data collect cabinet		\$ 7,800		\$			\$	-	1	\$	7,800		\$	-		\$	7,800
Data acquisition system		\$ 10,000	0	\$		1	\$	10,000	2	\$	20,000	2	\$	20,000	2	\$	20,000
Digital surv camera - F/W		\$ 2,000	0	\$		0	\$		24	\$	48,000	24	\$	48,000	24	\$	48,000
Accountability scale monitor + camera		\$ 1,500	0	\$		0	\$		2	\$	3,000	2	\$	3,000	2	\$	3,000
ID tag interrogation antennas		\$ 20		\$		0	\$		0	\$		162	\$	3,240	162	\$	3,240
ID tag interrogation readers		\$ 200		\$		0	\$		0			150	\$	30,000	150	\$	30,000
ID tags		\$ 10 \$ 33		\$	0.000	0	\$		0	\$		555.3333	\$	5,553	555.3333	\$	5,553
Seals (IAEA costs/seal)		\$ 33	100	\$	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300
Total equipment cost per annum b		400		\$	19,710		\$	29,013		\$	104,220		\$	231,651		\$	245,951
Equip. spares&installation =% of a	nnual cost	10%	o .		\$1,971			\$2,901			\$10,422			\$23,165			\$24,595
Total Annual Equipment Costs					\$21,681			\$31,914			\$114,641			\$254,816			\$270,546
		% of Equip															
Annual equipment cost - repairs,	trips.	Cost															
costsas factor of equip. cost	ро,	Factor															
Est. Annual Equipment Upkeep Co	sts	10.0%	6		\$2,168.1			\$3,191.4			\$11,464.1			\$25,481.6			\$27,054.6
Total Annual Equipment Costs				\$	23,849		\$	35,105		\$	126,106		\$	280,298		\$	297,601
					<u>, </u>			<u> </u>						<u> </u>			<u> </u>
Inspections Needed per Option Re	gime			# of Ir	spections		# of In	spections		# of	Inspections		# of	Inspections		# of Inspe	ections
No. routine inspections/yr	•				9			9			. 8			. 3			3
No. supplemental inspections/yr					2			2			2			2			2
No. Addl LFUA inspections/yr					6			0			0			0			C
No. PIV/yr					1		İ	1			1			1			1
Annual Sample Procedure Costs	per Option	Cost/		Samp	le		Sampl	e		Sam	ple		Sam	ple			
Regime		Sam ple	Sam ple	Costs	/Year	Sam ple	Costs	Year .	Sample	Cost	s/Year	Sam ple	Cost	s/Year	Sam ple	Sample C	osts/Year
DA Sample - procedures /yr		\$ 700	40	\$	28,000	10	\$	7,000	6	\$	4,200	3	\$	2,100	3	\$	2,100
ES Samples/yr		\$ 500	6	\$	3,000	6	\$	3,000	6	\$	3,000	6	\$	3,000	6	\$	3,000
TOTAL Sample Costs/yr				\$	31,000		\$	10,000		\$	7,200		\$	5,100		\$	5,100

Table 23: Labor Cost of Safeguards Options at 1000 MtSWU/yr GCEP for INFCIRC/153 Safeguards with NDA PD= 50%, DA PD=10%

	Assay											
EXAMPLE GCEP of 1000	Unit											
MTSWU/yr Capacity	Totals	TOTAL	0	ption A	0	ption B	0	ption C	O	ption D		Option E
Nom. Feed cylinders/yr /assay unit	115	230										
Nom. Product cylinders/year	59	118										
Nom. Tails cylinders/year	104	208.66667										
Cascade Halls	8 23	16 46	ł									
Load cell monitors/assay unit Assay units	23	40	Trad/Int Sgo	·le	мѕ	SP SPECS	N	EUT DET	ΔΙ	EM ACC	NEUT DET +	AFM ACC
rioday anno	_		Trudyllic Ogc		INC	101 01 200		LOT BET		an Acc	NEOT DET T	ALII AGG
Inspection Staffing per Inspection	n Cost			# of Inspectors		# of Inspectors		# of Inspectors		# of Inspectors		# of Inspectors
Inspectors / routine inspection					2	2		2		2		2
Inspectors / suppl inspection					1	1		1		1		1
Inspectors / LFUA inspection					2	0		0		0		0
Inspectors / PIV inspection					2	2		2		2		2
Inspection Time Cost				Length (Days)		Length (Days)		Length (Days)		Length (Days)		Length (Days)
Duration of routine inspection					3	3		3		3		3
Duration of suppl inspection					1	1		1		1		1
Duration of LFUA inspection					1	0		0		0		0
Duration of PIV inspection				1)	10		10		7		7
Rest days during routine inspection					o l	0		0		0		0
Rest days during suppl inspection)	0		0		0		0
Rest days during LFUA inspection)	0		0		0		0
Rest days during PIV inspection					2	2		2		2		2
Travel days/inspector/trip	•				2	2		2		2		2
Office Time Cost (Prep/Aanalysis)			Length (Days)		Length (Days)		Length (Days)		Length (Days)		Length (Days)
Office days/IIV inspection day				0.	4	0.6		0.8		1		1
Office days/suppl inspection day				0.2	5	0.25		0.25		0.25		0.25
Office days/LFUA inspection day				0.12	5	0.125		0.125		0.125		0.125
Office days/PIV inspection day				0.2	5	0.25		0.5		1		1
Labor Cost of Inspector - burden	ed			Cost (USD)		Cost (USD)		Cost (USD)		Cost (USD)		Cost (USD)
Staff cost/day - trip PDI				\$2,00)	\$2,000		\$2,000		\$2,000		\$2,000
Staff cost/day - trip Rest Day				\$1,00)	\$1,000		\$1,000		\$1,000		\$1,000
Travel cost /trip				\$4,65)	\$4,650		\$4,650		\$4,650		\$4,650
Staff cost/day - office				\$1,05	4	\$1,054		\$1,054		\$1,054		\$1,054
Inspector Labor Costs by Insp. T	уре		PDI	Cost (USD)	PDI	Cost (USD)	PDI	Cost (USD)	PDI	Cost (USD)	PDI	Cost (USD)
Staff costs for routine inspection			54	\$ 180,000	54	\$ 180,000	48	\$ 160,000	18	\$ 60,000	18	\$ \$ 60,000
Staff costs for suppl inspection			2	\$ 8,000	2	\$ 8,000	2	\$ 8,000	2	\$ 8,000	2	\$ 8,000
Staff costs for LFUA inspection			12	\$ 48,000	0	\$ -	0	\$ -	0	\$ -	0	\$ -
Staff costs for PIV inspection			20	\$ 56,000	20	\$ 56,000	20	\$ 56,000	14	\$ 44,000	14	\$ 44,000
Total Inspector Labor Cost			88	\$ 292,000	76	\$ 244,000	70	\$ 224,000	34	\$ 112,000	34	\$ 112,000
Inspector Travel Costs by Insp. T	уре									·		
Travel costs for routine inspection				\$ 83,700		\$ 83,700		\$ 74,400		\$ 27,900		\$ 27,900
Travel costs for suppl inspection				\$ 9,300	_	\$ 9,300		\$ 9,300		\$ 9,300		\$ 9,300
Travel costs for LFUA inspection				\$ 55,800		\$ -		\$ -		\$ -		\$ -
Travel costs for PIV inspection Total travel cost				\$ 9,300 \$ 158,100		\$ 9,300 \$ 102,300		\$ 9,300 \$ 93,000		\$ 9,300 \$ 46,500		\$ 9,300 \$ 46,500
Inspector Office Costs by Insp. T	vpe			Ψ 130,100		Ψ 102,300		95,000		Ψ 40,500		Ψ 40,500
Staff office costs for routine inspection				\$ 22,766		\$ 34,150		\$ 40,474		\$ 18,972		\$ 18,972
Staff office costs for suppl inspection				\$ 527		\$ 527		\$ 527		\$ 527		\$ 527
Staff office costs for LFUA inspection	า			\$ 1,581		\$ -		\$ -		\$ -		\$ -
Staff office costs for PIV inspection				\$ 5,270		\$ 5,270		\$ 10,540		\$ 14,756		\$ 14,756
Total staff office costs				\$ 30,144		\$ 39,947 \$ 386,247		\$ 51,541		\$ 34,255		\$ 34,255
Total annual labor/staff/sampling	y costs			\$ 480,244		\$ 386,247		\$ 368,541		\$ 192,755		\$ 192,755
Total Annual costs				\$ 535,094		\$ 431,352		\$ 501,846		\$ 478,153		\$ 495,456
accuracy			\$M			0.4	\$M	0.5	\$M		\$M	0.5

Table 24: Hardware Cost of Safeguards Options at 1000 MtSWU/yr GCEP for INFCIRC/540 Safeguards with NDA PD= 20%, DA PD=20%

1/	Assay												_				
	Unit																
	Totals	TOTAL		ption A			ption E	3		Option	n C	٥ ا	ptior	D.		Option E	
Nom. Feed cylinders/yr /assay unit	115	230		, p			P.1.0.1		•	puo.		_	p			орион _	
Nom. Product cylinders/year	58	117															
Nom. Tails cylinders/year	104	209															
Cascade Halls	8	16															
Load cell monitors/assay unit	23	46															
Assay units	23	40	Trad/Int Sg	de		мс	SP SPEC	٠.	١,	NEUT D	NET.		EM A	cc	NEUT DET +	AEM ACC	
Item SG system capital costs per		Annual	Trau/IIIt 5g	u 5		IVIC	OF OF EC	,,,		VLO1 L	<i></i>		LIVIA	-	NEOT DET	ADW ACC	
basis (10 year life span for equipm		Cost/ item	Items	Total item Co	ost	Items	Total ite	em Cost	Items	Tota	l item Cost	Items	Tota	l item Cost	Items	Total item	Cost
DA Sample Bottles	,	\$ 16	21	\$	326	29	\$	450	15	\$	233	5	\$	78	5	\$	78
Portable LCBWS		\$ 680	1	\$	680	1	\$	680	1	\$	680	1	\$	680	1	\$	680
Reference w eights		\$ -	1	\$		1	\$	-	1	\$	-	1	\$	-	1	\$	-
HPGe gamma spec (IMCG)		\$ 3,700	2		7.400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Nal Detector		\$ 3,700	2		7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Upgraded CHEM system		\$ 15,000	0	\$	-	0	\$		0	\$		0	\$		0	\$	
Load cell monitors		\$ 500	0	\$	-	0	\$	-	0	\$	_	46	\$	23,000	46	\$	23,000
PNUH		\$ 40,000	0	\$		0	\$	-	0	\$	-	0	\$	-	0	\$	
AEM- Installed detection system		\$ 10,000	0	\$	-	0	\$	-	0	\$	_	6	\$	60,000	6	\$	60,000
AEM - Data collect cabinet		\$ 10,000	0	\$		0	\$	-	0	\$	-	2	\$	20,000	2	\$	20,000
Neutron Detection System		\$ 6,500	0	\$	-	0	\$	-	1	\$	6,500	0	\$	-	1	\$	6,500
Neut Det - Data collect cabinet		\$ 7,800	0	\$	-	0	\$	-	1	\$	7,800	0	\$	_	1	\$	7,800
Data acquisition system		\$ 10,000	0	\$	-	1	\$	10,000	2	\$	20,000	2	\$	20,000	2	\$	20,000
Digital surv camera - F/W		\$ 2,000	0	\$	-	0	\$	-	24	\$	48,000	24	\$	48,000	24	\$	48,000
Accountability scale monitor + camera		\$ 1,500	0	\$		0	\$	-	2	\$	3,000	2	\$	3,000	2	\$	3,000
ID tag interrogation antennas		\$ 20	0	\$	-	0	\$	-	0	\$	-	162	\$	3,240	162	\$	3,240
ID tag interrogation readers		\$ 200	0	\$	-	0	\$	-	0	\$	_	150	\$	30,000	150	\$	30,000
ID tags		\$ 10	0	\$		0	\$	-	0	\$	-	555.3333	\$	5,553	555	\$	5,553
Seals (IAEA costs/seal)		\$ 33	100		3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300
Total equipment cost per annum ba	asis	*			9,106		\$	29,230		\$	104,313		\$	231,651		\$	245,951
Equip. spares&installation =% of an		10%		•	1,911		*	\$2,923		Ť	\$10,431		Ť	\$23,165		*	\$24,595
Total Annual Equipment Costs					1,016			\$32,152			\$114,744			\$254,816			\$270,546
Annual equipment cost - repairs, tr	rips,	% of Equip. Cost Factor															
Est. Annual Equipment Upkeep Cos	sts	10.0%		\$2,	101.6			\$3,215.2			\$11,474.4			\$25,481.6			\$27,054.6
Total Annual Equipment Costs					3,118		\$	35,368		\$	126,218		\$	280,298		\$	297,601
Inspections Needed per Option Reg	gime			# of Inspect	ions		# of Ins	pections		# of	Inspections		# of	Inspections		# of Inspe	ctions
No. routine inspections/yr					8			8			7			3			3
No. supplemental inspections/yr					2			2			2			2			2
No. Addl LFUA inspections/yr					6			0			0			0			(
No. PIV/yr					1			1			1			1			1
Annual Sample Procedure Costs po	er Option	Cost/		Sam ple			Sam ple			Sam			Sam				
Regime		Sam ple	Sample	Costs/Year		Sam ple	Costs/		Sam ple		ts/Year	Sam ple		s/Year	Sam ple	Sample Co	osts/Year
DA Sample - procedures /yr		\$ 700	14		9,800	19	\$	13,300	10	\$	7,000	3	\$	2,100	3	\$	2,100
ES Samples/yr		\$ 500	6		3,000	6	\$	3,000	6	\$	3,000	6	\$	3,000	6	\$	3,000
TOTAL Sample Costs/yr				\$ 12	2,800		\$	16,300		\$	10,000		\$	5,100		\$	5,100

Table 25: Labor Cost of Safeguards Options at 1000 MtSWU/yr GCEP for INFCIRC/540 Safeguards with NDA PD=20%, DA PD=20%

EVAMPLE COEP of 4000	Assay											
EXAMPLE GCEP of 1000 MTSWU/yr Capacity	Unit Totals	TOTAL	_	Smaller A	١ ,	untion D	_	mailam C		ation D		Ontion F
	_	TOTAL	,	Option A	U	ption B	U	ption C	U	otion D		Option E
Nom. Feed cylinders/yr /assay unit Nom. Product cylinders/year	115 59	230 118	1									
Nom. Tails cylinders/year	104	209	-									
Cascade Halls	8	16										
Load cell monitors/assay unit	23	46										
Assay units	2		Trad/Int Sg	ds	MS	SP SPECS	N	EUT DET	A	EM ACC	NEUT DET +	AEM ACC
Inspection Staffing per Inspection	n Cost			# of Inspectors		# of Inspectors		# of Inspectors		# of Inspectors		# of Inspectors
Inspectors / routine inspection				2		2		2		2		2
Inspectors / suppl inspection				1		1		1		1		1
Inspectors / LFUA inspection				2		0		0		0		0
Inspectors / PIV inspection				2		2		2		2		2
Inspection Time Cost				Length (Days)		Length (Days)		Length (Days)		Length (Days)		Length (Days)
Duration of routine inspection				3		3		3		3		3
Duration of suppl inspection				1		1		1		1		1
Duration of LFUA inspection				1		0		0		0		0
Duration of PIV inspection				10		10		10		7		7
Rest days during routine inspection		<u> </u>	<u> </u>	0		0		0		0	t	0
Rest days during suppl inspection				0		0		0		0	1	0
				0		0		0		0	-	0
Rest days during LFUA inspection	1											0
Rest days during PIV inspection				2		2		2		2		2
Travel days/inspector/trip				2		2		2		2		2
Office Time Cost (Prep/Aanalysis)			Length (Days)		Length (Days)		Length (Days)		Length (Days)		Length (Days)
Office days/IIV inspection day				0.4		0.6		0.8		1		1
Office days/suppl inspection day				0.25		0.25		0.25		0.25		0.25
Office days/LFUA inspection day				0.125		0.125		0.125		0.125		0.125
Office days/PIV inspection day				0.25		0.25		0.5		1		1
Labor Cost of Inspector - burden	ed			Cost (USD)		Cost (USD)		Cost (USD)		Cost (USD)		Cost (USD)
Staff cost/day - trip PDI				\$2,000		\$2,000		\$2,000		\$2,000		\$2,000
Staff cost/day - trip Rest Day				\$1,000		\$1,000		\$1,000		\$1,000		\$1,000
Travel cost /trip				\$4,650		\$4,650		\$4,650		\$4,650		\$4,650
Staff cost/day - office				\$1,054		\$1,054		\$1,054		\$1,054		\$1,054
Inspector Labor Costs by Insp. T	уре		PDI	Cost (USD)	PDI	Cost (USD)	PDI	Cost (USD)	PDI	Cost (USD)	PDI	Cost (USD)
Staff costs for routine inspection			48	\$ 160,000	48	\$ 160,000	42	\$ 140,000	18	\$ 60,000	18	\$ 60,000
Staff costs for suppl inspection			2	\$ 8,000	2	\$ 8,000	2	\$ 8,000	2	\$ 8,000	2	\$ 8,000
Staff costs for LFUA inspection			12	\$ 48,000	0	\$ -	0	\$ -	0	\$ -	0	\$ -
Staff costs for PIV inspection			20	\$ 56,000	20		20	\$ 56,000	14	\$ 44,000	14	\$ 44,000
Total Inspector Labor Cost			82	\$ 272,000	70	\$ 224,000	64	\$ 204,000	34	\$ 112,000	34	\$ 112,000
Inspector Travel Costs by Insp. T	vpe			¥ 2.2,000		¥ 22.,666		201,000	•	V 1.12,000		112,000
Travel costs for routine inspection		1	1	\$ 74,400		\$ 74,400		\$ 65,100		\$ 27,900		\$ 27,900
Travel costs for suppl inspection				\$ 9,300		\$ 9,300		\$ 9,300		\$ 9,300		\$ 9,300
Travel costs for LFUA inspection				\$ 55,800		\$ -		\$ -		\$ -		\$ -
Travel costs for PIV inspection				\$ 9,300		\$ 9,300		\$ 9,300		\$ 9,300		\$ 9,300
Total travel cost				\$ 148,800		\$ 93,000		\$ 83,700		\$ 46,500		\$ 46,500
Inspector Office Costs by Insp. T	-	 	 	¢ 20.007	-	. 20.055		ф о <u>г</u> (111		£ 40.070	-	£ 40.070
Staff office costs for routine inspection		<u> </u>	-	\$ 20,237 \$ 527		\$ 30,355 \$ 527		\$ 35,414 \$ 527		\$ 18,972 \$ 527		\$ 18,972 \$ 527
Staff office costs for suppl inspection Staff office costs for LFUA inspection		 	 	\$ 527 \$ 1,581	 	\$ 527 \$ -		\$ 527		\$ 527	 	\$ 527
Staff office costs for PIV inspection		1	1	\$ 5,270	t	\$ 5,270		\$ 10,540		\$ 14,756	t	\$ 14,756
Total staff office costs			1	\$ 27,615		\$ 36,152		\$ 46,481		\$ 34,255		\$ 34,255
Total annual labor/staff/sampling	g costs			\$ 448,415		\$ 353,152		\$ 334,181		\$ 192,755		\$ 192,755
		1	,									
Total Annual costs				\$ 484,332		\$ 404,820		\$ 470,400		\$ 478,153		\$ 495,456
Total Annual costs in 1M\$ reflect	ting		614	0.5	614	0.4	¢	0 F	¢.,	0.5	614	0.5
accuracy			\$IVI	0.5	\$IVI	0.4	\$M	0.5	\$M	0.5	\$IVI	0.5

Table 26: Hardware Cost of Safeguards Options at 1000 MtSWU/yr GCEP for INFCIRC/540 Safeguards with NDA PD=20%, DA PD=10%

	Assay									_			_				
	Unit																
	Totals	TOTAL	,	option A		,	Intion	D		Ontion		_	otion	D		Ontion E	
			,	ption A		,	Option	D		Option	10	U	ption	עו		Option E	
Nom. Feed cylinders/yr /assay unit	115	230															
Nom. Product cylinders/year	58	116.66667															
Nom. Tails cylinders/year	104	208.66667															
Cascade Halls	8	16															
Load cell monitors/assay unit	23	46															
Assay units	2		Trad/Int Sg	ds		MS	SSP SPE	cs		NEUT D)ET	Α	EM A	cc	NEUT DET +	AEM ACC	
Item SG system capital costs per	annum	Annual															
basis (10 year life span for equipm	nent)	Cost/ item	Items	Total iter	m Cost	Items	Total i	tem Cost	Items	Tota	l item Cost	Items	Tota	item Cost	Items	Total item	Cost
DA Sample Bottles		\$ 16	21	\$	326	15	\$	233	9	\$	140	5	\$	78	5	\$	78
Portable LCBWS		\$ 680	1	\$	680	1	\$	680	1	\$	680	1	\$	680	1	\$	680
Reference w eights		\$ -	1	\$	-	1	\$		1	\$	-	1	\$	-	1	\$	-
HPGe gamma spec (IMCG)		\$ 3,700	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Nal Detector		\$ 3,700	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Upgraded CHEM system		\$ 15,000	0	\$	-	0	\$		0	\$	-	0	\$	-	0	\$	-
Load cell monitors		\$ 500	0	\$	-	0	\$	-	0	\$	-	46	\$	23,000	46	\$	23,000
PNUH		\$ 40,000	0	\$	-	0	\$	-	0	\$	-	0	\$	-	0	\$	-
AEM- Installed detection system		\$ 10,000	0	\$	-	0	\$	-	0	\$	-	6	\$	60,000	6	\$	60,000
AEM - Data collect cabinet		\$ 10,000	0	\$		0	\$	_	0	\$		2	\$	20,000	2	\$	20,000
Neutron Detection System		\$ 6,500	0	\$		0	\$	_	1	\$	6,500	0	\$	20,000	1	\$	6,500
Neut Det - Data collect cabinet		\$ 7,800	0	\$		0	\$	_	1	\$	7,800	0	\$		1	\$	7,800
Data acquisition system		\$ 10,000	0	\$		1	\$	10,000	2	\$	20.000	2	\$	20.000	2	\$	20,000
Digital surv camera - F/W		\$ 2,000	0	\$		0	\$	10,000	24	\$	48,000	24	\$	48,000	24	\$	48,000
Accountability scale monitor + camera		\$ 1,500	0	\$		0	\$	_	2	\$	3,000	2	\$	3,000	2	\$	3,000
		\$ 1,500	0	\$		0	\$	-	0	\$	3,000	162	\$	3,240	162	\$	3,240
ID tag interrogation antennas			0	\$	-	0	\$	-	0	\$		150	\$	30,000	150	\$	30,000
ID tag interrogation readers				•			\$	-		_			_			•	
ID tags		\$ 10	0	\$		0			0	\$		555.3333	\$	5,553	555.3333	\$	5,553
Seals (IAEA costs/seal)		\$ 33	100	\$	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300
Total equipment cost per annum ba				\$	19,106		\$	29,013		\$	104,220		\$	231,651		\$	245,951
Equip. spares&installation =%of an	nnual cost	10%			\$1,911			\$2,901			\$10,422			\$23,165			\$24,595
Total Annual Equipment Costs					\$21,016			\$31,914			\$114,641			\$254,816			\$270,546
Annual equipment cost - repairs, tr	rips,	% of Equip. Cost Factor															
Est. Annual Equipment Upkeep Cos	sts	10.0%			\$2,101.6			\$3,191.4			\$11,464.1			\$25,481.6			\$27,054.6
Total Annual Equipment Costs		10.070		\$	23,118		\$	35,105		\$	126,106		\$	280,298		\$	297,601
Total Alliaur Equipment costs				<u> </u>	20,110		ų.	00,100		T T	120,100		Ψ	200,200			201,001
Inspections Needed per Option Reg	nime			# of Insp	ections		# of In	spections		# of	Inspections		# of	nspections		# of Inspec	tions
	9			" oi ilisp	7		,, OI III	7		# OI	6		OI	3		" or maper	7.1.J113
No. routine inspections/yr No. supplemental inspections/yr				 	2			2			2			2			2
''' '				 	6		1			+	0						0
No. Addl LFUA inspections/yr				 	b		1	0		+	- 0			0			0
No. PIV/yr	or Ontion	Coct/		Sample	1		Sam =			Sarr	nlo.		Com				1
Annual Sample Procedure Costs pe	er Option	Cost/ Sample	Sample	Sample Costs/Ye	ar.	Sample	Sampl Costs		Sam ple	Sam	pie :s/Year	Sam ple	Sam	ole s/Year	Sample	Sample Co	ete/Voor
Regime		\$ 700	_	\$	9,800	_	\$	7,000		\$	4,200	Sample 3	\$	2,100	Sample 3	\$	2,100
DA Sample - procedures /yr		\$ 500	14 6	\$	3,000	10 6	\$	3,000	6	\$	3.000	6	\$		6	\$	3.000
ES Samples/yr		э 500	р	D.	3,000	ь	Ф	3,000	ь	\$	3,000	ď	Ф	3,000	Ö	Ф	3,000
TOTAL Sample Costs/yr				\$	12,800		\$	10,000		\$	7,200		\$	5,100		\$	5,100

Table 27: Labor Cost of Safeguards Options at 1000 MtSWU/yr GCEP for INFCIRC/540 Safeguards with NDA PD=20%, DA PD=10%

Assay EXAMPLE GCEP of 1000 Unit MTSWU/yr Capacity Totals Nom. Feed cylinders/yr /assay unit 115 Nom. Product cylinders/year 59	TOTAL 230															
Nom. Feed cylinders/yr /assay unit 115 Nom. Product cylinders/year 59		Option A														
Nom. Product cylinders/year 59	230	,	ption	n A	0	ption	В	0	ption	n C	0	ption	D		Option E	
	118															
Nom. Tails cylinders/year 104	208.66667	4														
Cascade Halls 8 Load cell monitors/assay unit 23	16 46	1														
Load cell monitors/assay unit 23 Assay units 2	40	Trad/Int Sg	de		ме	SP SP	ECS	N	EUT D	net	٨	EM AC	·~	NEUT DET +	VEW VCC	
rioday unito		Trau/iiit og	1		IVIO	51 51			101 1	<i></i>		DVI AC	,,,	NEOI DEI T	ALM ACC	
Inspection Staffing per Inspection Cost			# of I	nspectors		# of I	nspectors		# of	Inspectors		# of I	nspectors		# of Inspe	ctors
Inspectors / routine inspection				2			2			2			2			2
Inspectors / suppl inspection				1			1			1			1			1
Inspectors / LFUA inspection				2			0			0			0			0
Inspectors / PIV inspection				2			2			2			2			2
Inspection Time Cost			Leng	th (Days)		Leng	th (Days)		Leng	gth (Days)		Leng	th (Days)		Length (Da	ays)
Duration of routine inspection				3			3			3			3			3
Duration of suppl inspection				1			1			1			1			1
Duration of LFUA inspection				1			0			0			0			0
Duration of PIV inspection				10			10			10			7			7
Rest days during routine inspection				0			0			0			0			0
Rest days during suppl inspection				0			0			0			0			0
Rest days during LFUA inspection				0			0			0			0			0
Rest days during PIV inspection				2			2			2			2			2
Travel days/inspector/trip				2			2			2			2			2
Office Time Cost (Prep/Aanalysis)			Lena	th (Days)		Lena	th (Days)		Lend	gth (Days)		Leng	th (Days)		Length (Da	avs)
Office days/IIV inspection day				0.4			0.6			0.8			1			1
Office days/suppl inspection day				0.25			0.25			0.25			0.25			0.25
Office days/LFUA inspection day				0.125			0.125			0.125			0.125			0.125
Office days/PIV inspection day				0.25			0.25			0.5			1			1
Labor Cost of Inspector - burdened			Cost	(USD)		Cost	(USD)		Cost	t (USD)		Cost	(USD)		Cost (USD	
Staff cost/day - trip PDI			0001	\$2,000		0001	\$2,000		000.	\$2,000		0001	\$2,000		0031 (002	\$2,000
				\$1,000			\$1,000			\$1,000			\$1,000			\$1,000
Staff cost/day - trip Rest Day Travel cost /trip				\$4,650			\$4,650			\$4,650			\$4,650			\$4,650
Staff cost/day - office				\$1,054			\$1,054			\$1,054			\$1,054			\$1,054
Inspector Labor Costs by Insp. Type		PDI	Cost	(USD)	PDI	Cost	(USD)	PDI	Cost	t (USD)	PDI	Cost	(USD)	PDI	Cost (USD	
Staff costs for routine inspection		42	\$	140,000	42	_	140,000	36	\$	120,000	18	\$	60,000	18	\$	60,000
		2	\$	8,000	2	,	8,000	2	\$	8,000	2	\$	8,000	2	\$	8,000
Staff costs for suppl inspection		12	\$	48,000		\$	0,000	0	,	0,000	0	\$	0,000	0		0,000
Staff costs for LFUA inspection					20	_	F6 000			F6 000		\$	44.000	14		44.000
Staff costs for PIV inspection		20	\$	56,000			56,000	20	\$	56,000	14		44,000			44,000
Total Inspector Labor Cost		76	\$	252,000	64	\$	204,000	58	Þ	184,000	34	\$	112,000	34	\$	112,000
Inspector Travel Costs by Insp. Type Travel costs for routine inspection			\$	65,100		\$	65,100		\$	55,800		\$	27,900		\$	27,900
Travel costs for suppl inspection			\$	9,300		\$	9,300		\$	9,300		\$	9,300		\$	9,300
Travel costs for LFUA inspection			\$	55,800		\$	-		\$	-		\$	-		\$	-
Travel costs for PIV inspection			\$	9,300		\$	9,300		\$	9,300		\$	9,300		\$	9,300
Total travel cost			\$	139,500		\$	83,700		\$	74,400		\$	46,500		\$	46,500
Inspector Office Costs by Insp. Type																
Staff office costs for routine inspection			\$	17,707		\$	26,561		\$	30,355		\$	18,972		\$	18,972
Staff office costs for suppl inspection Staff office costs for LFUA inspection		+	\$	1,581		\$	527		\$	527		\$	527		\$	527
Staff office costs for PIV inspection		+	\$	5,270		\$	5,270		\$	10,540		\$	14,756		\$	14,756
Total staff office costs		†	\$	25,085		\$	32,358		\$	41,422		\$	34,255		\$	34,255
Total annual labor/staff/sampling costs			\$	416,585		\$	320,058		\$	299,822		\$	192,755		\$	192,755
Total Annual costs			\$	452,503		\$	365,163		\$	433,128		\$	478,153		\$	495,456
Total Annual costs in 1M\$ reflecting																
accuracy		\$M	0.5		\$M	0.4		\$M	0.4		\$M	0.5		\$M	0.5	

Appendix C: Costs of Safeguards at a 3000 MtSWU/yr GCEP

Table 28-Table 34 display the itemized cost analysis for safeguards at a GCEP of capacity 3000 MtSWU/yr compared with current methods based on the HSP for normal and reduced P_D under both INFCIRC/153 and INFCIRC/540 safeguards regimes.

Table 28: Hardware Cost of Safeguards Options at 3000 MtSWU/yr GCEP for INFCIRC/153 Safeguards with NDA PD=50%, DA PD=50%

EXAMPLE GCEP of 3000	Assay Unit																	
MTSWU/yr Capacity	Totals	тот	AL		Option	A		Option	В		Option (:		Option	ı D		Option	E
Nom. Feed cylinders/yr /assay unit	115	_	690						_									
Nom. Product cylinders/year	58		350															
Nom. Tails cylinders/year	104		626	1														
Cascade Halls	8		48	1														
Load cell monitors/assay unit	23		138	1														
Assay units	6			Trad/Int S	Sgds			ASSP SPE	cs		NEUT DET			AEM A	CC	NEUT DET	+ AEM ACC	;
Item SG system capital costs per a	nnum basis (10	Aı	nnual															
year life span for equipment)		Cos	st/ item	Items	Total ite	m Cost	Items	Total ite	m Cost	Items	Total item	n Cost	Items	Total	item Cost	Items	Total iter	n Cost
DA Sample Bottles		\$	16	119	\$	1,845	248	\$	3,844	122	\$	1,891	30	\$	465	30	\$	465
Portable LCBWS		\$	680	1	\$	680	1	\$	680	1	\$	680	1	\$	680	1	\$	680
Reference w eights		\$	-	1	\$	-	1	\$	-	1	\$	-	1	\$	-	1	\$	-
HPGe gamma spec (IMCG)		\$	3,700	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Nal Detector		\$	3,700	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Upgraded CHEM system		\$	15,000	0	\$	-	0	\$	-	0	\$	-	0	\$	_	0	\$	-
Load cell monitors		\$	500	0	\$	-	0	\$	-	0	\$		138	\$	69,000	138	\$	69,000
PNUH		\$	40,000	0	\$	-	0	\$	-	0	\$	-	0	\$	_	0	\$	-
AEM- Installed detection system		\$	10,000	0	\$	-	0	\$	-	0	\$		18	\$	180,000	18	\$	180,000
AEM - Data collect cabinet		\$	10,000	0	\$	-	0	\$	-	0	\$		6	\$	60,000	6	\$	60,000
Neutron Detection System		\$	6,500	0	\$	-	0	\$	-	1	\$	6,500	0	\$	-	1	\$	6,500
Neut Det - Data collect cabinet		\$	7,800	0	\$		0	\$		1	\$	7,800	0	\$		1	\$	7.800
Data acquisition system		\$	10,000	0	\$		1	\$	10,000	2	\$	20,000	6	\$	60,000	6	\$	60,000
Digital surv camera - F/W		\$	2,000	0	\$		0	\$.0,000	24	\$	48,000	24	\$	48,000	24	\$	48,000
Accountability scale monitor + camera		\$	1,500	0	\$		0	\$		2	\$	3,000	2	\$	3,000	2	\$	3,000
ID tag interrogation antennas		\$	20	0	\$		0	\$		0	\$	3,000	162	\$	3,240	162	\$	3,240
ID tag interrogation readers		\$	200	0	\$		0	\$		0	\$		150	\$	30,000	150	\$	30,000
ID tags		\$	10	0	\$		0	\$		0	\$		1666	\$	16,660	1666	\$	16,660
Seals (IAEA costs/seal)		\$	33	100	\$	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300
Total equipment cost per annum bas	ai e	φ	33	100	\$	20,625	100	\$	32,624	100	\$	105,971	100	\$	489,145	100	\$	503,445
					Ť			Ť			1			Ť			T	
Equip. spares&installation =% of ann	nual cost		10%			\$2,062 \$22.687			\$3,262 \$35.886			\$10,597 \$116,568			\$48,915 \$538,060			\$50,345 \$553.790
Total Annual Equipment Costs						\$22,007			\$35,000			\$110,000			\$536,000			\$553,790
Annual equipment cost - repairs, trip factor of equip. cost	ps, costsas		Equip. t Factor															
Est. Annual Equipment Upkeep Costs	S		10.0%			\$2,268.7			\$3,588.6			\$11,656.8			\$53,806.0			\$55,379.0
Total Annual Equipment Costs					\$	24,956		\$	39,475		\$	128,225		\$	591,865		\$	609,168
Inspections Needed per Option Regi	me				# of Insp	nections		# of Inst	ections		# of Inspe	ections		# of I	nspections		# of Insp	ections
No. routine inspections/yr	-				2	11		2	11			11		T	3			3
No. supplemental inspections/yr						2			2			2		1	2			2
No. Addl LFUA inspections/yr		1				8			0		†	0	1	1	<u> </u>		 	0
No. PIV/yr		1				1			1		†	1	1		1	†	†	1
		_	Cost/								<u> </u>			Samp	\le			'
Annual Sample Procedure Costs per	Option Regime		m ple	Sample	Sam ple	Costs/Year	Sam ple	Sam ple	Costs/Year	Sam ple	Sample C	osts/Year	Sam ple		s/Year	Sam ple	Sample 0	osts/Year
DA Sample - procedures /yr	_	\$	700	79	\$	55,300	165	\$	115,500	81	\$	56,700	20	\$	14,000	20	\$	14,000
ES Samples/yr		\$	500	6	\$	3,000	6	\$	3,000	6	\$	3,000	6	\$	3,000	6	\$	3,000
TOTAL Sample Costs/yr		1			\$	58,300		\$	118,500		\$	59,700		\$	17,000		\$	17,000

Table 29: Labor Cost of Safeguards Options at 3000 MtSWU/yr GCEP for INFCIRC/153 Safeguards with NDA PD=50%, DA PD=50%

EXAMPLE GCEP of 3000	Assay Unit	TOTAL												,		0.00	
MTSWU/yr Capacity	Totals	TOTAL		Option	А		Option I	В		Option	10	C	Option	עו		Option E	
Nom. Feed cylinders/yr /assay unit	115 59	690 354	ł														
Nom. Product cylinders/year Nom. Tails cylinders/year	104	626	ł														
Cascade Halls	8	48															
Load cell monitors/assay unit	23	138	i														
Assay units	6		Trad/Int S	ads			ASSP SPE	cs		NEUT D	DET		AEM AC	cc	NEUT DET -	- AEM ACC	
Inspection Staffing per Inspection (Cost			# of Insp	ectors		# of Insp	ectors		# of Ins	spectors		# of In	nspectors		# of Inspec	tors
Inspectors / routine inspection					2			2			2			2			2
Inspectors / suppl inspection					1			1			1			1			1
Inspectors / LFUA inspection					2			0			0			0			0
Inspectors / PIV inspection					3			3			3			3			3
Inspection Time Cost				Length (Days)		Length (Days)		Length	(Days)		Lengt	th (Days)		Length (Da	ys)
Duration of routine inspection					3			3			3			3			3
Duration of suppl inspection					1			1			1			1			1
Duration of LFUA inspection					1			0			0			0			0
Duration of PIV inspection					10			10			10			7			7
Rest days during routine inspection					0			0			0			0			0
Rest days during suppl inspection					0			0			0			0			0
Rest days during LFUA inspection					0			0			0			0			0
Rest days during PIV inspection					2			2			2			2			2
Travel days/inspector/trip					2			2			2			2			2
Office Time Cost (Prep/Aanalysis)				Length (Days)		Length (Days)		Length	(Days)		Lengt	th (Days)		Length (Da	ys)
Office days/IIV inspection day					0.4			0.6			8.0			1			1
Office days/suppl inspection day					0.25			0.25			0.25			0.25			0.25
Office days/LFUA inspection day					0.125			0.125			0.125			0.125			0.125
Office days/PIV inspection day					0.25			0.25			0.5			1			1
Labor Cost of Inspector - burdened				Cost (US	SD)		Cost (US	SD)		Cost (L	JSD)		Cost ((USD)		Cost (USD)	
Staff cost/day - trip PDI					\$2,000			\$2,000			\$2,000			\$2,000			\$2,000
Staff cost/day - trip Rest Day					\$1,000			\$1,000			\$1,000			\$1,000			\$1,000
Travel cost /trip					\$4,650			\$4,650			\$4,650			\$4,650			\$4,650
Staff cost/day - office					\$1,054			\$1,054			\$1,054			\$1,054			\$1,054
Inspector Labor Costs by Insp. Typ	e		PDI	Cost (US	-	PDI	Cost (US	-	PDI	Cost (L		PDI	Cost (PDI	Cost (USD)	
Staff costs for routine inspection			66	_	220,000	66	_	220,000	66		220,000	18		60,000	18		60,000
Staff costs for suppl inspection			2	\$	8,000	2	\$	8,000	2	\$	8,000		\$	8,000	2		8,000
Staff costs for LFUA inspection			16	,	64,000	0		-	0	_	-		\$	-	0	•	-
Staff costs for PIV inspection			30	\$	84,000	30		84,000	30		84,000	21		66,000	21		66,000
Total Inspector Labor Cost			114	\$	376,000	98	\$	312,000	98	\$	312,000	41	\$	134,000	41	\$	134,000
Inspector Travel Costs by Insp. Typ	e			•	100.000			400.000		\$	400.000		\$	07.000			07.000
Travel costs for routine inspection Travel costs for suppl inspection				\$	102,300 9,300		\$	102,300 9,300		\$	102,300 9,300		\$	27,900 9,300		\$	27,900 9,300
Travel costs for LFUA inspection				\$	74,400		\$			\$	-		\$			\$	
Travel costs for PIV inspection				\$	13,950		\$	13,950		\$	13,950		\$	13,950		\$	13,950
Total travel cost				\$	199,950		\$	125,550		\$	125,550		\$	51,150		\$	51,150
Inspector Office Costs by Insp. Typ	е			_			_									_	
Staff office costs for routine inspection				\$	27,826		\$	41,738		\$	55,651		\$	18,972		\$	18,972
Staff office costs for suppl inspection Staff office costs for LFUA inspection		-		\$	527 2,108		\$	527		\$	527		\$	527		\$	527
Staff office costs for PIV inspection				\$	7,905		\$	7,905		\$	15,810		\$	22,134		\$	22,134
Total staff office costs				\$	38,366		\$	50,170		\$	71,988		\$	41,633		\$	41,633
Total annual labor/staff/sampling of	costs			\$	614,316		\$	487,720		\$	509,538		\$	226,783		\$	226,783
Total Annual costs				\$	697,571		\$	645,695		s	697,463		\$	835,648		\$	852,951
					00.,071			0.0,000		-	33.,.00		Ť	000,040		Ť	302,001
Total Annual costs in 1M\$ reflection	ng accuracy		\$M	0.7		\$M	0.6		\$M	0.7		\$M	8.0		\$M	0.9	

Table~30:~Hardware~Cost~of~Safeguards~Options~at~3000~MtSWU/yr~GCEP~for~INFCIRC/153~Safeguards~with~NDA~PD=50%, DA~PD=50%, DA~PD=5

EXAMPLE GCEP of 3000	Assay Unit														
	Totals	TOTAL		Option A		Option B			Option C		Option	D		Option E	
Nom. Feed cylinders/yr /assay unit	115	690		- 1							•				
Nom. Product cylinders/year	58	350													
Nom. Tails cylinders/year	104	626													
Cascade Halls	8	48													
Load cell monitors/assay unit	23	138													
Assay units	6		Trad/Int S	Sads		MSSP SPECS			NEUT DET		AEM AC	3	NEUT DET	+ AEM ACC	
				9								-			
than SC austam assital asstance as	bi- (40														
Item SG system capital costs per ar	inum basis (10	Annual		T-4-1/4 O4		T-1-1 h 01			T-4-134 O4		T-4-13	0		T-4-1 14	0
year life span for equipment) DA Sample Bottles		\$ 16	Items 119	Total item Cost \$ 1,845	Items 41	Total item Cost	636	Items 20	Total item Cost \$ 310	Items 8	\$	em Cost 124	Items 8	Total item	124
Portable LCBWS		\$ 680	1	\$ 680	1		680	1	\$ 680	1	\$	680	1	\$	680
Reference weights		\$ -	1	\$ -	1	\$	000	1	\$ -	1	\$	000	1	\$	000
HPGe gamma spec (IMCG)		\$ 3,700	2	\$ 7,400	2		400	2	\$ 7,400	2	\$	7,400	2	\$	7,400
Nal Detector		\$ 3,700	2	\$ 7,400	2		400	2	\$ 7,400	2	\$	7,400	2	\$	7,400
Upgraded CHEM system		\$ 15,000	0	\$ -	0	\$	-	0	\$ -	0	\$	7,400	0	\$	7,400
Load cell monitors		\$ 500	0	\$ -	0	\$	-	0	\$ -	138	\$	69,000	138	\$	69,000
PNUH		\$ 40,000	0	\$ -	0	\$	-	0	\$ -	0	\$	-	0	s	-
AEM- Installed detection system		\$ 10,000	0	\$ -	0	\$	-	0	\$ -	18	\$	180.000	18	s	180,000
AEM - Data collect cabinet		\$ 10,000	0	\$ -	0	\$	-	0	\$ -	6	\$	60,000	6	\$	60,000
Neutron Detection System		\$ 6,500	0	\$ -	0	\$	-	1	\$ 6,500	0	\$	-	1	\$	6,500
Neut Det - Data collect cabinet		\$ 7,800	0	\$ -	0	\$	-	1	\$ 7,800	0	\$	-	1	\$	7,800
Data acquisition system		\$ 10,000	0	\$ -	1	\$ 10.	000	2	\$ 20,000	6	\$	60,000	6	\$	60,000
Digital surv camera - F/W		\$ 2,000	0	\$ -	0	\$	-	24	\$ 48,000	24	\$	48,000	24	\$	48,000
Accountability scale monitor + camera		\$ 1,500	0	\$ -	0	\$	-	2	\$ 3,000	2	\$	3,000	2	\$	3,000
ID tag interrogation antennas		\$ 20	0	\$ -	0	\$	-	0	\$ -	162	\$	3,240	162	\$	3,240
ID tag interrogation readers		\$ 200	0	\$ -	0	\$	-	0	\$ -	150	\$	30,000	150	\$	30,000
ID tags		\$ 10	0	\$ -	0	\$	-	0	\$ -	1666	\$	16,660	1666	\$	16,660
Seals (IAEA costs/seal)		\$ 33	100	\$ 3,300	100	\$ 3,	300	100	\$ 3,300	100	\$	3,300	100	\$	3,300
Total equipment cost per annum bas	is			\$ 20,625		\$ 29,	416		\$ 104,390		\$	488,804		\$	503,104
Equip. spares&installation =%of ann	ual cost	10%		\$2,062		¢2	,942		\$10,439			\$48,880			\$50,310
Total Annual Equipment Costs	uar cost	10 /6		\$22,687			,357		\$114,829			\$537,684			\$553,414
Annual equipment cost - repairs, trip	os. costsas	% of Equip.		φ22,007		\$32	,001		φ114,023			ψ331,004	l		ψυυυ, 14
factor of equip. cost	,	Cost Factor													
Est. Annual Equipment Upkeep Costs	5	10.0%		\$2,268.7		\$3,2	35.7		\$11,482.9)		\$53,768.4			\$55,341.4
Total Annual Equipment Costs				\$ 24,956		\$ 35,	593		\$ 126,312		\$	591,453		\$	608,756
Inspections Needed per Option Regi	me			# of Inspections		# of Inspections			# of Inspections		# of In:	spections		# of Inspec	ctions
No. routine inspections/yr				9			9		8			3		ļ	3
No. supplemental inspections/yr				2		ļ	2		2	4	1	2		ļ	2
No. Addl LFUA inspections/yr				6			0		C)	-	0		ļ	0
No. PIV/yr		0		1			1		1			1		ļ	1
Annual Sample Procedure Costs per	Option Regime	Cost/ Sample	Sam ple	Sample Costs/Year	Sample	Sample Costs/Y		Sample	Sample Costs/Year	Sam ple	Sample Costs/	Year	Sample	Sample Co	
DA Sample - procedures /yr		\$ 700	79	\$ 55,300	27		900	13	\$ 9,100	5	\$	3,500	5	\$	3,500
ES Samples/yr		\$ 500	6	\$ 3,000	6		000	6	\$ 3,000	6	\$	3,000	6	\$	3,000
TOTAL Sample Costs/yr				\$ 58,300		\$ 21,	900		\$ 12,100		\$	6,500		\$	6,500

Table 31: Labor Cost of Safeguards Options at 3000 MtSWU/yr GCEP for INFCIRC/153 Safeguards with NDA PD=50%, DA PD=10%

EXAMPLE GCEP of 3000	Assay Unit													
MTSWU/yr Capacity	Totals	TOTAL		Option	Α		Option B		Option C		Option D		Option E	
Nom. Feed cylinders/yr /assay unit	115	690					•		•		•		•	
Nom. Product cylinders/year	59	354]											
Nom. Tails cylinders/year	104	626												
Cascade Halls	8	48												
Load cell monitors/assay unit	23	138												
Assay units	6		Trad/Int S	gds			ISSP SPECS		NEUT DET		AEM ACC	NEUT DET	+ AEM ACC	
Inspection Staffing per Inspection	Cost			# of Insp			# of Inspectors		# of Inspectors		# of Inspectors	_	# of Inspec	tors
Inspectors / routine inspection					2		2		2			2		2
Inspectors / suppl inspection					1		1		1			1		1
Inspectors / LFUA inspection					2		C		0			0		0
Inspectors / PIV inspection					3		3	i	3			3		3
Inspection Time Cost				Length ((Days)		Length (Days)		Length (Days)		Length (Days)		Length (Da	ıys)
Duration of routine inspection					3		3	1	3			3		3
Duration of suppl inspection					1		1		1			1		1
Duration of LFUA inspection					1		C	1	0			0		0
Duration of PIV inspection					10		10		10			7		7
Rest days during routine inspection					0		C		0			0		0
Rest days during suppl inspection					0		C		0			0		0
Rest days during LFUA inspection					0		C		0			0		C
Rest days during PIV inspection					2		2		2			2		
Travel days/inspector/trip					2		2		2			2		2
Office Time Cost (Prep/Aanalysis)				Length ((Days)		Length (Days)		Length (Days)		Length (Days)		Length (Da	ıys)
Office days/IIV inspection day				,	0.4		0.6		0.8		3 (),	1		1
Office days/suppl inspection day					0.25		0.25		0.25		0.	25		0.25
Office days/LFUA inspection day					0.125		0.125	_	0.125		0.1			0.125
Office days/PIV inspection day					0.25		0.25		0.5			1		1
Labor Cost of Inspector - burdene	d			Cost (US			Cost (USD)		Cost (USD)		Cost (USD)		Cost (USD))
Staff cost/day - trip PDI				,	\$2,000		\$2,000		\$2,000		\$2,0	00	,	\$2,000
Staff cost/day - trip Rest Day					\$1,000		\$1,000	_	\$1,000		\$1,0			\$1,000
Travel cost /trip					\$4,650		\$4,650		\$4,650		\$4,6			\$4,650
Staff cost/day - office					\$1,054		\$1,054		\$1,054		\$1,0			\$1,054
Inspector Labor Costs by Insp. Ty	oe .		PDI	Cost (US		PDI	Cost (USD)	PDI	Cost (USD)	PDI	Cost (USD)	PDI	Cost (USD)	
Staff costs for routine inspection			54	\$	180,000	54		48		18	•			60,000
Staff costs for suppl inspection			2	s	8,000	2	\$ 8,000	2	\$ 8,000	2	<u> </u>	_	2 \$	8,000
Staff costs for LFUA inspection			12	-	48,000	0			\$ -	0	_	_	0 \$	- 0,000
Staff costs for PIV inspection			30	,	84,000	30			\$ 84,000	21				66,000
		+	98	•	320,000	86		80		41				134,000
Total Inspector Labor Cost Inspector Travel Costs by Insp. Ty	ne	+	30	Ψ	320,000	00	\$ 272,000	- 00	φ 232,000	71	\$ 134,00	70 41	ų.	134,000
Travel costs for routine inspection	pc			\$	83,700		\$ 83,700		\$ 74,400		\$ 27,90	00	\$	27,900
Travel costs for suppl inspection				\$	9,300		\$ 9,300		\$ 9,300		\$ 9,30		\$	9,300
Travel costs for LFUA inspection				\$	55,800		\$ -		\$ -		\$	-	\$	
Travel costs for PIV inspection				\$	13,950		\$ 13,950		\$ 13,950		\$ 13,95	50	\$	13,950
Total travel cost				\$	162,750		\$ 106,950		\$ 97,650		\$ 51,15	50	\$	51,150
Inspector Office Costs by Insp. Ty														
Staff office costs for routine inspection	1	-		\$	22,766		\$ 34,150		\$ 40,474		\$ 18,97		\$	18,972
Staff office costs for suppl inspection		 	1	\$	527 1,581		\$ 527 \$ -	 	\$ 527 \$ -	-	\$ 52 \$	27	\$	527
Staff office costs for LFUA inspection Staff office costs for PIV inspection		+		\$	7,905		\$ 7,905	1	\$ 15,810		\$ 22,13	84	\$	22,134
Total staff office costs		+	1	\$	32,779		\$ 7,905 \$ 42,582	 	\$ 56,811		\$ 22,13		\$	41,633
Total annual labor/staff/sampling	costs		1	\$	515,529		\$ 421,532		\$ 406,461		\$ 226,78		\$	226,783
Total Annual costs				\$	598,785		\$ 479,024		\$ 544,873		\$ 824,73		\$	842,039
Total Annual costs in 1M\$ reflect	ing accuracy		\$M	0.6		\$M	0.5	\$M	0.5	\$M	0.8	\$1	0.8	

Table 32: Hardware Cost of Safeguards Options at 3000 MtSWU/yr GCEP for INFCIRC/540 Safeguards with NDA PD=20%, DA PD=20%

EXAMPLE GCEP of 3000	Assay Unit											
	Totals	TOTAL		Option A		Option B		Option C		Option D		Option E
Nom. Feed cylinders/yr /assay unit	115	690		Option A		Орион В		Option 0		Option D		Option L
	58	350										
Nom. Product cylinders/year	104	626										
Nom. Tails cylinders/year												
Cascade Halls	8	48										
Load cell monitors/assay unit	23	138			_							
Assay units	6		Trad/Int S	igds		MSSP SPECS	ļ	NEUT DET	,	AEM ACC	NEUT DET	+ AEM ACC
Item SG system capital costs per ar	inum basis (10	Annual		T-4-1 i4 O4		T-4-1 i4 O4		T-4-1 it C4		T-4-1 it 04		Total item Cost
year life span for equipment) DA Sample Bottles		Cost/ item \$ 16	Items 60	Total item Cost \$ 930	Items 80	Total item Cost \$ 1,240	Items 41	Total item Cost \$ 636	Items 12	Total item Cost \$ 186	Items 12	\$ 186
			1	\$ 680	4	, , ,	1		1		1	\$ 680
Portable LCBWS			1		1	\$ 680	1				1	
Reference weights		\$ -	1	\$ -	1	\$ -	1	\$ -	1	\$ -		\$ -
HPGe gamma spec (IMCG)		\$ 3,700	2	\$ 7,400	2	\$ 7,400	2	\$ 7,400	2	\$ 7,400	2	\$ 7,400
Nal Detector		\$ 3,700	2	\$ 7,400	2	\$ 7,400	2	\$ 7,400	2	\$ 7,400	2	\$ 7,400
Upgraded CHEM system		\$ 15,000	0	\$ -	0	\$ -	0	\$ -	0	\$ -	0	\$ -
Load cell monitors		\$ 500	0	\$ -	0	\$ -	0	\$ -	138	\$ 69,000	138	\$ 69,000
PNUH		\$ 40,000	0	\$ -	0	\$ -	0	\$ -	0	\$ -	0	\$ -
AEM- Installed detection system		\$ 10,000	0	\$ -	0	\$ -	0	\$ -	18	\$ 180,000	18	\$ 180,000
AEM - Data collect cabinet		\$ 10,000	0	\$ -	0	\$ -	0	\$ -	6	\$ 60,000	6	\$ 60,000
Neutron Detection System		\$ 6,500	0	\$ -	0	\$ -	1	\$ 6,500	0	\$ -	1	\$ 6,500
Neut Det - Data collect cabinet		\$ 7,800	0	\$ -	0	\$ -	1	\$ 7,800	0	\$ -	1	\$ 7,800
Data acquisition system		\$ 10,000	0	\$ -	1	\$ 10,000	2	\$ 20,000	6	\$ 60,000	6	\$ 60,000
Digital surv camera - F/W		\$ 2,000	0	\$ -	0	\$ -	24	\$ 48,000	24	\$ 48,000	24	\$ 48,000
Accountability scale monitor + camera		\$ 1,500	0	\$ -	0	\$ -	2	\$ 3,000	2	\$ 3,000	2	\$ 3,000
ID tag interrogation antennas		\$ 20	0	\$ -	0	\$ -	0	\$ -	162	\$ 3,240	162	\$ 3,240
ID tag interrogation readers		\$ 200	0	\$ -	0	\$ -	0	\$ -	150	\$ 30,000	150	\$ 30,000
ID tags		\$ 10	0	\$ -	0	\$ -	0	\$ -	1666	\$ 16,660	1666	\$ 16,660
Seals (IAEA costs/seal)		\$ 33	100	\$ 3,300	100	\$ 3,300	100	\$ 3,300	100	\$ 3,300	100	\$ 3,300
Total equipment cost per annum basi	is			\$ 19,710		\$ 30,020		\$ 104,716		\$ 488,866		\$ 503,166
	-			,		* ******		, ,,,,,,,,		100,000		7,
Equip. spares&installation =% of ann	ual cost	10%		\$1,971		\$3,002		\$10,472		\$48,887		\$50,317
Total Annual Equipment Costs				\$21,681		\$33,022		\$115,187		\$537,753		\$553,483
Annual equipment cost - repairs, trip	s, costsas	% of Equip.		4 =., 6 0.		400,0==		7.10,101		4000,000		7000,100
factor of equip. cost		Cost Factor										
Est. Annual Equipment Upkeep Costs	;	10.0%		\$2,168.1		\$3,302.2		\$11,518.7		\$53,775.3	1	\$55,348.3
Total Annual Equipment Costs				\$ 23,849		\$ 36,324		\$ 126,706		\$ 591,528		\$ 608,831
Inspections Needed per Option Regir	ne			# of Inspections		# of Inspections		# of Inspections		# of Inspections		# of Inspections
No. routine inspections/yr				8		8		7		3		3
No. supplemental inspections/yr				2		2		2		2		2
No. Addl LFUA inspections/yr				6		0		0		0)	0
No. PIV/yr				1		1	1	1		1		1
		Cost/								Sample		
Annual Sample Procedure Costs per	Option Regime	Sample	Sam ple	Sample Costs/Year	Sample	Sample Costs/Year	Sample	Sample Costs/Year	Sample	Costs/Year	Sam ple	Sample Costs/Year
DA Sample - procedures /yr		\$ 700	40	\$ 28,000	53	\$ 37,100	27	\$ 18,900	8	\$ 5,600	8	\$ 5,600
ES Samples/yr		\$ 500	6	\$ 3,000	6	\$ 3,000	6	\$ 3,000	6	\$ 3,000	6	\$ 3,000
TOTAL Sample Costs/yr				\$ 31.000		\$ 40.100		\$ 21,900		\$ 8.600		\$ 8.600

Table 33: Labor Cost of Safeguards Options at 3000 MtSWU/yr GCEP for INFCIRC/540 Safeguards with NDA PD=20%, DA PD=20%

EXAMPLE GCEP of 3000	Assay Unit																
MTSWU/yr Capacity	Totals	TOTAL		Optio	n A		Option E	3		Option	С	c	Option	D		Option E	
Nom. Feed cylinders/yr /assay unit	115	690					-										
Nom. Product cylinders/year	59	354															
Nom. Tails cylinders/year	104	626															
Cascade Halls	8	48															
Load cell monitors/assay unit	23	138															
Assay units	6		Trad/Int S	gds		N	ISSP SPEC	cs		NEUT DE	ET	A	AEM AC	cc	NEUT DET +	- AEM ACC	
Inspection Staffing per Inspection (Cost			# of Ins	spectors		# of Insp	ectors		# of Ins	pectors		# of Ir	nspectors		# of Inspe	ctors
Inspectors / routine inspection					2			2			2			2			2
Inspectors / suppl inspection					1			1			1			1			1
Inspectors / LFUA inspection					2			0			0			0			0
Inspectors / PIV inspection					3			3			3			3			3
Inspection Time Cost				l enath	(Days)		Length (I	Days)		Length			l engt	th (Days)		Length (Da	avs)
Duration of routine inspection				_og	3		20119111 (2	3			3		_0g.	3		2011gtii (21	3
								1			1			1			1
Duration of suppl inspection Duration of LFUA inspection		1			1			0		1	0			0			- 1
					10												-
Duration of PIV inspection		1			10			10			10			7			
Rest days during routine inspection					0			0			0			0			0
Rest days during suppl inspection			ļ		0			0			0			0			0
Rest days during LFUA inspection					0			0			0			0			0
Rest days during PIV inspection					2			2			2			2			2
Travel days/inspector/trip					2			2			2			2			2
Office Time Cost (Prep/Aanalysis)				Length	(Days)		Length (I	Days)		Length	(Days)		Lengt	th (Days)		Length (Da	ays)
Office days/IIV inspection day					0.4			0.6			0.8			1			1
Office days/suppl inspection day					0.25			0.25			0.25			0.25			0.25
Office days/LFUA inspection day					0.125			0.125			0.125			0.125			0.125
Office days/PIV inspection day					0.25			0.25			0.5			1			1
Labor Cost of Inspector - burdened	1			Cost (L			Cost (US			Cost (U			Cost	(USD)		Cost (USD))
Staff cost/day - trip PDI					\$2,000			\$2,000		(-	\$2,000			\$2,000			\$2,000
					\$1,000			\$1,000			\$1,000			\$1,000			\$1,000
Staff cost/day - trip Rest Day Travel cost /trip					\$4,650			\$4,650			\$4,650			\$4,650			\$4,650
Staff cost/day - office					\$1,054			\$1,054			\$1,054			\$1,054			\$1,054
	_		PDI	Cast (I		PDI	Cost (US		PDI	Cost (U		PDI	Cost		PDI	Cost (USD	
Inspector Labor Costs by Insp. Typ	le .			Cost (L	-		_	-		_	-		_				
Staff costs for routine inspection		+	48	\$	160,000	48	_	160,000	42	_	140,000	18	_	60,000	18		60,000
Staff costs for suppl inspection			2	\$	8,000		\$	8,000	2	_	8,000	2	_	8,000	2		8,000
Staff costs for LFUA inspection			12	\$	48,000		\$	-	0	,	-		\$	-	0		-
Staff costs for PIV inspection			30	\$	84,000	30		84,000	30		84,000	21		66,000	21		66,000
Total Inspector Labor Cost			92	\$	300,000	80	\$	252,000	74	\$	232,000	41	\$	134,000	41	\$	134,000
Inspector Travel Costs by Insp. Typ	oe .			•	=		•	=			0= 100		_				
Travel costs for routine inspection				\$	74,400		\$	74,400		\$	65,100		\$	27,900		\$	27,900
Travel costs for suppl inspection				\$	9,300		\$	9,300		\$	9,300		\$	9,300		\$	9,300
Travel costs for LFUA inspection Travel costs for PIV inspection				\$	55,800 13,950		\$	13,950		\$	13,950		\$	13,950		\$	13,950
Total travel cost				\$	153,450		\$	97,650		\$	88,350		\$	51,150		\$	51,150
Inspector Office Costs by Insp. Typ	e			Ψ	100,400		Ψ	37,000			00,000		Ψ	01,100		Ψ	01,100
Staff office costs for routine inspection			1 1	\$	20,237		\$	30,355		\$	35,414		\$	18,972		\$	18,972
Staff office costs for suppl inspection				\$	527		\$	527		\$	527		\$	527		\$	527
Staff office costs for LFUA inspection				\$	1,581		\$	-		\$	-		\$	-		\$	-
Staff office costs for PIV inspection				\$	7,905		\$	7,905		\$	15,810		\$	22,134		\$	22,134
Total staff office costs				\$	30,250		\$	38,787		\$	51,751		\$	41,633		\$	41,633
Total annual labor/staff/sampling of	costs			\$	483,700		\$	388,437		\$	372,101		\$	226,783		\$	226,783
Total August a sate				•	500 F 12		•	404.061		•	500.757		•	000.011		•	044.044
Total Annual costs			6	\$	538,549	¢	\$	464,861	¢	\$	520,707	^	\$	826,911	^	\$ 0.8	844,214
Total Annual costs in 1M\$ reflecti	ng accuracy		\$M	0.5		\$M	0.5		\$M	0.0		ψM	8.0		\$ IVI	0.0	

Table~34:~Labor~Cost~of~Safeguards~Options~at~3000~MtSWU/yr~GCEP~for~INFCIRC/540~Safeguards~with~NDA~PD=20%,~DA~PD=10%,

EXAMPLE GCEP of 3000	Assay Unit																	
MTSWU/yr Capacity	Totals	тота			Option	Δ		Option	R		Optio	ın C		Option	N D		Option	F
Nom. Feed cylinders/yr /assay unit	115	69			Option			Option	_		Optio	0		Орио			Орион	-
Nom. Product cylinders/year	58	35																
Nom. Tails cylinders/year	104	62																
Cascade Halls	8	4																
Load cell monitors/assay unit	23	13	8															_
Assay units Item SG system capital costs per a	6			Trad/Int S	Sgds			MSSP SPE	:CS		NEUT	DET		AEM A	CC	NEUT DET	+ AEM AC	С
	innum basis (10	Ann Cost/			Total ite	- 04		Total ite	04		T-4-1:	tem Cost		T-4-1	item Cost		Total ite	04
year life span for equipment) DA Sample Bottles		\$	16	Items 60	\$	930	Items 41	\$	636	ltems 20	\$	310	Items 8	\$	124	Items 8	\$	124
Portable LCBWS		\$	680	1	\$	680	1	\$	680	1	\$	680	1	\$	680	1	\$	680
Reference weights		\$	000	1	\$	000	1	\$	000	1	\$	000	1	\$	000	1	\$	000
HPGe gamma spec (IMCG)		_	3,700	2	\$	7.400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Nal Detector			3,700	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Upgraded CHEM system			5,000	0	\$	7,400	0	\$	7,400	0	\$	7,400	0	\$	7,400	0	\$	7,400
		\$ 1		0	\$		0	\$		0	\$		138	\$	69,000	138	\$	69,000
Load cell monitors PNUH			0,000	0	\$		0	\$		0	\$		0	\$	69,000	0	\$	69,000
			0,000	0	\$		0	\$		0	\$		18	\$	180,000	18	\$	180,000
AEM- Installed detection system AEM - Data collect cabinet			0,000	0	\$		0	\$		0	\$		6	\$	60,000	6	\$	60,000
Neutron Detection System		_	6,500	0	\$		0	\$		1	\$	6.500	0	\$	60,000	1	\$	6,500
Neut Det - Data collect cabinet			7,800	0	\$		0	\$		1	\$	7.800	0	\$		1	\$	7,800
Data acquisition system			0,000	0	\$		1	\$	10,000	2	\$	20,000	6	\$	60,000	6	\$	60,000
Digital surv camera - F/W			2,000	0	\$		0	\$	10,000	24	\$	48,000	24	\$	48,000	24	\$	48,000
Accountability scale monitor + camera			1,500	0	\$		0	\$		24	\$	3,000	24	\$	3,000	24	\$	3,000
ID tag interrogation antennas		\$	20	0	\$		0	\$		0	\$	3,000	162	\$	3,240	162	\$	3,240
ID tag interrogation antermas		\$	200	0	\$		0	\$		0	\$		150	\$	30,000	150	\$	30,000
ID tags interrogation readers		\$	10	0	\$		0	\$		0	\$		1666	\$	16,660	1666	\$	16,660
Seals (IAEA costs/seal)		\$	33	100	\$	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300	1000	\$	3,300
Total equipment cost per annum ba	oi o	Ф	33	100	\$	19,710	100	\$	29,416	100	\$	104,390	100	\$	488,804	100	\$	503,104
Equip. spares&installation =%of an			10%		·	\$1,971			\$2,942		Ť	\$10,439		Ĺ	\$48,880			\$50,310
Total Annual Equipment Costs		0/ -4 5				\$21,681			\$32,357			\$114,829			\$537,684			\$553,414
Annual equipment cost - repairs, tri factor of equip. cost	ps, costsas	% of Ed																
Est. Annual Equipment Upkeep Cost	e	_	10.0%			\$2,168.1			\$3,235.7			\$11,482.9			\$53,768.4			\$55,341.4
Total Annual Equipment Costs			10.070		S	23,849		\$	35,593		¢	126,312		\$	591,453		s	608,756
Total Amual Equipment oosts					<u> </u>	20,040		<u> </u>	00,000		Ψ	120,012		Ψ	001,400		,	000,700
Inspections Needed per Option Reg	ime				# of Insp	ections		# of Ins	pections		# of In	spections		# of I	nspections		# of Ins	ections
No. routine inspections/yr						7			7			6			3			3
No. supplemental inspections/yr						2			2			2			2			2
No. Addl LFUA inspections/yr						6			0			0			0			0
No. PIV/yr						1			1			1			1			1
Annual Sample Procedure Costs pe	r Option Regime	Co: Sam		Sample	Sam ple	Costs/Year	Sample	Sam ple	Costs/Year	Sample	Sampl	le Costs/Year	Sam ple	Sam p Costs	ole s/Year	Sample		Costs/Year
DA Sample - procedures /yr		\$	700	40	\$	28,000	27	\$	18,900	13	\$	9,100	5	\$	3,500	5	\$	3,500
ES Samples/yr		\$	500	6	\$	3,000	6	\$	3,000	6	\$	3,000	6	\$	3,000	6	\$	3,000
TOTAL Sample Costs/yr					\$	31,000		\$	21,900		\$	12,100		\$	6,500		\$	6,500

Appendix D:

Costs of Safeguards at a 6000 MtSWU/yr GCEP

Table 35-Table 42 display the itemized cost analysis for safeguards at a GCEP of capacity 6000 MtSWU/yr compared with current methods based on the HSP for normal and reduced $P_{\rm D}$ under both INFCIRC/153 and INFCIRC/540 safeguards regimes.

Table 35: Hardware Cost of Safeguards Options at 6000 MtSWU/yr GCEP for INFCIRC/153 Safeguards with NDA PD= 50%, DA PD=50%

	Assay																
EXAMPLE GCEP of 6000	Unit																
MTSWU/yr Capacity	Totals	TOTAL		Option A		О	ption B		(Option C			Option D			Option E	
Nom. Feed cylinders/yr /assay unit	115	1380															
Nom. Product cylinders/year	58	700															
Nom. Tails cylinders/year	104	1252															ļ
Cascade Halls	8	96															
Load cell monitors/assay unit	23	276															
Assay units	12		Trad/Int Sg	ds		MS	SP SPECS			NEUT DET			AEM ACC		NEUT DET +	AEM ACC	
Item SG system capital costs per a	nnum	Annual															
basis (10 year life span for equipm	ent)	Cost/ item	Items	Total item	Cost	Items	Total ite	n Cost	Items	Total ite	m Cost	Items	Total item	Cost	Items	Total item C	ost
DA Sample Bottles		\$ 16	357	\$	5,534	494	\$	7,657	243	\$	3,767	59	\$	915	59	\$	915
Portable LCBWS		\$ 680	1	\$	680	1	\$	680	1	\$	680	1	\$	680	1	\$	680

Table 36: Labor Cost of Safeguards Options at 6000 MtSWU/yr GCEP for INFCIRC/153 Safeguards with NDA PD=50%, DA PD=50%

LUAU CEII HIDHIIOFS		Ψ	w	U		Ψ	-1 0	ĮΨ		v	Į×	· -	210	Ψ	100,000	210	Ψ	100,000
	Assay																	
EXAMPLE GCEP of 6000 MTSWU/vr Capacity	Unit	TOTAL			٠ <i>،</i>				. 5						D		O 11 -	
Neutron Detection System, unit	Totals	TOTAL \$380 ^{6,5}	00	0		tion A \$	-1 0	ptio		1 1	Jpt I S	tion C \$ 6,500	1 0	Jpti \$	on D	1	Optic I \$	6,500
No Newt Det. Data collect gabinet	115 59	\$708 7,8	00	0	_	\$. 0	\$		1	9		0	\$	_	1	\$	7.800
No Data acquisition system	104	\$2530,0	00	0	T	\$. 1	\$	10,000	2	9	\$ 20,000	12	\$	120,000	12	\$	120,000
Ca Digital sury camera - F/W	.0	\$96 2,0	OO	0		\$	- 0	\$		24	9	\$ 48,000	24	\$	48,000	24	\$	48,000
Accountability scale monitor + came	ra 22	\$276 1,5	OO.	0	T	\$	- 0	\$	-	2	9	\$ 3,000	2	\$	3,000	2	\$	3,000
As ID tag interrogation antennas	12		٩.	ad/Int Sgo	10	\$	· 0 MS	SP C	PECS	0	NI S	S DET -	162	\$	ACC 3,240	NEUT BET +	AEM.	3,240
			Ħ	uu/iii ogi		•		J. 10.	, 200		I	, , , ,	<u> </u>					
Inspection Statting per inspection	Cost	\$	22	100	# c	Inspectors 3 300	100	# ở	f Inspectors	100	# }	of Inspectors	3332	چ ام	f Inspectors	3332 100	# ^{of I}	nspectors
Inspectors of continue in a pection of a normal		*	۳	100	П	\$ 24.37		1	36.437		,	9 0,000	100	ě	875.25 5	100	¢	889.555 ²
Inspectors / suppl inspection	I Da SIS		Ħ		Ħ	1	=	Н,	30,437 1		Н,	107,847		3	873,233 1		-	1
Ins Equip spareskinstallation =% o	f annual cost	1	0%		H	\$2,43		Ħ	\$3,64		Ħ	\$10,785		H	\$87,525			\$88,955
Inspectors / Prox inspection I otal Annual Equipment Costs Inspectors / Prox inspection			Ħ		Ħ	\$26,74		Ш	\$40,08			\$118,631			\$962,780			\$978,510
Inspection Time Cost		% of Equ	1		1	ngth (Days)		ler	ngth (Days)	1	٦	ength (Days)	1		ngth (Days)		Leno	th (Days)
Du Apayal equiement gost - repairs	s. trips.	Cost	лр.		1	3	 	1001	3		1	angth (Days)		Lei	igiii (Days)		Leng	ui (Days)
costsas factor of equip. cost	o,po,	Factor	+		H	3	 	+	3		╫	3		₩-	3			
Dulation of suppl inspection Est. Annual Equipment Upkeep	Costs	10.	0%		Ε	\$2,674	5		\$4,008.			\$11,863.1			\$96,278.0			\$97,851.0
Duration of LFUA inspection			Н		Н	\$ 29,41		\$	44,089		- 4	\$ 130,494		\$	1,059,058		\$	1, 076,361 ⁰
Dulation of PIV inspection					Н	10		-	10		#	10			7			7
Restruispeculations Needide in precouption	Regime		+		#	# of Inspections0		#	of Inspections0		#	f of Inspections		# c	of Inspections 0		# of	nspections 0
Rest days during suppl inspection			Ш		Ш	0	1	Ш	0		#	0		<u> </u>	0			0
No. routine inspections/yr Rest days during LFUA inspection			Ħ		Ħ		Ľ	ш	0		井	0			6			- 8
Rest days during PIV inspection			Ш		Ш	2	7	Ш	2	2	Щ	2,			3			- 2
Travel days/inspector/trip					П	2			2		Ш	2			2			2
Office Trindel-EloStin Preginaminalysis)			Ш		Le	ngun (Dayo)	2	Ler	ngth (Days))	Le	ength (Days)		Ler	ngth (Days) 0		Leng	th (Days) 0
Off Ag-day-VIIV inspection day			Ш		Ш	0.4	1	Щ	0.6		Щ	0.81			. 1			1
Annual Sample Procedure Cost Office days/suppl inspection day	s per Option	Cost. Sampl		Sample	١,	Sample Costs/Yea	r Sample		ample osts/Year 0.25	Sam ple		Costs/Year 0.25	Sample		mple sts/Year 0.25	Sample	Sam	ole Costs/Year
Officia dayadu FUArinsa dan tisan day			00	238		\$ 106,65		\$	230,13050	162	9		39	\$	210,31205	39	\$	2703026
Office Sayspiles/jimspection day		\$ 5	00	6		\$ 3,260	6	\$	30,02080	6	9	\$ 3,000,6	6	\$	3,000	6	\$	3,0001
La TOTAL Sample Costs/Viburdene	d		П		c	\$ _{t (USD)} 169,600		d	et (USD) 233,300		Č	\$ _{st (USD} 116,400		్స్ట్రీ	st (USD) 30,300		Ĉħst	(USD) 30,300
Staff cost/day - trip PDI						\$2,000			\$2,000			\$2,000			\$2,000			\$2,000
Staff cost/day - trip Rest Day						\$1,000			\$1,000			\$1,000			\$1,000			\$1,000
Travel cost /trip						\$4,650			\$4,650			\$4,650			\$4,650			\$4,650
Staff cost/day - office						\$1,054			\$1,054			\$1,054			\$1,054			\$1,054
Inspector Labor Costs by Insp. Ty	ре			PDI	Со	st (USD)	PDI	Cos	st (USD)	PDI	Co	ost (USD)	PDI	Cos	st (USD)	PDI	Cost	(USD)
Staff costs for routine inspection				66	\$	220,000	66	\$	220,000	24	\$	80,000	18	\$	60,000	18	\$	60,000
Staff costs for suppl inspection				7	\$	28,000	12	\$	48,000	3	\$	12,000	3	\$	12,000	2	\$	8,000
Staff costs for LFUA inspection			T	24	\$	96,000	C	\$	-	0	\$	-	0	\$	-	0	\$	
Staff costs for PIV inspection			T	30	\$	84,000	30	-	84,000	30	\$	84,000	21	\$	66,000	21	\$	66,000
Total Inspector Labor Cost				127	\$	428,000	108	\$	352,000	57	\$	176,000	42	\$	138,000	41	\$	134,000
Inspector Travel Costs by Insp. Ty	pe		T	-	Ė	.,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,			,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,		Ĺ	.,			, , ,			,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,
Travel costs for routine inspection			T		\$	102,300		\$	102,300		\$	37,200		\$	27,900		\$	27,900
Travel costs for suppl inspection					\$	32.550		\$	55.800		\$	13.950		\$	13.950		\$	9,300

Table~37:~Hardware~Cost~of~Safeguards~Options~at~6000~MtSWU/yr~GCEP~for~INFCIRC/153~Safeguards~with~NDA~PD=50%,~DA~PD=1

	1															
Assay																
																_
			Option A	١	C	option B			Option	C		Option	n D		Option	E
58	700															
104	1252															
8	96															
23	276															
12		Trad/Int Sg	ds		M	SSP SPECS			NEUT D	ET		AEM A	CC	NEUT DET	+ AEM AC	CC
	Annual															
nt)	1					_			_			_				em Cost
		357		-,	77			38			12			12		186
		1		680	1		680	1		680	1	_	680	1		680
							-	1	_	-			-			-
	\$ 3,700			,						,			,	2		7,400
	4 0,			7,400			7,400			7,400			7,400			7,400
	\$ 15,000	0		-			-	_	_	-		_	-			-
	\$ 500	0	\$	-	0		-	0	\$		276	\$	138,000	276	\$	138,000
	\$ 40,000	0		-	0		-	0		-	0		-	0		-
	\$ 10,000	0	\$	-	0	\$	-	0	\$	-	36	\$	360,000	36	\$	360,000
	\$ 10,000	0	\$	-	0	\$		0	\$	-	12	\$	120,000	12	\$	120,000
	\$ 6,500	0	\$	-	0	\$		1	\$	6,500	0	\$	-	1	\$	6,500
	\$ 7,800	0	\$	-	0	\$	-	1	\$	7,800	0	\$	-	1	\$	7,800
	\$ 10,000	0	\$	-	1	\$	10,000	2	\$	20,000	12	\$	120,000	12	\$	120,000
	\$ 2,000	0	\$	-	0	\$	-	24	\$	48,000	24	\$	48,000	24	\$	48,000
	\$ 1,500	0	\$	-	0	\$	-	2	\$	3,000	2	\$	3,000	2	\$	3,000
	\$ 20	0	\$	-	0	\$	-	0	\$	-	162	\$	3,240	162	\$	3,240
	\$ 200	0	\$	-	0	\$	-	0	\$	-	150	\$	30,000	150	\$	30,000
	\$ 10	0	\$	-	0	\$	-	0	\$	-	3332	\$	33,320	3332	\$	33,320
	\$ 33	100	\$	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300
S			\$	24,314		\$	29,974		\$	104,669		\$	874,526		\$	888,826
ual cost	10%			\$2,431			\$2,997			\$10,467			\$87,453			\$88,883
				\$26,745			\$32,971			\$115,136			\$961,979			\$977,709
5,																
				\$2 674 5			\$3 297 1			\$11 513 6			\$96 197 9			\$97,770.9
	10.070		s			s			s			\$			\$	1.075.479
			<u> </u>	20,		<u> </u>	00,200		Ť	.20,0.0		Ť	1,000,110		Ť	.,0.0,0
ne			# of Insp	ections		# of Insp	ections		# of Ir	nspections		# of I	nspections		# of Ins	spections
							11			3			3			3
				_			_			_						_
	1	 	1	7		+			-			+	2		+	2
	1	 	1	12		+			-	0		+			+	- 0
0-4:	0		 	1	 	C	1		C	1		C	1		-	1
Option		Sample	Sample	CasteNess	Sample		n ar	Sample			Sample			Sample	Sample	Costs/Year
									_							5,600
	\$ 500	6	\$	3.000	6	\$	3,000	6	\$	3.000	6	\$	3,000	6	\$	3,000
	Unit Totals 115 58 104 8 23	Unit Totals TOTAL 115 1380 58 700 104 1252 8 96 23 276 12 Annual Cost/ item \$ 16 \$ 680 \$ \$ - \$ 3,700 \$ 15,000 \$ 10,000	Unit Totals TOTAL 115	Unit Totals TOTAL 115	Unit Totals TOTAL 115	Unit Totals Total Tota	Unit Totals Total Tota	Unit Totals Total Total See Total Total See Total See Total See Total See Total See Total See See	Unit Totals TOTAL 115 1380 58 700 104 1252 23 8 96 12 MSSP SPECS 112 Trad/Int Sg/s MSSP SPECS Inum (II) Annual 23 Items Total item Cost 357 Items Total item Cost 5 5,534 Trotal item Cost 77 Items Total item Cost 7,400 Items 1,194 38 8 680 1 \$ 680 1 <	Unit Total Total	Unit Totals TOTAL 1380 58 700 104 1252 8 96 23 276 12 Trad/int Sgds	Unit	Unit Totals Total Tota	Unit Totals TOTAL Option A	Unit Totals Total Tota	Unit TOTAL 115 1390 58 700 150 1

Table 38: Labor Cost of Safeguards Options at 6000 MtSWU/yr GCEP for INFCIRC/153 Safeguards with NDA PD=50%, DA PD=10%

	Assay											
EXAMPLE GCEP of 6000	Unit											
MTSWU/yr Capacity	Totals	TOTAL		Option A	O	ption B	c	Option C	(Option D		Option E
Nom. Feed cylinders/yr /assay unit	115	1380		-								
Nom. Product cylinders/year	59	708										
Nom. Tails cylinders/year	104	1252										
Cascade Halls	8	96										
Load cell monitors/assay unit	23	276										
Assay units	12		Trad/Int Sg	ds	MSS	SP SPECS	N	NEUT DET	,	AEM ACC	NEUT DET +	AEM ACC
Inspection Staffing per Inspection (Cost			# of Inspectors		# of Inspectors		# of Inspectors		# of Inspectors		# of Inspectors
Inspectors / routine inspection	5031			2		2		2		2		2
Inspectors / suppl inspection				1		1		1		1		1
Inspectors / LFUA inspection				2		0		0		0		
Inspectors / PIV inspection				3		3		3		3		3
Inspection Time Cost				Length (Days)		Length (Days)		Length (Days)		Length (Days)		Length (Days)
				Length (Days)				Length (Days)		Length (Days)		Lengin (Days)
Duration of routine inspection Duration of suppl inspection		1		3		3		3		3	 	3
Duration of LFUA inspection				1		0		0		0		0
Duration of PIV inspection		†	†	10		10		10		7	1	7
Rest days during routine inspection		†	 	0		0		0		0		7
Rest days during suppl inspection				0		0	†	0		0		0
Rest days during LFUA inspection				0		0		0		0		0
				2		2		2		2		2
Rest days during PIV inspection		-		2		2		2		2		2
Travel days/inspector/trip			-	Langth (Dava)		_		Langth (Dava)				Langth (Days)
Office Time Cost (Prep/Aanalysis) Office days/IIV inspection day				Length (Days) 0.4		Length (Days) 0.6		Length (Days) 0.8		Length (Days)		Length (Days)
Office days/suppl inspection day		-		0.25		0.25		0.25		0.25		0.25
Office days/LFUA inspection day				0.125		0.125		0.125		0.125		0.125
Office days/PIV inspection day		1		0.125		0.125		0.125		0.123		0.125
				Cost (USD)		Cost (USD)		Cost (USD)		Cost (USD)		Cost (USD)
Labor Cost of Inspector - burdened				\$2,000		\$2,000		\$2,000		\$2,000		\$2,000
Staff cost/day - trip PDI		1										
Staff cost/day - trip Rest Day			-	\$1,000 \$4,650		\$1,000		\$1,000 \$4,650		\$1,000		\$1,000
Travel cost /trip Staff cost/day - office				\$1,054		\$4,650 \$1,054		\$1,054		\$4,650 \$1,054		\$4,650 \$1,054
			PDI	Cost (USD)	PDI	Cost (USD)	PDI	Cost (USD)	PDI	Cost (USD)	PDI	Cost (USD)
Inspector Labor Costs by Insp. Typ Staff costs for routine inspection			66		66		18		18		18	
Staff costs for suppl inspection			7	\$ 28,000	5		2		2		2	
Staff costs for LFUA inspection			24		0		0			\$ -	0	
Staff costs for PIV inspection			30		30	-	30		21		21	-
			127	\$ 428,000	101	\$ 324,000	50		41	\$ 134,000	41	\$ 134,000
Total Inspector Labor Cost Inspector Travel Costs by Insp. Typ	10		121	\$ 428,000	101	\$ 324,000	30	\$ 152,000	41	\$ 134,000	41	\$ 134,000
Travel costs for routine inspection	, c			\$ 102,300		\$ 102,300		\$ 27,900		\$ 27,900		\$ 27,900
Travel costs for suppl inspection				\$ 32,550		\$ 23,250		\$ 9,300		\$ 9,300		\$ 9,300
Travel costs for LFUA inspection				\$ 111,600		\$ -		\$ -		\$ -		\$ -
Travel costs for PIV inspection				\$ 13,950		\$ 13,950		\$ 13,950		\$ 13,950		\$ 13,950
Total travel cost		1		\$ 260,400		\$ 139,500		\$ 51,150		\$ 51,150		\$ 51,150
Inspector Office Costs by Insp. Typ	е											
Staff office costs for routine inspection Staff office costs for suppl inspection		1	-	\$ 27,826 \$ 1,845		\$ 41,738 \$ 1,318	-	\$ 15,178 \$ 527		\$ 18,972 \$ 527		\$ 18,972 \$ 527
Staff office costs for Suppl Inspection		1		\$ 1,845		\$ 1,318		\$ 527		\$ 527		\$ 527
Staff office costs for PIV inspection		1		\$ 7,905		\$ 7,905		\$ 15,810		\$ 22,134		\$ 22,134
Total staff office costs				\$ 40,737		\$ 50,961		\$ 31,515		\$ 41,633		\$ 41,633
Total annual labor/staff/sampling of	costs			\$ 729,137		\$ 514,461		\$ 234,665		\$ 226,783		\$ 226,783
Total Annual costs			A	\$ 928,156	A	\$ 589,429		\$ 381,814	A	\$ 1,293,559	^	\$ 1,310,862
Total Annual costs in 1M\$ reflecti	ng accurác	/	\$M	0.9	\$M	0.6	\$M	0.4	\$M	1.3	\$M	1.3

Table 39: Hardware Cost of Safeguards Options at 6000 MtSWU/yr GCEP for INFCIRC/540 Safeguards with NDA PD= 20%, DA PD=20%

	Assay																
	Unit Totals	TOTAL		Option /	Δ		Option B			Option	С		Optio	n D		Option	F
Nom. Feed cylinders/yr /assay unit	115	1380		орион.	•		op 2			•р•	Ť		- p			Op.io.	_
Nom. Product cylinders/year	58	700															
Nom. Tails cylinders/year	104	1252															
Cascade Halls	8	96															
Load cell monitors/assay unit	23	276															
Assay units	12	2/0	Trad/Int Sg	.do			SSP SPECS			NEUT DE	-		AEM A	cc	NEUT DET		cc
Item SG system capital costs per ar		Annual	Trau/IIII og	jus		IVI	SSF SFECS)		NEO! DE	-1		ACIVI A		NEUT DET	+ ACVI A	50
basis (10 year life span for equipme		Cost/ item	Items	Total ite	m Cost	Items	Total ite	m Cost	Items	Total i	tem Cost	Items	Total	litem Cost	Items	Total i	tem Cost
DA Sample Bottles	,	\$ 16	116	\$	1,798	159	\$	2,465	78	\$	1,209	20	\$	310	20	\$	310
Portable LCBWS		\$ 680	1	\$	680	1	\$	680	1	\$	680	1	\$	680	1	\$	680
Reference weights		\$ -	1	\$		1	\$		1	\$	-	1	\$	-	1	\$	
HPGe gamma spec (IMCG)		\$ 3,700	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Nal Detector		\$ 3,700	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Upgraded CHEM system		\$ 15,000	0	\$	-,.50	0	\$	-,.50	0	\$		0	\$		0	\$	-,.50
Load cell monitors		\$ 500	0	\$		0	\$		0	\$		276	\$	138.000	276	\$	138.000
PNUH		\$ 40,000	0	\$		0	\$	-	0	\$		0	\$.00,000	0	\$	- 100,000
AEM- Installed detection system		\$ 10,000	0	\$		0	\$		0	\$	-	36	\$	360.000	36	\$	360,000
AEM - Data collect cabinet		\$ 10,000	0	\$		0	\$		0	\$		12	\$	120,000	12	\$	120,000
Neutron Detection System		\$ 6,500	0	\$		0	\$		1	\$	6,500	0	\$	120,000	1	\$	6,500
Neut Det - Data collect cabinet		\$ 7,800	0	\$		0	\$		1	\$	7,800	0	\$		1	\$	7,800
Data acquisition system		\$ 10,000	0	\$	_	1	\$	10,000	2	\$	20,000	12	\$	120,000	12	\$	120,000
Digital surv camera - F/W		\$ 2,000	0	\$		0	\$	10,000	24	\$	48,000	24	\$	48,000	24	\$	48,000
Accountability scale monitor + camera		\$ 1,500	0	\$		0	\$		2	\$	3,000	2	\$	3,000	2	\$	3,000
ID tag interrogation antennas		\$ 20	0	\$	_	0	\$		0	\$	0,000	162	\$	3,240	162	\$	3,240
ID tag interrogation readers		\$ 200	0	\$		0	\$		0	\$		150	\$	30,000	150	\$	30,000
ID tags		\$ 10	0	\$		0	\$		0	\$		3332	\$	33,320	3332	\$	33,320
Seals (IAEA costs/seal)		\$ 33	100	\$	3,300	100	\$	3.300	100	\$	3,300	100	\$	3,300	100	\$	3,300
Total equipment cost per annum bas	ie	ψ 55	100	\$	20,578	100	\$	31,245	100	\$	105,289	100	\$	874,650	100	\$	888,950
Equip. spares&installation =% of ann		10%		Ψ	\$2,058		Ψ	\$3,124		-	\$10,529		Ψ	\$87,465		Ψ	\$88,895
Total Annual Equipment Costs	uar cost	1070	1		\$22,636			\$34,369			\$115,818			\$962,115			\$977,845
Total Allitual Equipment Costs					\$22,030			\$34,309			\$113,010			\$902,113			\$911,645
Annual equipment cost - repairs, trip	os,	% of Equip. Cost															
costsas factor of equip. cost		Factor															
Est. Annual Equipment Upkeep Costs	3	10.0%	,		\$2,263.6			\$3,436.9			\$11,581.8			\$96,211.5			\$97,784.5
Total Annual Equipment Costs				\$	24,899		\$	37,806		\$	127,400		\$	1,058,327		\$	1,075,630
Inspections Needed per Option Regir	me			# of Ins	pections		# of Ins	pections		# of In	spections		# of I	Inspections		# of In	spections
No. routine inspections/yr					11			13			3			3			3
No. supplemental inspections/yr		ļ			7			5			2			2		<u> </u>	2
No. Addl LFUA inspections/yr					12			0		1	0			0			0
No. PIV/yr					1			1			1			1			1
Annual Sample Procedure Costs per	Option	Cost/	L .			L .	Sample		L .	Samp			Sam		L .	L .	
Regime		Sample	Sample		Costs/Year		Costs/Y		Sample	Costs		Sample	_	s/Year	Sample		e Costs/Year
DA Sample - procedures /yr		\$ 700	77	\$	53,900	106	\$	74,200	52	\$	36,400	13	\$	9,100	13	\$	9,100
ES Samples/yr		\$ 500	6	\$	3,000	6	\$	3,000	6	\$	3,000	6	\$	3,000	6	\$	3,000
TOTAL Sample Costs/yr				\$	56,900		\$	77,200		\$	39,400		\$	12,100		\$	12,100

Table~40: Labor~Cost~of~Safeguards~Options~at~6000~MtSWU/yr~GCEP~for~INFCIRC/540~Safeguards~with~NDA~PD=20%, DA~PD=20%,
	Assay											
EXAMPLE GCEP of 6000	Unit											
MTSWU/yr Capacity	Totals	TOTAL		Option A	Ol	ption B	C	Option C	(Option D		Option E
Nom. Feed cylinders/yr /assay unit	115	1380	4									
Nom. Product cylinders/year Nom. Tails cylinders/year	59 104	708 1252	1									
Cascade Halls	8	96	1									
Load cell monitors/assay unit	23	276	1									
Assay units	12		Trad/Int Sg	ds	MS	SP SPECS		NEUT DET		AEM ACC	NEUT DET +	AEM ACC
•												
Inspection Staffing per Inspection C	Cost			# of Inspectors		# of Inspectors		# of Inspectors		# of Inspectors		# of Inspectors
Inspectors / routine inspection					2	2		2		2		2
Inspectors / suppl inspection					1	1		1		1		1
Inspectors / LFUA inspection					2	0		0		0		(
Inspectors / PIV inspection					3	3		3		3		3
Inspection Time Cost				Length (Days)		Length (Days)		Length (Days)		Length (Days)		Length (Days)
Duration of routine inspection					3	3		3		3		3
Duration of suppl inspection					1	1		1		1		1
Duration of LFUA inspection					1	0		0		0		(
Duration of PIV inspection				1	0	10		10		7		7
Rest days during routine inspection					0	0		0		0		(
Rest days during suppl inspection					0	0		0		0		(
Rest days during LFUA inspection					0	0		0		0		(
Rest days during PIV inspection					2	2		2		2		2
Travel days/inspector/trip					2	2		2		2		2
Office Time Cost (Prep/Aanalysis)				Length (Days)		Length (Days)		Length (Days)		Length (Days)		Length (Days)
Office days/IIV inspection day				0	.4	0.6		0.8		1		1
Office days/suppl inspection day				0.2		0.25		0.25		0.25		0.25
Office days/LFUA inspection day				0.12		0.125		0.125		0.125		0.125
Office days/PIV inspection day				0.2		0.25		0.5		1		1
Labor Cost of Inspector - burdened	ı			Cost (USD)		Cost (USD)		Cost (USD)		Cost (USD)		Cost (USD)
Staff cost/day - trip PDI	·			\$2,00	00	\$2,000		\$2,000		\$2,000		\$2,000
Staff cost/day - trip Rest Day				\$1,00		\$1,000		\$1,000		\$1,000		\$1,000
Travel cost /trip				\$4,65		\$4,650		\$4,650		\$4,650		\$4,650
Staff cost/day - office				\$1,05		\$1,054		\$1,054		\$1,054		\$1,054
Inspector Labor Costs by Insp. Typ	۵		PDI	Cost (USD)	PDI	Cost (USD)	PDI	Cost (USD)	PDI	Cost (USD)	PDI	Cost (USD)
Staff costs for routine inspection			66	\$ 220,00			18		18		18	\$ 60,000
Staff costs for suppl inspection			7	\$ 28,00		/	2	,	2	\$ 8,000	2	\$ 8,000
Staff costs for LFUA inspection			24	\$ 96,00	_		0		0	\$ -	0	\$ -
Staff costs for PIV inspection			30	\$ 84,00			30		21		21	\$ 66,000
Total Inspector Labor Cost			127	\$ 428,00			50		41	\$ 134,000	41	\$ 134,000
Inspector Travel Costs by Insp. Typ	ne .			.20,00		V 001,000		,		,		+ 101,000
Travel costs for routine inspection	-			\$ 102,30	0	\$ 120,900		\$ 27,900		\$ 27,900		\$ 27,900
Travel costs for suppl inspection				\$ 32,55		\$ 23,250		\$ 9,300		\$ 9,300		\$ 9,300
Travel costs for LFUA inspection				\$ 111,60	_	\$ -		\$ -		\$ -		\$ -
Travel costs for PIV inspection		1	ļ	\$ 13,95		\$ 13,950		\$ 13,950		\$ 13,950		\$ 13,950
Total travel cost		1		\$ 260,40	0	\$ 158,100		\$ 51,150		\$ 51,150		\$ 51,150
Inspector Office Costs by Insp. Typ	е			\$ 27,82	6	\$ 49,327		\$ 15,178		\$ 18,972		\$ 18,972
Staff office costs for routine inspection Staff office costs for suppl inspection		+	 	\$ 27,82 \$ 1,84		\$ 49,327 \$ 1,318		\$ 15,178 \$ 527		\$ 18,972 \$ 527		\$ 18,972
Staff office costs for LFUA inspection				\$ 3,16		\$ -		\$ -		\$ -		\$ -
Staff office costs for PIV inspection				\$ 7,90		\$ 7,905		\$ 15,810		\$ 22,134		\$ 22,134
Total staff office costs				\$ 40,73		\$ 58,550		\$ 31,515		\$ 41,633		\$ 41,633
Total annual labor/staff/sampling of	osts			\$ 729,13	7	\$ 580,650		\$ 234,665		\$ 226,783		\$ 226,783
Total Annual costs				\$ 810,93	6	\$ 695,656		\$ 401,464		\$ 1,297,210		\$ 1,314,513

Table 41: Hardware Cost of Safeguards Options at 6000 MtSWU/yr GCEP for INFCIRC/540 Safeguards with NDA PD= 20%, DA PD=10%

	Assay																
	Unit																
MTSWU/yr Capacity	Totals	TOTAL		Option A		,	Option B			Option	C		Optio	n D		Optio	n E
Nom. Feed cylinders/yr /assay unit	115	1380		opuon z	•	,	puon B			Орион	•		Optio			Optio	
Nom. Product cylinders/year	58	700															
Nom. Tails cylinders/year	104	1252															
Cascade Halls	8	96															
Load cell monitors/assay unit	23	276															
Assay units	12	270	Trad/Int Sg	ds		М:	SSP SPEC	s		NEUT D	FT		AEM A	cc	NEUT DET	+ AFM	vcc
Item SG system capital costs per ar		Annual	Tradyint og				0. 0. 20						71		TALUT DE	1712117	
basis (10 year life span for equipme		Cost/ item	Items	Total ite	m Cost	Items	Total it	em Cost	Items	Total	item Cost	Items	Total	item Cost	Items	Total	item Cost
DA Sample Bottles		\$ 16	9	\$	140	20	\$	310	38	\$	589	12	\$	186	12	\$	186
Portable LCBWS		\$ 680	1	\$	680	1	\$	680	1	\$	680	1	\$	680	1	\$	680
Reference w eights		\$ -	1	\$	-	1	\$	-	1	\$		1	\$	-	1	\$	-
HPGe gamma spec (IMCG)		\$ 3,700	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Nal Detector		\$ 3,700	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Upgraded CHEM system		\$ 15,000	0	\$	-	0	\$	-	0	\$	-	0	\$	-	0	\$	
Load cell monitors		\$ 500	0	\$	-	0	\$	-	0	\$		276	\$	138,000	276	\$	138,000
PNUH		\$ 40,000	0	\$	-	0	\$		0	\$		0	\$	-	0	\$	-
AEM- Installed detection system		\$ 10,000	0	\$		0	\$	-	0	\$	-	36	\$	360,000	36	\$	360,000
AEM - Data collect cabinet		\$ 10,000	0	\$	-	0	\$		0	\$		12	\$	120,000	12	\$	120,000
Neutron Detection System		\$ 6,500	0	\$		0	\$	-	1	\$	6,500	0	\$	-	1	\$	6,500
Neut Det - Data collect cabinet		\$ 7,800	0	\$	-	0	\$	-	1	\$	7,800	0	\$	-	1	\$	7,800
Data acquisition system		\$ 10,000	0	\$	-	1	\$	10,000	2	\$	20,000	12	\$	120,000	12	\$	120,000
Digital surv camera - F/W		\$ 2,000	0	\$		0	\$	-	24	\$	48,000	24	\$	48,000	24	\$	48,000
Accountability scale monitor + camera		\$ 1,500	0	\$	-	0	\$		2	\$	3,000	2	\$	3,000	2	\$	3,000
ID tag interrogation antennas		\$ 20	0	\$		0	\$	-	0	\$	-	162	\$	3,240	162	\$	3,240
ID tag interrogation readers		\$ 200	0	\$	-	0	\$	-	0	\$		150	\$	30,000	150	\$	30,000
ID tags		\$ 10	0	\$	-	0	\$		0	\$		3332	\$	33,320	3332	\$	33,320
Seals (IAEA costs/seal)		\$ 33	100	\$	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300
Total equipment cost per annum bas	is			\$	18,920		\$	29,090		\$	104,669		\$	874,526		\$	888,826
Equip. spares&installation =% of ann		10%			\$1,892			\$2,909			\$10,467			\$87,453	3	<u> </u>	\$88,883
Total Annual Equipment Costs					\$20,811			\$31,999			\$115,136			\$961,979			\$977,709
		% of Equip.															
Annual equipment cost - repairs, trip	s,	Cost															
costsas factor of equip. cost		Factor			00.004.4			40.400.0			011 510 0		_	400 407 0		_	407 770
Est. Annual Equipment Upkeep Costs		10.0%		•	\$2,081.1		•	\$3,199.9			\$11,513.6			\$96,197.9		_	\$97,770.9
Total Annual Equipment Costs				\$	22,893		\$	35,199		\$	126,649		\$	1,058,176		\$	1,075,479
Inspections Needed per Option Regir				# of Insp	nations		# of Inc	pections		# of I	spections		# of I	nspections		# 05 1	nspections
No. routine inspections/yr	iie			# OI IIIS	8		# OI IIIS	8		# 01 11	3		# 011	З		# 01 1	rispections
No. supplemental inspections/yr					7		1	5		+	2			2		_	2
No. Addl LFUA inspections/yr					12		+	0		+	0	1	+	0		+	
No. PIV/vr		<u> </u>			12		+	1		1	1	1	1	1	1	+	1
Annual Sample Procedure Costs per	Option	Cost/					Sample	<u> </u>		Samp	le I	 	Samp	ole	1	+	
Regime	-		Sample	Sample	Costs/Year	Sample	Costs/		Sample		/Year	Sample		s/Year	Sample	Samr	le Costs/Year
DA Sample - procedures /yr		\$ 700	6	\$	4,200	13	\$	9,100	25	\$	17,500	8	\$	5,600	8	\$	5,600
ES Samples/yr		\$ 500	6	\$	3,000	6	\$	3,000	6	\$	3,000	6	\$	3.000	6	\$	3,000
TOTAL Sample Costs/yr				\$	7,200		\$	12,100		\$	20,500		\$	8.600		\$	8,600

Table 42: Labor Cost of Safeguards Options at 6000 MtSWU/yr GCEP for INFCIRC/540 Safeguards with NDA PD= 20%, DA PD=10%

EXAMPLE GCEP of 6000 MTSWU/yr Capacity	Assay Unit Totals	TOTAL		Ontina A		0	otion E			\:-	6		D-4:	on D		Option	-
	115	1380	'	Option A		Op	otion E	5	U	ptic	on C	,	Jptic	טח ט		Option	E
Nom. Feed cylinders/yr /assay unit	59	708	1														
Nom. Product cylinders/year Nom. Tails cylinders/year	104	1252	1														
Cascade Halls	8	96	1														
Load cell monitors/assay unit	23	276	1														
Assay units	12		Trad/Int Sg	ds		MSS	SP SPEC	cs	N	IEUT	DET		AEM .	ACC	NEUT DET +	AEM AC	:c
•																	
Inspection Staffing per Inspection C	ost			# of Inspector	rs		# of In	nspectors		# of	f Inspectors		# of	Inspectors		# of Ins	pectors
Inspectors / routine inspection				-	2			2			2			2			2
Inspectors / suppl inspection					1			1			1			1			1
					2			0			0			0			
Inspectors / LFUA inspection					3			3			0			3			0
Inspectors / PIV inspection					J						3		. 				<i>5</i>
Inspection Time Cost				Length (Days))		Lengt	th (Days)		Len	ngth (Days)		Len	gth (Days)		Length	(Days)
Duration of routine inspection			<u> </u>		3		<u> </u>	3			3		—	3		<u> </u>	3
Duration of suppl inspection		1	 		1		 	1			1		-	1		<u> </u>	1
Duration of LFUA inspection		<u> </u>	<u> </u>		1		<u> </u>	0		<u> </u>	0		-	0		<u> </u>	0
Duration of PIV inspection			ļ		10			10			10		<u> </u>	7			7
Rest days during routine inspection					0			0			0			0			0
Rest days during suppl inspection					0			0			0			0			0
Rest days during LFUA inspection					0			0			0			0			0
Rest days during PIV inspection					2			2			2			2			2
Travel days/inspector/trip					2			2			2			2			2
Office Time Cost (Prep/Aanalysis)				Length (Days))		Lengt	th (Days)		Len	ngth (Days)		Len	gth (Days)		Length	(Days)
Office days/IIV inspection day					0.4			0.6			0.8			1			1
Office days/suppl inspection day					0.25			0.25			0.25			0.25			0.25
Office days/LFUA inspection day					0.125			0.125			0.125			0.125			0.125
Office days/PIV inspection day					0.25			0.25			0.5			1			1
Labor Cost of Inspector - burdened				Cost (USD)			Cost ((USD)		Cos	st (USD)		Cos	t (USD)		Cost (U	JSD)
Staff cost/day - trip PDI					2,000		,	\$2,000			\$2,000			\$2,000		,	\$2,000
Staff cost/day - trip Rest Day					1,000			\$1,000			\$1,000			\$1,000			\$1,000
Travel cost /trip					4,650			\$4,650			\$4,650			\$4,650			\$4,650
Staff cost/day - office					1,054			\$1,054			\$1,054			\$1,054			\$1,054
Inspector Labor Costs by Insp. Type			PDI	Cost (USD)	.,	PDI	Cost (PDI	Cos	st (USD)	PDI	Cos	t (USD)	PDI	Cost (U	
Staff costs for routine inspection			48		0,000	48	_	160,000	18		60,000	18		60,000	18		60,000
Staff costs for suppl inspection			7		3,000	5	_	20,000	2	_	8,000	2	,	8,000	2		8,000
Staff costs for LFUA inspection			24		5,000	0	_	20,000	0		0,000	0	_	0,000	0		0,000
			30			30	\$	84,000	30		84,000	21	\$	66,000	21		66,000
Staff costs for PIV inspection			109		1,000	83	\$			\$			\$		41	\$	
Total Inspector Labor Cost Inspector Travel Costs by Insp. Type			109	\$ 300	3,000	63	Þ	264,000	50	Þ	152,000	41	ð	134,000	41	Þ	134,000
Travel costs for routine inspection	-			\$ 74	1,400		\$	74,400		\$	27,900		\$	27,900		\$	27,900
Travel costs for suppl inspection					2,550		\$	23,250		\$	9,300		\$	9,300		\$	9,300
Travel costs for LFUA inspection					1,600		\$	-		\$	-		\$	-		\$	-
Travel costs for PIV inspection				\$ 13	3,950		\$	13,950		\$	13,950		\$	13,950		\$	13,950
Total travel cost				\$ 232	2,500		\$	111,600		\$	51,150		\$	51,150		\$	51,150
Inspector Office Costs by Insp. Type	•																
Staff office costs for routine inspection			<u> </u>),237		\$	30,355		\$	15,178		\$	18,972		\$	18,972
Staff office costs for suppl inspection		1	 		1,845		\$	1,318		\$	527		\$	527		\$	527
Staff office costs for LFUA inspection Staff office costs for PIV inspection		1	1		3,162 7,905		\$	7,905		\$	15.810		\$	22,134		\$	22.134
Total staff office costs					3,148		\$	39,578		\$	31,515		\$	41,633		\$	41,633
Total annual labor/staff/sampling co	osts				3,648		\$	415,178		\$	234,665		\$	226,783		\$	226,783
					,			,									,_
Total Annual costs				\$ 663	3,741		\$	462,477		\$	381,814		\$	1,293,559		\$	1,310,862
Total Annual costs in 1M\$ reflecting	ig accuracy		\$M	0.7		\$М	0.5		\$M	0.4		\$M	1.3		\$М	1.3	

Appendix E:

Costs of Safeguards at a 9000 MtSWU/yr GCEP

Table 43-Table 50 display the itemized cost analysis for safeguards at a GCEP of capacity 9000 MtSWU/yr compared with current methods based on the HSP for normal and reduced $P_{\rm D}$ under both INFCIRC/153 and INFCIRC/540 safeguards regimes.

Table 43: Hardware Cost of Safeguards Options at 9000 MtSWU/yr GCEP for INFCIRC/153 Safeguards with NDA PD=50%, DA PD=50%

EVAMBLE COED - COOO	Assay																
EXAMPLE GCEP of 9000	Unit	TOTAL		O			O			Q., 17.	0		0				_
MTSWU/yr Capacity	Totals	TOTAL		Option .	А		Optio	nв		Optio	on C		Optio	ח ח		Option	E
Nom. Feed cylinders/yr /assay unit	115	2070															Ų
Nom. Product cylinders/year	58	1050															Ų
Nom. Tails cylinders/year	104	1878															
Cascade Halls	8	144															
Load cell monitors/assay unit	23	414															
Assay units Item SG system capital costs per an	18		Trad/Int Sg	ds		N	ASSP S	PECS		NEUT	DET		AEM A	cc	NEUT DET + /	AEM AC	<u> </u>
(10 year life span for equipment)	ilulii basis	Annual Cost/ item	Items	Total ite	m Coot	Items	Total	item Cost	Items	Tota	l item Cost	Items	Total it	em Cost	Items	Total	litem Cost
DA Sample Bottles		\$ 16	534	\$	8.277	740	\$	11.470	363	\$	5.627	87	\$	1.349	87	\$	1.349
Portable LCBWS		\$ 680	1	\$	680	1	\$	680	1	\$	680	1	\$	680	1	\$	680
Reference w eights		\$ -	1	\$		1	\$		1	\$		1	\$		1	\$	
HPGe gamma spec (IMCG)		\$ 3,700	2	S	7.400	2	\$	7.400	2	\$	7.400	2	\$	7.400	2	\$	7.400
Nal Detector		\$ 3,700	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Upgraded CHEM system		\$ 15,000	0	\$	7,400	0	\$	7,400	0	\$	7,400	0	\$	7,400	0	\$	7,400
Load cell monitors		\$ 500	0	\$		0	\$	_	0	\$		414	\$	207.000	414	\$	207.000
PNUH		\$ 40,000	0	\$		0	\$		0	\$		0	\$	207,000	0	\$	201,000
AEM- Installed detection system		\$ 10,000	0	\$		0	\$		0	\$		54	\$	540,000	54	\$	540,000
AEM - Data collect cabinet		\$ 10,000	0	\$		0	\$	_	0	\$		18	\$	180,000	18	\$	180,000
Neutron Detection System		\$ 6,500	0	\$		0	\$		1	\$	6,500	0	\$	100,000	1	\$	6,500
Neut Det - Data collect cabinet		\$ 7,800	0	\$		0	\$		1	\$	7,800	0	\$		1	\$	7,800
Data acquisition system		\$ 10,000	0	\$		1	\$	10,000	2	\$	20,000	18	\$	180,000	18	\$	180,000
Digital surv camera - F/W		\$ 2,000	0	\$		0	\$	10,000	24	\$	48,000	24	\$	48,000	24	\$	48,000
Accountability scale monitor + camera		\$ 1,500	0	\$		0	\$	-	2	\$	3,000	2	\$	3,000	2	\$	3,000
ID tag interrogation antennas		\$ 20	0	\$		0	\$	-	0	\$		162	\$	3,240	162	\$	3,240
ID tag interrogation readers		\$ 200	0	\$		0	\$	-	0	\$		150	\$	30,000	150	\$	30,000
ID tags		\$ 10	0	\$	_	0	\$	-	0	\$		4998	\$	49,980	4998	\$	49,980
Seals (IAEA costs/seal)		\$ 33	100	\$	3.300	100	\$	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300
Total equipment cost per annum basis	•	Ψ 00	100	s	27.057		\$	40.250	100	\$	109,707		\$	1.261.349		\$	1.275.649
Equip. spares&installation =% of annu		10%		*	\$2,706		1	\$4,025		Ť	\$10,971		*	\$126,135			\$127,565
Total Annual Equipment Costs					\$29,763			\$44,275			\$120,677			\$1,387,483			\$1,403,213
Total / Illian Equipment Code					\$20,100			Ų::, <u>,</u> 2:0			\$120,011			\$1,001,100			V 1,100,210
		% of Equip.															
Annual equipment cost - repairs, trips	s, costsas																
factor of equip. cost		Factor															
Est. Annual Equipment Upkeep Costs		10.0%			\$2,976.3			\$4,427.5			\$12,067.7			\$138,748.3			\$140,321.3
Total Annual Equipment Costs				\$	32,739		\$	48,703		\$	132,745		\$	1,526,232		\$	1,543,535
Inspections Needed per Option Regim	ie			# of Ins	pections		# of I	nspections		# of	Inspections		# of In:	spections		# of	Inspections
No. routine inspections/yr					15			11			5			3			3
No. supplemental inspections/yr				 	7		 	2		+	3			3			3
No. Addl LFUA inspections/yr				_	8		1	0			0			0		-	0
No. PIV/yr	0	0		 	1		 	1		+	1			1		0	1
Annual Sample Procedure Costs per (Regime	Option	Cost/ Sample	Sample	Sample	Costs/Year	Sample	Same	ole Costs/Year	Sample	Sam	ple Costs/Year	Sam nio	Samel	e Costs/Year	Sam ple	Sam	ple s/Year
DA Sample - procedures /yr		\$ 700	356	\$	249,200	493	\$	345,100	242	\$	169,400	58	\$	40,600	58	\$	40,600
ES Samples/yr		\$ 500	6	\$	3,000	6	\$	3,000	6	\$	3,000	6	\$	3,000	6	\$	3,000
TOTAL Sample Costs/yr		ψ 500		S	252.200	-	\$	348.100	U	\$	172.400	U	\$	43.600	, , ,	\$	43.600
TO THE Gample Gustayi		<u> </u>	<u> </u>	ş	252,200	l	Þ	340,100		Þ	172,400		Þ	43,000		Þ	43,000

Table 44: Labor Cost of Safeguards Options at 9000 MtSWU/yr GCEP for INFCIRC/153 Safeguards with NDA PD=50%, DA PD=50%

EXAMPLE GCEP of 9000	Assay Unit															
MTSWU/yr Capacity	Totals	TOTAL		Option A			Option B		Option C			Option D		0	otion E	
Nom. Feed cylinders/yr /assay unit	115	2070														
Nom. Product cylinders/year	59	1062	1													
Nom. Tails cylinders/year	104	1878														
Cascade Halls	8	144														
Load cell monitors/assay unit	23	414														
Assay units	18		Trad/Int Sg	ds		М	SSP SPECS		NEUT DET			AEM ACC		NEUT DET + AE	M ACC	
Inspection Staffing per Inspection Cos	t			# of Inspecto	ors		# of Inspectors		# of Inspe	ctors		# of Inspec	tors		# of Ins	pectors
Inspectors / routine inspection					2			2		2			2			2
Inspectors / suppl inspection					1			1		1			1			1
Inspectors / LFUA inspection					2			0		0			0			0
Inspectors / PIV inspection					3			3		3			3			3
Inspection Time Cost				Length (Days	-)		Length (Days)		Length (Da	ave)		Length (Da			Longth	(Days)
				Length (Days	3			1	Length (D	1y5 <i>)</i>		Lengin (Da	ys)		Lengui	(Days)
Duration of routine inspection					1			1		3			3 1			3
Duration of suppl inspection Duration of LFUA inspection		 	†		- 1			0		1			0			
		1	}		10				1	- 0	1	 	7			
Duration of PIV inspection		1	 		10		1		 	10						
Rest days during routine inspection					0			0		0			0			0
Rest days during suppl inspection					0			0		0			0			0
Rest days during LFUA inspection					0			0		0			0			0
Rest days during PIV inspection					2			2		2			2	!		2
Travel days/inspector/trip					2			2		2			2			2
Office Time Cost (Prep/Aanalysis)				Length (Days	s)		Length (Days)		Length (Da	ays)		Length (Da	ys)		Length	(Days)
Office days/IIV inspection day					0.4		0.	6		0.8			1			1
Office days/suppl inspection day					0.25		0.2	5		0.25			0.25			0.25
Office days/LFUA inspection day					0.125		0.12	5		0.125			0.125			0.125
Office days/PIV inspection day					0.25		0.2	5		0.5			1			1
Labor Cost of Inspector - burdened				Cost (USD)			Cost (USD)		Cost (USD)		Cost (USD)			Cost (U	(SD)
Staff cost/day - trip PDI					\$2,000		\$2,00	0		\$2,000		, ,	\$2,000		,	\$2,000
Staff cost/day - trip Rest Day					\$1,000		\$1,00			\$1,000			\$1,000			\$1,000
Travel cost /trip					\$4,650		\$4,65			\$4,650			\$4,650			\$4,650
Staff cost/day - office					\$1,054		\$1,05			\$1,054			\$1,054			\$1,054
Inspector Labor Costs by Insp. Type			PDI	Cost (USD)	. ,	PDI	Cost (USD)	PDI	Cost (USD		PDI	Cost (USD)		PDI	Cost (U	
Staff costs for routine inspection			90		00,000	66		-	\$	100,000		\$	60,000	18	_	60,000
Staff costs for suppl inspection					28,000		\$ 8,000		\$	12,000		\$	12,000	3	\$	12,000
Staff costs for LFUA inspection			16		64,000		\$		\$	12,000		\$	12,000	0	\$	12,000
Staff costs for PIV inspection		1	30		84,000	30	,		_	84,000		\$	66,000	21	\$	66,000
Total Inspector Labor Cost			143		76,000	98	\$ 312,000		s	196,000	42		138,000	42	\$	138,000
Inspector Travel Costs by Insp. Type			143	3 41	76,000	90	\$ 312,000	03	ð	190,000	42	ð	130,000	42	Þ	130,000
Travel costs for routine inspection		1		\$ 13	39,500		\$ 102,300	1	S	46,500		\$	27,900		\$	27,900
Travel costs for suppl inspection					32,550		\$ 9,300		\$	13,950		\$	13,950		\$	13,950
Travel costs for LFUA inspection					74,400		\$		\$	-		\$	-		\$	-
Travel costs for PIV inspection				\$	13,950		\$ 13,950		\$	13,950		\$	13,950		\$	13,950
Total travel cost				\$ 26	60,400		\$ 125,550		\$	74,400		\$	55,800		\$	55,800
Inspector Office Costs by Insp. Type																
Staff office costs for routine inspection				_	37,944		\$ 41,738	i	\$	25,296		\$	18,972		\$	18,972
Staff office costs for suppl inspection		<u> </u>	<u> </u>	\$	1,845		\$ 527	 	\$	791		\$	791	ļ	\$	791
Staff office costs for LFUA inspection		1	 	\$	2,108		\$ 7.905	-	\$	15 040	-	\$	20 40 4	-	\$	20.404
Staff office costs for PIV inspection Total staff office costs		<u> </u>		\$	7,905 49,802		\$ 7,905 \$ 50,17 0		\$	15,810 41,897		\$	22,134 41,897		\$	22,134 41,897
Total annual labor/staff/sampling cost	's	1			86,202		\$ 487,720		\$	312,297		\$	235,697		\$	235,697
good					,					,,,						
Total Annual costs				\$ 1,07	71,140		\$ 884,523		\$	617,441		\$	1,805,528		\$	1,822,831
Total Annual costs in 1M\$ reflecting	accuracy		\$M	1.1		\$M	0.9	\$N	0.6		\$M	1.8		\$M	1.8	

Table 45: Hardware Cost of Safeguards Options at 9000 MtSWU/yr GCEP for INFCIRC/153 Safeguards with NDA PD= 50%, DA PD=10%

	Assay																
EXAMPLE GCEP of 9000	Unit																
MTSWU/yr Capacity	Totals	TOTAL		Option A			Option	В		Option	n C		Option	n D	1 .	Option	E
Nom. Feed cylinders/yr /assay unit	115	2070		-			-	_									_
Nom. Product cylinders/year	58	1050	1														
Nom. Tails cylinders/year	104	1878	1														
Cascade Halls	8	144	1														
Load cell monitors/assay unit	23	414	i														
Assay units	18	414	Trad/Int Sg	do			ISSP SPE	EC 6		NEUT D	NET.		AEM A		NEUT DET + A		^
Item SG system capital costs per ann		Annual	irau/iii og	us			1331 311	LC3		INLOT E	<i>_</i>		ALWIA	00	NEOT DET 47	ALWI AC	<u> </u>
(10 year life span for equipment)		Cost/ item	Items	Total iten	n Cost	Items	Total ite	em Cost	Items	Total	item Cost	Items	Total it	em Cost	Items	Tota	item Cost
DA Sample Bottles		\$ 16	534	\$	8.277	116	\$	1.798	57	\$	884	17	\$	264	17	\$	264
Portable LCBWS		\$ 680	1	\$	680	1	\$	680	1	\$	680	1	\$	680	1	\$	680
Reference w eights		S -	1	\$		1	\$	-	1	\$	-	1	\$	-	1	\$	-
HPGe gamma spec (IMCG)		\$ 3,700	2	\$	7.400	2	\$	7,400	2	\$	7.400	2	\$	7.400	2	\$	7.400
Nal Detector		\$ 3,700	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Upgraded CHEM system		\$ 15,000	0	\$		0	\$		0	\$	- 1,1.00	0	\$		0	\$	-
Load cell monitors		\$ 500	0	\$		0	\$	-	0	\$	-	414	\$	207.000	414	\$	207,000
PNUH		\$ 40,000	0	\$	-	0	\$	_	0	\$	-	0	\$		0	\$	-
AEM- Installed detection system		\$ 10,000	0	\$	-	0	\$	_	0	\$	-	54	\$	540,000	54	\$	540,000
AEM - Data collect cabinet		\$ 10,000	0	\$	-	0	\$	_	0	\$	-	18	\$	180,000	18	\$	180,000
Neutron Detection System		\$ 6,500	0	\$	-	0	\$	_	1	\$	6,500	0	\$	-	1	\$	6,500
Neut Det - Data collect cabinet		\$ 7,800	0	\$		0	\$	_	1	\$	7,800	0	\$	-	1	\$	7,800
Data acquisition system		\$ 10,000	0	\$	-	1	\$	10,000	2	\$	20,000	18	\$	180,000	18	\$	180,000
Digital surv camera - F/W		\$ 2,000	0	\$		0	\$	-	24	\$	48,000	24	\$	48,000	24	\$	48,000
Accountability scale monitor + camera		\$ 1,500	0	\$	-	0	\$	_	2	\$	3,000	2	\$	3,000	2	\$	3,000
ID tag interrogation antennas		\$ 20	0	\$		0	\$	-	0	\$	-	162	\$	3,240	162	\$	3,240
ID tag interrogation readers		\$ 200	0	\$	-	0	\$	_	0	\$	-	150	\$	30,000	150	\$	30,000
ID tags		\$ 10	0	\$		0	\$	-	0	\$	-	4998	\$	49,980	4998	\$	49,980
Seals (IAEA costs/seal)		\$ 33	100	\$	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300
Total equipment cost per annum basis		,		\$	27,057		\$	30,578		\$	104,964		\$	1,260,264		\$	1,274,564
Equip. spares&installation =% of annua	al cost	10%			\$2,706			\$3,058			\$10,496			\$126,026	i		\$127,456
Total Annual Equipment Costs					\$29,763			\$33,636			\$115,460			\$1,386,290			\$1,402,020
, , , , , , , , , , , , , , , , , , ,					, ,, ,,									, , , , , , , , , , , , , , , , , , , ,			, , , , , ,
		% of Equip.															
Annual equipment cost - repairs, trips,	, costsas	Cost															
factor of equip. cost		Factor															
Est. Annual Equipment Upkeep Costs		10.0%			\$2,976.3			\$3,363.6			\$11,546.0			\$138,629.0)		\$140,202.0
Total Annual Equipment Costs				\$	32,739		\$	36,999		\$	127,006		\$	1,524,919		\$	1,542,222
Inspections Needed per Option Regime	9			# of Insp			# of Ins	spections		# of Ir	nspections		# of Ins	pections		# of	nspections
No. routine inspections/yr					15			11		-	5		 	3		+	3
No. supplemental inspections/yr					7		<u> </u>	0		1	3	1	+	3	1	-	3
No. Addl LFUA inspections/yr				 	8		1	0		+	0	1	╂	0	1	+	C
No. PIV/yr Annual Sample Procedure Costs per O	ntion	Cost/		1	1		l	1		+	1	1	+	1	1	Sam	1 No.
Regime	ption		Sam ple	Sample C	Costs/Year	Sample	Sample	Costs/Year	Sam ple	Samn	le Costs/Year	Sample	Sample	Costs/Year	Sam ple		s/Year
DA Sample - procedures /yr		\$ 700	356	\$	249,200	77	\$	53,900	38	\$	26,600	11	\$	7,700	11	\$	7,700
ES Samples/yr		\$ 500	6	\$	3,000	6	\$	3,000	6	\$	3,000	6	\$	3,000	6	\$	3,000
TOTAL Sample Costs/yr		ψ 000		\$	252,200		\$	56,900		\$	29,600		\$	10,700	Ŭ	\$	10,700

Table 46: Labor Cost of Safeguards Options at 9000 MtSWU/yr GCEP for INFCIRC/153 Safeguards with NDA PD=50%, DA PD=10%

	Assay														
EXAMPLE GCEP of 9000	Unit														
MTSWU/yr Capacity	Totals	TOTAL		Optio	on A	(Option B		Option	С		Option D	О	ption E	
Nom. Feed cylinders/yr /assay unit	115	2070													
Nom. Product cylinders/year	59	1062													
Nom. Tails cylinders/year	104	1878													
Cascade Halls	8	144													
Load cell monitors/assay unit	23	414								_					
Assay units	6		Trad/Int Sg	ds		M	SSP SPECS		NEUT DE	Т		AEM ACC	NEUT DET + AE	MACC	
Inspection Staffing per Inspection Cos	t			# of I	nspectors		# of Inspectors		# of Ins	pectors		# of Inspectors		# of Inspec	ctors
Inspectors / routine inspection					2		2			2		2			2
Inspectors / suppl inspection					1		1			1		1			1
Inspectors / LFUA inspection					2		0			0		0			
Inspectors / PIV inspection					3		3			3		3	t		3
Inspection Time Cost				Long	th (Days)		Length (Days)		Length			Length (Days)		Length (Da	ave)
				Leng	3 (Days)		3		Length	(Days) 3		Length (Days)		Length (Da	ys) 2
Duration of routine inspection Duration of suppl inspection					3		3			J		3	1		
Duration of LFUA inspection					1		0			0		0			
·					10		10			10		7			
Duration of PIV inspection										0					
Rest days during routine inspection		-	-		0		0					0			0
Rest days during suppl inspection					0		0			0		0			0
Rest days during LFUA inspection					0		0			0		0	4		0
Rest days during PIV inspection					2		2			2		2			2
Travel days/inspector/trip					2		2			2		2			2
Office Time Cost (Prep/Aanalysis)				Leng	th (Days)		Length (Days)		Length			Length (Days)		Length (Da	ıys)
Office days/IIV inspection day					0.4		0.6			8.0		1			1
Office days/suppl inspection day					0.25		0.25			0.25		0.25			0.25
Office days/LFUA inspection day					0.125		0.125			0.125		0.125			0.125
Office days/PIV inspection day					0.25		0.25			0.5		1			1
Labor Cost of Inspector - burdened				Cost	(USD)		Cost (USD)		Cost (U	ISD)		Cost (USD)		Cost (USD))
Staff cost/day - trip PDI					\$2,000		\$2,000			\$2,000		\$2,000			\$2,000
Staff cost/day - trip Rest Day					\$1,000		\$1,000			\$1,000		\$1,000			\$1,000
Travel cost /trip					\$4,650		\$4,650			\$4,650		\$4,650			\$4,650
Staff cost/day - office					\$1,054		\$1,054			\$1,054		\$1,054			\$1,054
Inspector Labor Costs by Insp. Type			PDI	Cost	(USD)	PDI	Cost (USD)	PDI	Cost (U	ISD)	PDI	Cost (USD)	PDI	Cost (USD))
Staff costs for routine inspection			90	\$	300,000	66	\$ 220,000	30	\$	100,000	18	\$ 60,000	18	\$	60,000
Staff costs for suppl inspection			7	\$	28,000	2	\$ 8,000	3	\$	12,000	3	\$ 12,000	3	\$	12,000
Staff costs for LFUA inspection			16	\$	64,000	0	\$ -	0	\$		0	\$ -	0	\$	-
Staff costs for PIV inspection			30	\$	84,000	30	\$ 84,000	30	\$	84,000	21		21	\$	66,000
Total Inspector Labor Cost			143	\$	476,000	98	\$ 312,000	63	\$	196,000	42	\$ 138,000	42	\$ 1	38,000
Inspector Travel Costs by Insp. Type					,		,					•			
Travel costs for routine inspection				\$	139,500		\$ 102,300		\$	46,500		\$ 27,900		\$	27,900
Travel costs for suppl inspection				\$	32,550		\$ 9,300		\$	13,950		\$ 13,950			13,950
Travel costs for LFUA inspection				\$	74,400		\$ -		\$	-		\$ -		\$	
Travel costs for PIV inspection				\$	13,950		\$ 13,950		\$	13,950		\$ 13,950			13,950
Total travel cost				\$	260,400		\$ 125,550		\$	74,400		\$ 55,800		\$	55,800
Inspector Office Costs by Insp. Type Staff office costs for routine inspection				\$	37,944		\$ 41,738		\$	25,296		\$ 18,972		\$	18,972
Staff office costs for suppl inspection				\$	1,845		\$ 527		\$	791		\$ 791		\$	791
Staff office costs for LFUA inspection				\$	2,108		\$ -		\$			\$ -		\$	
Staff office costs for PIV inspection				\$	7,905		\$ 7,905		\$	15,810		\$ 22,134			22,134
Total staff office costs				\$	49,802		\$ 50,170		\$	41,897		\$ 41,897			41,897
Total annual labor/staff/sampling cost	s			\$	786,202		\$ 487,720		\$	312,297		\$ 235,697		\$ 2	235,697
Total Assessed a code				•	4.0=4.44				•	100 000					100.015
Total Annual costs				\$	1,071,140		\$ 581,620		\$	468,902		\$ 1,771,315		\$ 1,7	88,618
Total Annual costs in 1M\$ reflecting	accuracy		\$M	1.1		\$M	0.6	\$M	0.5		\$M	1.8	\$M	1.8	

Table 47: Hardware Cost of Safeguards Options at 9000 MtSWU/yr GCEP for INFCIRC/540 Safeguards with NDA PD= 20%, DA PD=20%

	Assay															
EXAMPLE GCEP of 9000	Unit															
MTSWU/yr Capacity	Totals	TOTAL		Option A		Option B			Option			Option			Option	_
	115	2070		Option A		Орион в			Option	10		Optioi	10		Option	_
Nom. Feed cylinders/yr /assay unit	115 58		-													
Nom. Product cylinders/year		1050	-													
Nom. Tails cylinders/year	104	1878	4													
Cascade Halls	8	144														
Load cell monitors/assay unit	23	414														
Assay units	18		Trad/Int Sg	ıds	- 1	MSSP SPECS			NEUT D	ET		AEM A	CC	NEUT DET + /	AEM AC	3
Item SG system capital costs per an	num basis	Annual		L						_			_	_	L .	
(10 year life span for equipment)		Cost/ item	Items	Total item Cost	Items	Total item Cost		Items		tem Cost	Items		m Cost	Items	_	item Cost
DA Sample Bottles		\$ 16	173	\$ 2,682		\$ 3,7		119	\$	1,845	30	\$	465	30	\$	465
Portable LCBWS		\$ 680	1	\$ 680	-		80	11	\$	680	1	\$	680	1	\$	680
Reference w eights		\$ -	1	\$	1	\$	-	1	\$	-	1	\$		1	\$	-
HPGe gamma spec (IMCG)		\$ 3,700	2	\$ 7,400		\$ 7,4		2	\$	7,400	2	\$	7,400	2	\$	7,400
Nal Detector		\$ 3,700	2	\$ 7,400	-	\$ 7,4	00	2	\$	7,400	2	\$	7,400	2	\$	7,400
Upgraded CHEM system		\$ 15,000	0	\$	0	\$	-	0	\$	-	0	\$	-	0	\$	-
Load cell monitors		\$ 500	0	\$	0	\$	-	0	\$	-	414	\$	207,000	414	\$	207,000
PNUH		\$ 40,000	0	\$	0	\$	-	0	\$	-	0	\$	-	0	\$	-
AEM- Installed detection system		\$ 10,000	0	\$	0	\$	-	0	\$	-	54	\$	540,000	54	\$	540,000
AEM - Data collect cabinet		\$ 10,000	0	\$	0	\$	-	0	\$	-	18	\$	180,000	18	\$	180,000
Neutron Detection System		\$ 6,500	0	\$	0	\$	-	1	\$	6,500	0	\$	-	1	\$	6,500
Neut Det - Data collect cabinet		\$ 7,800	0	\$	0	\$	-	1	\$	7,800	0	\$	-	1	\$	7,800
Data acquisition system		\$ 10,000	0	\$	1	\$ 10,0	00	2	\$	20,000	18	\$	180,000	18	\$	180,000
Digital surv camera - F/W		\$ 2,000	0	\$	0	\$	-	24	\$	48,000	24	\$	48,000	24	\$	48,000
Accountability scale monitor + camera		\$ 1,500	0	\$	0	\$	-	2	\$	3,000	2	\$	3,000	2	\$	3,000
ID tag interrogation antennas		\$ 20	0	\$	0	\$	-	0	\$	-	162	\$	3,240	162	\$	3,240
ID tag interrogation readers		\$ 200	0	\$	0	\$	-	0	\$	-	150	\$	30,000	150	\$	30,000
ID tags		\$ 10	0	\$	0	\$	-	0	\$	-	4998	\$	49,980	4998	\$	49,980
Seals (IAEA costs/seal)		\$ 33	100	\$ 3,300	100	\$ 3,3	00	100	\$	3,300	100	\$	3,300	100	\$	3,300
Total equipment cost per annum basis	5			\$ 21,462		\$ 32,4	85		\$	105,925		\$	1,260,465		\$	1,274,765
Equip. spares&installation =% of annu		10%		\$2,14	-	\$3,				\$10,592			\$126,047	·		\$127,477
Total Annual Equipment Costs				\$23,60		\$35,	_			\$116,517			\$1,386,512			\$1,402,242
						700,	-			* · · · · · · · · · · · · · · · · · · ·			+ 1,000,01			+ -,,
		% of Equip.														
Annual equipment cost - repairs, trips	s, costsas															
factor of equip. cost		Factor														
Est. Annual Equipment Upkeep Costs		10.0%	5	\$2,360.		\$3,57				\$11,651.7			\$138,651.2			\$140,224.2
Total Annual Equipment Costs				\$ 25,968		\$ 39,3	06		\$	128,169		\$	1,525,163		\$	1,542,466
Inspections Needed per Option Regim	e			# of Inspections		# of Inspections			# of In	spections		# of Ins	pections		# of I	nspections
No. routine inspections/yr				1	5		11			5			3			3
No. supplemental inspections/yr					7	1	2			3			3			3
No. Addl LFUA inspections/yr					3		0			0			C			0
No. PIV/yr	-				1		1			1			1			1
Annual Sample Procedure Costs per	Option	Cost/					Ţ								Samp	
Regime		Sample	Sam ple	Sample Costs/Year		Sample Costs/Ye	_	Sample	_	le Costs/Year			Costs/Year	Sample	_	s/Year
DA Sample - procedures /yr		\$ 700	115	\$ 80,500		\$ 111,3		79	\$	55,300	20	\$	14,000	20	\$	14,000
ES Samples/yr		\$ 500	6	\$ 3,000	6	\$ 3,0	_	6	\$	3,000	6	\$	3,000	6	\$	3,000
TOTAL Sample Costs/yr		l		\$ 83,500		\$ 114,3	00		\$	58,300		\$	17,000		\$	17,000

Table 48: Labor Cost of Safeguards Options at 9000 MtSWU/yr GCEP for INFCIRC/540 Safeguards with NDA PD= 20%, DA PD=20%

	Assay																
EXAMPLE GCEP of 9000	Unit																
MTSWU/yr Capacity	Totals	TOTAL		Option .	Α		Option E	3		Opti	ion C		Optio	n D	O	otion E	
Nom. Feed cylinders/yr /assay unit	115	2070															
Nom. Product cylinders/year	59	1062	1														ļ
Nom. Tails cylinders/year	104	1878															ļ
Cascade Halls	8	144															ļ
Load cell monitors/assay unit	23	414	l														ļ
Assay units	18		Trad/Int Sgo	ds		M	SSP SPEC	s		NEUT	T DET		AEM A	ACC	NEUT DET + AE	M ACC	
In an add a Chaffin and a large add a Con-				# of Inc.	nootoro		# of Inco	ootore.		# 05	f Inconcetors		# of In	cneeters		# of Inc	nootoro
Inspection Staffing per Inspection Cos Inspectors / routine inspection	st			# of Ins	pectors 2		# of Insp	2		# OI	f Inspectors		# Of In	spectors 2		# Of Ins	spectors
					- 4					1							
Inspectors / suppl inspection					- 1			1		 	0			0			
Inspectors / LFUA inspection		-			2			0		<u> </u>	0						
Inspectors / PIV inspection					3			3		<u> </u>	3			3			3
Inspection Time Cost				Length			Length (Len	ngth (Days)		Lengt	h (Days)		Length	(Days)
Duration of routine inspection					3			3			3			3			3
Duration of suppl inspection					1			1		<u> </u>	1			1			1
Duration of LFUA inspection					1			0			0			0			0
Duration of PIV inspection					10			10		<u> </u>	10			7			7
Rest days during routine inspection					0			0			0			0			0
Rest days during suppl inspection					0			0			0			0			0
Rest days during LFUA inspection					0			0			0			0			0
Rest days during PIV inspection					2			2			2			2			2
Travel days/inspector/trip					2			2			2			2			2
Office Time Cost (Prep/Aanalysis)				Length	(Days)		Length (Days)		Len	ngth (Days)		Lengt	h (Days)		Length	(Days)
Office days/IIV inspection day					0.4			0.6			0.8			1			1
Office days/suppl inspection day					0.25			0.25			0.25			0.25			0.25
Office days/LFUA inspection day					0.125			0.125			0.125			0.125			0.125
Office days/PIV inspection day					0.25			0.25			0.5			1			1
Labor Cost of Inspector - burdened				Cost (U			Cost (US			Cos	st (USD)		Cost (USD)		Cost (L	ISD)
Staff cost/day - trip PDI					\$2,000			\$2,000		1	\$2,000			\$2,000		(-	\$2,000
Staff cost/day - trip Rest Day					\$1,000			\$1,000		<u> </u>	\$1,000			\$1,000			\$1,000
Travel cost /trip					\$4,650			\$4,650			\$4,650			\$4,650			\$4,650
Staff cost/day - office					\$1,054			\$1,054			\$1,054			\$1,054			\$1,054
			PDI	Cost (U		PDI	Cost (US		PDI	Coo	st (USD)	PDI	Cost (PDI	Cost (L	
Inspector Labor Costs by Insp. Type			90	\$	300,000	66 66	,	220,000	30		100,000	18	\$	60,000	18		60,000
Staff costs for routine inspection Staff costs for suppl inspection			7	\$	28,000	2	\$	8,000	30	\$	12,000	3	\$	12,000	3	\$	12,000
Staff costs for LFUA inspection			16	\$	64,000	0	\$	0,000	0		12,000	0	\$	12,000	0	\$	12,000
Staff costs for PIV inspection			30	\$	84,000	30	\$	84,000	30	_	84,000	21	\$	66,000	21	\$	66,000
Total Inspector Labor Cost			143	\$	476,000	98	\$	312,000	63	\$	196,000	42	\$	138,000	42	\$	138,000
Inspector Travel Costs by Insp. Type				*	,		•	,		Ť	,		•	100,000			,
Travel costs for routine inspection				\$	139,500		\$	102,300		\$	46,500		\$	27,900		\$	27,900
Travel costs for suppl inspection				\$	32,550		\$	9,300		\$	13,950		\$	13,950		\$	13,950
Travel costs for LFUA inspection				\$	74,400		\$	-		\$	-		\$	-		\$	-
Travel costs for PIV inspection				\$	13,950		\$	13,950		\$	13,950		\$	13,950		\$	13,950
Total travel cost				\$	260,400		\$	125,550		\$	74,400		\$	55,800		\$	55,800
Inspector Office Costs by Insp. Type				_	07.011		•	44.700		_	0.5.000			10.000		_	10.070
Staff office costs for routine inspection		1		\$	37,944 1,845		\$	41,738 527		\$	25,296 791		\$	18,972 791	-	\$	18,972 791
Staff office costs for suppl inspection Staff office costs for LFUA inspection		1		\$	2,108		\$	52/		\$	791		\$	791		\$	791
Staff office costs for PIV inspection				\$	7,905		\$	7,905		\$	15,810		\$	22,134		\$	22,134
Total staff office costs				\$	49,802		\$	50,170		\$	41,897		\$	41,897		\$	41,897
Total annual labor/staff/sampling cost	ts			\$	786,202		\$	487,720		\$	312,297		\$	235,697		\$	235,697
Total Annual costs				\$	895,670		\$	641,327		\$	498,765		\$	1,777,859		\$	1,795,162
Total Annual agets in 1MC reflections	200111201		614			624	0.6		es.	0.5		Cas	10		614	10	
Total Annual costs in 1M\$ reflecting	accuracy		\$M	0.9		\$M	0.0		\$IVI	0.5		\$M	1.0		\$M	1.0	

Table 49: Hardware Cost of Safeguards Options at 9000 MtSWU/yr GCEP for INFCIRC/540 Safeguards with NDA PD= 20%, DA PD=10%

	Assay																
	Unit																
MTSWU/yr Capacity	Totals	TOTAL		Option A			Option I	В		Option	n C		Option	ı D		Optio	n E
Nom. Feed cylinders/yr /assay unit	115	2070															
Nom. Product cylinders/year	58	1050	1														
Nom. Tails cylinders/year	104	1878	1														
Cascade Halls	8	144	1														
Load cell monitors/assay unit	23	414	1														
Assav units	18	7.17	Trad/Int Sg	de		N	SSP SPE	cs		NEUT D	NET		AEM A	cc	NEUT DET 4	ΔEM Δ	cc
Item SG system capital costs per annu		Annual	Tradyllit Og	u3			001 01 2			INLOT E	<u></u>		ALINA		INCOT DET	ALIIA	30
(10 year life span for equipment)		Cost/ item	Items	Total item Cos	t	Items	Total ite	m Cost	Items	Total	item Cost	Items	Total it	em Cost	Items	Tot	al item Cost
DA Sample Bottles		\$ 16	173	\$ 2	2,682	116	\$	1,798	57	\$	884	17	\$	264	17	\$	264
Portable LCBWS		\$ 680	1	\$	680	1	\$	680	1	\$	680	1	\$	680	1	\$	680
Reference w eights		\$ -	1	\$	-	1	\$	-	1	\$	-	1	\$	-	1	\$	-
HPGe gamma spec (IMCG)		\$ 3,700	2	\$ 7	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Nal Detector		\$ 3,700	2	\$ 7	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400	2	\$	7,400
Upgraded CHEM system		\$ 15,000	0	\$	-	0	\$	-	0	\$	-	0	\$	-	0	\$	-
Load cell monitors		\$ 500	0	\$	-	0	\$	-	0	\$	-	414	\$	207,000	414	\$	207,000
PNUH		\$ 40,000	0	\$	-	0	\$	-	0	\$	-	0	\$	-	0	\$	-
AEM- Installed detection system		\$ 10,000	0	\$	-	0	\$	-	0	\$	-	54	\$	540,000	54	\$	540,000
AEM - Data collect cabinet		\$ 10,000	0	\$	-	0	\$	-	0	\$	-	18	\$	180,000	18	\$	180,000
Neutron Detection System		\$ 6,500	0	\$	-	0	\$	-	1	\$	6,500	0	\$	-	1	\$	6,500
Neut Det - Data collect cabinet		\$ 7,800	0	\$		0	\$		1	\$	7,800	0	\$	_	1	\$	7,800
Data acquisition system		\$ 10,000	0	\$	-	1	\$	10,000	2	\$	20,000	18	\$	180,000	18	\$	180,000
Digital surv camera - F/W		\$ 2,000	0	\$		0	\$	-	24	\$	48,000	24	\$	48,000	24	\$	48,000
Accountability scale monitor + camera		\$ 1,500	0	\$	-	0	\$		2	\$	3,000	2	\$	3,000	2	\$	3,000
ID tag interrogation antennas		\$ 20	0	\$		0	\$	-	0	\$	-	162	\$	3,240	162	\$	3,240
ID tag interrogation readers		\$ 200	0	\$		0	\$	-	0	\$	-	150	\$	30,000	150	\$	30,000
ID tags		\$ 10	0	\$		0	\$	-	0	\$	-	4998	\$	49,980	4998	\$	49,980
Seals (IAEA costs/seal)		\$ 33	100	\$ 3	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300	100	\$	3,300
Total equipment cost per annum basis				\$ 21	,462		\$	30,578		\$	104,964		\$	1,260,264		\$	1,274,564
Equip. spares&installation =% of annual	l cost	10%	0	\$:	2,146			\$3,058			\$10,496			\$126,026	6		\$127,456
Total Annual Equipment Costs				\$2	3,608			\$33,636			\$115,460			\$1,386,290)		\$1,402,020
Annual equipment cost - repairs, trips,	costsas																
factor of equip. cost		Factor															
Est. Annual Equipment Upkeep Costs		10.0%	0		360.8			\$3,363.6			\$11,546.0			\$138,629.0			\$140,202.0
Total Annual Equipment Costs				\$ 25	5,968		\$	36,999		\$	127,006		\$	1,524,919		\$	1,542,222
				# -61			# - 6 1			# - 6 10			# - 6 1			4 -	Inspections
Inspections Needed per Option Regime No. routine inspections/yr				# of Inspection	13		# Of Ins	pections 11		# Of II	nspections 5		# Of Ins	pections	2	# 01	inspections
No. supplemental inspections/yr					6			2			3			-	3		
No. Addl LFUA inspections/yr			1		8		-	0		+	0		1		í	+	0
No. PIV/yr			1		1		-	1		+	1		1		1	+	1
Annual Sample Procedure Costs per Op	otion	Cost/	1				-			+		1	1		'	San	nple
Regime		Sample	Sample	Sample Costs/	Year	Sam ple	Sample	Costs/Year	Sample	Samn	le Costs/Year	Sample	Sample	Costs/Year	Sample		ts/Year
DA Sample - procedures /yr		\$ 700	115		0,500	77	\$	53,900	38	\$	26,600	11	\$	7,700		\$	7,700
ES Samples/yr		\$ 500	6		3,000	6	\$	3,000	6	\$	3.000	6	\$	3,000	-	\$	3,000
TOTAL Sample Costs/yr					3,500		s	56,900	Ť	\$	29,600		\$	10,700		\$	10,700

Table~50:~Labor~Cost~of~Safeguards~Options~at~9000~MtSWU/yr~GCEP~for~INFCIRC/540~Safeguards~with~NDA~PD=20%,~DA~PD=10%,

EVANDUE OOED (0000	Assay																
EXAMPLE GCEP of 9000 MTSWU/yr Capacity	Unit Totals	TOTAL		0-41			Ontion			0-4	tion C		Ontion	- D	0	-4i - m E	_
Nom. Feed cylinders/yr /assay unit	115	2070		Optior	1 A		Option	В		Opt	tion C		Option	ט ח	U	otion E	-
Nom. Product cylinders/yer/assay unit	59	1062															
Nom. Tails cylinders/year	104	1878	l														
Cascade Halls	8	144	i														
Load cell monitors/assay unit	23	414	İ														
Assay units	18		Trad/Int Sgo	ds		М	ISSP SPI	ECS		NEU	UT DET		AEM A	cc	NEUT DET + AE	M ACC	
Inspection Staffing per Inspection Cos	it			# of In	spectors		# of Ins	spectors		# o	of Inspectors		# of Ins	spectors		# of In	spectors
Inspectors / routine inspection					2			2			2			2			2
Inspectors / suppl inspection					1			1			1			1			1
Inspectors / LFUA inspection					2			0			0			0			0
Inspectors / PIV inspection					3			3			3			3			3
Inspection Time Cost				Lengti	h (Days)		Length	(Days)		Ler	ength (Days)		Length	n (Days)		Lengti	h (Days)
Duration of routine inspection					3			3			3			3			3
Duration of suppl inspection					1			1			1			1			1
Duration of LFUA inspection					1			0			0			0			0
Duration of PIV inspection		Ì			10			10		t	10			7			7
Rest days during routine inspection					0			0		t	0			0			n
Rest days during routine inspection		1			0			0		t	0			0			n
Rest days during LFUA inspection		1			0			0		t	0			0			0
					2			2		-	2			2			0
Rest days during PIV inspection		1			2			2		-	2			2			2
Travel days/inspector/trip				Longel	_		Longth			Las	noth (Days)		Longth			Longti	h (Dava)
Office Time Cost (Prep/Aanalysis)				Lengti	h (Days)		Length	(Days)		Lei	ength (Days)		Length	n (Days)		Lengti	h (Days)
Office days/IIV inspection day					0.4			0.6 0.25			0.8			0.25			0.05
Office days/suppl inspection day										-	0.25						0.25
Office days/LFUA inspection day		1			0.125			0.125		-	0.125			0.125			0.125
Office days/PIV inspection day					0.25			0.25			0.5			1			1
Labor Cost of Inspector - burdened				Cost (Cost (L			Cos	ost (USD)		Cost (L			Cost (
Staff cost/day - trip PDI					\$2,000			\$2,000			\$2,000			\$2,000			\$2,000
Staff cost/day - trip Rest Day					\$1,000			\$1,000			\$1,000			\$1,000			\$1,000
Travel cost /trip					\$4,650			\$4,650			\$4,650			\$4,650			\$4,650
Staff cost/day - office					\$1,054			\$1,054			\$1,054			\$1,054			\$1,054
Inspector Labor Costs by Insp. Type			PDI	Cost (PDI	Cost (L		PDI		ost (USD)		Cost (l		PDI	Cost (
Staff costs for routine inspection			78		260,000	66		220,000	30			18		60,000	18		60,000
Staff costs for suppl inspection			6	\$	24,000	2	\$	8,000	3	\$	12,000	3	\$	12,000	3	\$	12,000
Staff costs for LFUA inspection			16	\$	64,000	0	\$	-	0	\$	-	0	\$	-	0	\$	-
Staff costs for PIV inspection			30	\$	84,000	30	\$	84,000	30	\$	84,000	21	\$	66,000	21	\$	66,000
Total Inspector Labor Cost			130	\$	432,000	98	\$	312,000	63	\$	196,000	42	\$	138,000	42	\$	138,000
Inspector Travel Costs by Insp. Type																	
Travel costs for routine inspection				\$	120,900		\$	102,300		\$	46,500		\$	27,900		\$	27,900
Travel costs for suppl inspection				\$	27,900		\$	9,300		\$			\$	13,950		\$	13,950
Travel costs for LFUA inspection				\$	74,400 13,950		\$	13,950		\$			\$	13,950		\$	13,950
Travel costs for PIV inspection Total travel cost		 		\$	237,150		\$	125,550		\$			\$	55,800		\$	55,800
Inspector Office Costs by Insp. Type		1		*	201,100		*	120,000		"	7 4,400		•	55,500		*	00,000
Staff office costs for routine inspection		1		\$	32,885		\$	41,738		\$	25,296		\$	18,972		\$	18,972
Staff office costs for suppl inspection				\$	1,581		\$	527		\$			\$	791		\$	791
Staff office costs for LFUA inspection				\$	2,108		\$	-		\$			\$	-		\$	-
Staff office costs for PIV inspection				\$	7,905		\$	7,905		\$			\$	22,134		\$	22,134
Total staff office costs		-		\$	44,479		\$	50,170		\$,		\$	41,897		\$	41,897
Total annual labor/staff/sampling cos	ts	<u> </u>		\$	713,629		\$	487,720		\$	312,297		\$	235,697		\$	235,697
Total Annual costs				\$	823,097		\$	581,620		\$	468,902		\$	1,771,315		\$	1,788,618
Total Annual costs in 1M\$ reflecting	accuracy		\$M	0.8		\$M	0.6		¢n.	0.5	5	\$M	1.8		¢ na	1.8	
			· · · · · · · · · · · · · · · · · · ·			7111			4			7.00			V.I.		

CURRICULUM VITAE

BENJAMIN A. REIMOLD bar5083@psu.edu

419 East Manoa Rd. Havertown, PA 19083 Home: (610) 446-146 Cell: (610) 733-7360

Education:	The Pennsylvania State University, University Park, PA Bachelor of Science in Nuclear Engineering, Class of 2011. Middle Eastern Studies Minor. International Engineering Certificate, Concentrations in German and Turkish. Middle East Technical University, Ankara, Turkey Turkish Language and Culture, Spring 2009.
Academic Honors:	Schreyer Honors College Member of the Schreyer Honors College since Fall 2007. Dean's List 6 of 8 semesters. Academic Excellence Scholarship Fall 2007-Spring 2011. Exelon Fellowship Departmental Scholarship for academic excellence 2009-2010. Main Line Martin Luther King Association Scholarship Scholarship recognizing community service on the Main Line. Alpha Nu Sigma Nuclear Engineering Honors Society Pennsylvania Alpha Chapter, inducted Spring 2010. Tau Beta Pi Engineering Honors Society Pennsylvania Beta Chapter, inducted Spring 2010. Undergraduate Research Exhibition Second Place, Spring 2008. President's Freshman Award Spring 2008. National Residence Hall Honorary Society Inducted Spring 2011.

Work Experience:	NGSI Student Intern Summer 2010
	 Developed a comparison of advanced safeguards approaches incorporating Additional Protocol state-level conclusions for various Gas Centrifuge enrichment facilities. Collaborated as a member of a team to analyze advanced safeguards implementation and inspection frequency at Gas Centrifuge plants of various capacities. Used HPGe, NaI, and neutron coincidence detectors to determine uranium enrichment and plutonium isotopics through a NGSI Non-Destructive Assay training practicum.
	Irradiation Testing Intern Summer 2009
	 Worked with university researchers to develop irradiation experiments for the NTUF/ATR complex. Designed components for pneumatic "rabbit" shuttle system being installed at the NTUF/ATR. Practiced MCNP codes for criticality experiments. Attended lectures, symposiums and presentations on lab and industry research.
	Resident Assistant Fall 2009-Spring 2011
	 Pennsylvania State University Residence Life Supervise 55 undergraduate students in on-campus residence hall housing.
	 Organized and managed 50 residents repainting a floor of the building; budget approximately \$800 USD. Collaborate as a member of a team of resident assistants to foster a positive community within a highly diverse group of students.
Publications:	Boyer, B., Erpenbeck, H., Miller, K., Ianakiev, K., Reimold, B., Ward, S., Howell, J. Gas Centrifuge Enrichment Plants Inspection Frequency and Remote Monitoring Issues for Advanced Safeguards Implementation. IAEA Symposium on International Safeguards, Nov. 2010.
	Reimold, B. 2010. An Analysis of Costs Involved in Applying Advanced Safeguards Systems and Approaches to Gas Centrifuge Enrichment Plants. Honors Thesis, The Pennsylvania State University. 85 p.

Technical Skills:	Experience in programming using FORTRAN and MATLAB.
	Computer-aided design experience using Solidworks.
	MCNP-5 radiation transport simulation code
	(Project: Modeling a neutron diffusion experiment inside a graphite pile).
	GENIE gamma spectrum analysis program
	(Project: Compositional analysis of unknown sample using Neutron Activation Analysis).
	COBRA-IV thermal-hydraulic reactor analysis code
	(Project: Steady-state and transient accident scenario analysis of fuel assembly).
	 Westinghouse Advanced Nodal Code reactor design code (Project: Core Loading Pattern Design).
	CASMO-3 reactor core lattice physics code linked with SIMULATE-3 reactor fuel depletion code
	(Project: Multicycle Core Loading Optimization).
Activities and	Penn State Navigators Chapter, Student Leadership Team.
	American Nuclear Society, Penn State Student Chapter.
Community Service:	Common Ground, Student Organizer.
	Spring Break Service Trips, Orlando, FL, Atlanta, GA,
	Jacksonville, FL (2008-2011).